DRAFT REPORT

ECONOMIC IMPACT OF ENVIRONMENTAL REGULATIONS ON THE U.S. COPPER INDUSTRY

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Arthur D Little, Inc.

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Subject: Draft Report of Impact of EPA Regulations on the Domestic Copper Industry

From : Roy N. Gamse, Dir., EAD

To : Distribution List

The Economic Analysis Division of the Environmental Protection Agency (EPA) and Arthur D. Little, Inc. (ADL), have been conducting a study to quantify the economic effects of Federal environmental regulation on the domestic copper industry. The enclosed draft report, The Economic Impact of Environmental Regulations on the U.S. Copper Industry, contains the preliminary results of that effort.

We would appreciate your review of the draft. In order for EPA to meet its target date for completion, we request that this be completed by December 15, 1976. Please forward your comments to Dr. Douglas Hale (202-755-2669) of my staff.

Because the draft has not yet received extensive review, it can not be viewed as a formal expression of EPA's views. Hence, it should not be cited or quoted as reflecting the official position of EPA or ADL.

CHAPTER 1

INTRODUCTION

A. STUDY OBJECTIVE AND PURPOSE OF THIS REPORT

The objective of the current MBO nonferrous metals project undertaken by Arthur D. Little, Inc., on behalf of the U.S. Environmental Protection Agency (EPA) under Contract No. 68-01-2842 is to analyze the economic impact of costs of pollution abatement requirements imposed by Federal environmental regulations on the nonferrous metals industries (primary copper, aluminum, lead and zinc), with principal emphasis on the U.S. copper industry.

Accordingly, the purpose of this draft report is to present our preliminary findings on the economic impact of environmental regulations on the U.S. copper industry. In this report, the U.S. copper industry is defined to encompass all stages of production from mining through refining (mining and milling, smelting and refining).

B. ORGANIZATION OF THE REPORT

This report is organized in terms of ten chapters and is accompanied by a Technical Appendix, Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry, which is presented as a separate volume. The Technical Appendix is prepared to describe in technical detail the specification, estimation and key features of the econometric simulation and impact analysis model of the U.S. copper industry developed by ADL as part of this project to assess the economic impact of environmental regulations.

Chapters 2 through 9 consist of general background and methodological approach. Economic impact results are presented in Chapter 10. Given below is a capsule description of the contents of Chapters 2 through 9.

- Chapter 2 provides an introduction to production and pollution control technology in the copper industry, including a discussion of conventional copper production technology, the pollution control technology interfacing with this technology, and new technology expected to be less polluting than conventional technology.
- Chapter 3 provides a condensed and selective overview of the international structure of the copper industry, including world production and consumption patterns, key aspects of the copper industry's worldwide structure, international trade patterns in copper, and the trade relationships of the United States with the rest of the world.
- Chapter 4 describes the organizational structure and supply characteristics of the domestic copper industry, including the industry's segmentation into primary and secondary sectors, the firms involved, geographical and firm concentration, vertical integration, barriers to entry, and production cost trends.
- Chapter 5 focuses attention on the patterns of copper consumption and the dynamics of copper demand, with reference to econometric analyses of demand for copper.
- Chapter 6 provides an analysis of the institutional arrangements which characterize copper markets, the process of price formation among firms in the industry, and the emergence and rationale of

the "two-price system" for copper which in the past has been a dominant phenomenon in copper markets.

- Chapter 7 analyzes the financial characteristics of principal companies in the U.S. copper industry, including an overview of company financial performance, a discussion of ownership structure and inter-firm relationships, a review of the capital needs of the major firms, and a detailed examination of trends in debt and debt-equity ratios, the term structure of debt, and the amount and means of pollution control financing.
- Chapter 8 focuses on environmental regulations affecting the copper industry, including a review of the evolution of environmental legislation in the U.S., a discussion of the impact of environmental regulations on capacity expansion in the copper industry, and estimates of pollution control costs likely to be faced by the industry through 1985.
- Chapter 9 provides a nontechnical discussion of the methodological approach used to assess the economic impact of environmental regulations on the U.S. copper industry, including a description of the econometric simulation and impact analysis model developed for impact assessment purposes, a discussion of various theoretical and practical considerations associated with the model, and a comparison of the model with other econometric models of the copper industry.

C. SUMMARY OF THE CONTENTS OF CHAPTERS 2 THROUGH 9

We would like to present a condensed summary of Chapters 2 through 9 for readers who would like to develop a quick overview of the detailed background material presented in these chapters before turning to Chapter 10--Economic Impact Analysis.

Production and Pollution Control Technology

1. The production of copper from primary (virgin) sources involves four stages of processing: (1) mining--where ore containing 0.6-2.0 percent copper is mined; (2) beneficiation or milling--where copper-containing minerals are separated from waste rock to produce a concentrate containing about 25 percent copper; (3) smelting--where the concentrates are smelted to produce 98 percent pure "blister" copper; and (4) refining--where blister is either fire-refined or refined electrolytically to produce 99.9 percent pure cathode copper. Subsequently, cathode copper is melted and cast into various shapes for fabrications.

2. The major pollutants at the mining and milling stage are solid wastes and water effluents. However, in terms of complexity and cost, the air pollution problems of the smelters are the most important. The smelting technology in the U.S. evolved in a framework of low energy costs and in locations distant from sulfuric acid markets and urban population centers. This smelting technology relies on roasters,[1] reverberatory furnaces (reverbs), and converters to product blister copper. Sulfuric acid plants (essentially the only economical method for reducing emissions of sulfur dioxide from smelters) operate efficiently only on concentrated

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[1]Roasters are employed in about 50 percent of U.S. smelters, in the other 50 percent, concentrate is fed directly into reverbs.

gas streams from fluid bed roasters and converters and not on weak streams from multiple-hearth roasters and reverbs. Thus, in conventional smelting, only about 50-70 percent of the sulfur in the raw materials is captured as sulfuric acid; the rest is emitted to the atmosphere.

3. In the long run, new pyrometallurgical technology would decrease energy requirements for smelting and also increase sulfur capture to over 90 percent. However, except for electric smelting, the applicability of these processes to impure concentrates is unproven. New hydrometallurgical processes for sulfide concentrates are not energy efficient. Their attractiveness derives from the fact that such plants can be built on a much smaller scale than conventional smelters; moreover, they convert sulfur in concentrates to forms other than sulfuric acid.

The U.S. Copper Industry in World Perspective

1. In 1974, the United States accounted for 21.9 percent of world refined copper production, 18.4 percent of smelter production, and 18.3 percent of mine output. By contrast, in 1964 the U.S. accounted for 31.7 percent of refined copper production, 25.4 percent of smelter production, and 23.8 percent of mine output. The U.S. share of world consumption of refined copper dropped from 28.8 percent in 1963 to 23.5 percent in 1974, reflecting a relatively higher growth in demand for copper in the rest of the world.

2. At the mining level, copper output is highly concentrated in a relatively few countries. Along with the U.S.--still the largest single producer--five other countries (Canada, Chile, Zaire, Zambia, U.S.S.R.) together accounted for 71.2 percent of total world mine output in 1974.

Chile, Zambia, Peru and Zaire, the original four members of CIPEC,[1] together account for about 37 percent of Free World mine production in copper. With recent additions in its membership, CIPEC's participation in internationally traded copper has increased to over 70 percent.

3. Most major copper mining countries are also major smelters. Concentration by country in copper refining, by contrast, displays a different pattern. For example, several leading industrial countries (e.g., West Germany, the United Kingdom, Japan), with little or no mine production, and in many cases very little smelter production, are large copper refiners based on imported smelted copper.

4. During the postwar period, there has been a major change in the ownership structure of the world copper industry. In 1947, the four largest private mining companies accounted for about 60 percent of free-world mine output. This declined to 49 percent by 1956 and to less than 20 percent by 1974. Meanwhile, through nationalization, the share of government-owned enterprises in free-world mine output increased, reaching 34 percent in 1974. Moreover, governmental ownership of the copper industry is heavily concentrated in the copper exporting countries--mainly the CIPEC countries.

5. A substantial portion of the world's large copper firms are vertically integrated from mining to refining. In the United States at least one-third of the output of domestic copper refiners is sold to subsidiaries, and a substantial portion of the output of Japanese and

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[1] The Conseil Intergouvernemental des Pays Exportateurs de Cuivre (CIPEC), also known as Intergovernmental Council of Copper Exporting Countries.

and European refiners is also sold to their affiliates. Primary producers in North America and Japan have important fabricating operations as well. However, refiners in Europe are only partially integrated forward, and those in other producing countries have very little fabricating capacity.

6. Copper processing in individual countries or areas is characterized by a relatively high degree of concentration, which suggests an oligopolistic industry structure. However, little can be concluded a priori about possible implications of industry structure for industry behavior and market competition without consideration of other market forces that affect industry behavior.

7. The bulk of the world's copper exports is from the developing countries to Europe, Japan and the United States, with smaller amounts from Canada, South Africa and Australia. The United States and Western Europe also export refined copper, but are net importers of copper overall.

Although the United States has been virtually self-sufficient in copper, except in certain years coinciding with military developments or unusual "demand crunch" periods, the U.S. has been both a leading importer and exporter of copper. This, however, may change sharply in the future, partly as a result of the domestic environmental regulations affecting the U.S. copper industry.

Industry Structure and Supply Characteristics

1. For the analytical purposes of this study, the domestic copper industry has been segmented into primary and secondary sectors on the basis of the pricing behavior of firms in the industry. By this criterion, firms in the primary sector are those which sell the bulk of their refined copper output (mostly refined from mined copper but also including some

refined from scrap) on the basis of a commonly-followed domestic producers price. Firms in the secondary sector, on the other hand, are those which sell their copper output, regardless of its form (i.e., whether refined or scrap) and regardless of its origin (i.e., whether processed from mined copper--from domestic or foreign source--or refined from scrap), on the basis of one of several "outside market" prices.

2. The primary sector consists of: (1) a core group of seven large fully-integrated producers (Anaconda, Kennecott, Phelps Dodge, Inspiration, Magma,[1] Copper Range,[2] and Asarco,[3]); (2) one partially integrated firm (Cities Service Co., integrated through smelting), two large nonintegrated independent mining firms (Duval, a subsidiary of Pennzoil Co., and Cyprus[4]), and many small independent firms.

3. Through a high degree of vertical integration and firm concentration, the core group of primary producers are able to exercise discretionary pricing behavior in refined copper markets. In 1974, the seven vertically-integrated firms supplied 77.0 percent of domestic mine production of recoverable copper in the United States (79.6 percent in 1973, a peak year). At year-end 1975, these seven firms accounted for over 95 percent of total U.S. smelting capacity and 85 percent of refinery capacity.

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[1]Subsidiary of Newmont Mining Corporation.

[2]Of which White Pine Copper Co. (mining/milling, White Pine, Michigan) and Quincy Mining Co. (smelting/refining, Hancock, Michigan) are subsidiaries.

[3]In addition to being, in its own right, a major, fully-integrated primary producer, Asarco also plays a pivotal role in the domestic copper industry as a major custom/toll smelter and refiner.

[4]Of which Cyprus Pima Mining Co. and Cyprus Bagdad Copper Co. are subsidiaries.

4. Within the secondary sector, two broad segments can be distinguished. The first comprises a small number of firms processing scrap into secondary refined copper. Amax and Cerro have been the two most important of these firms during most of the postwar period. These secondary refiners sell their product at prices (explicit prices if in the open market or implicit prices if intra-company transfers are involved) which are more reflective of current market prices for scrap than of refined copper prices quoted by the primary producers. They have been responsible for an average of 12 percent of total refined copper supplied in the U.S. each year over the period 1950-1974 and have held about 11 percent of domestic refinery capacity during this same period.

The remainder of the secondary industry is comprised of a large number of firms, mostly small and individually-owned, engaged in the collection, processing, and consumption of unrefined scrap as well as in the trading of refined copper. These include scrap dealers, ingot makers, semi-fabricators, and merchants. Firms in this segment buy or sell unrefined scrap directly on the basis of quoted scrap prices.

5. The U.S. primary copper industry is characterized not only by a high degree of firm concentration and vertical integration at the mining through refining stages of production, but also by forward integration beyond refining. The major domestic producers (particularly Anaconda, Kennecott, and Phelps Dodge) are integrated forward into wire mill and brass mill operations. However, available evidence indicates a significantly lower degree of firm concentration at the semifabricator level than that existing at the mining through refining stages--low enough, at least, to

prevent individual semifabricators from having a significant influence on pricing or production decisions within the semifabricating industry as a whole.

6. Barriers to entry for fully integrated operations appear to be substantial. However, the existing high barrier to entry has apparently had little effect in moving the discretionary pricing behavior of the major primary producers, during the past three decades, in the direction of implicit monopolistic pricing behavior, given the continuous threat of long-run substitution from aluminum, among other factors.

7. Overall, real costs of refined copper production, although they have remained stable over a relatively long period, appear to have increased gradually during the 1950's and 1960's. Evidence exists, moreover, suggesting a sharp real increase in some factor costs during the past few years.

Labor productivity in the industry, meanwhile, stagnated through the 1950's and 1960's and registered an actual decline after 1971 in the face of continued degradation of the average ore grade mined in the U.S. This, combined with little prospect for improvements in labor productivity over the next few years, argues in the future for rising production costs in real terms along with increases in unit labor costs.

8. We have estimated industry-wide (aggregate) average total costs for producing refined copper (from mining through refining) for the primary producers in 1974 at 72¢ per pound (at roughly 86 percent of installed capacity). Of that total, average fixed costs were estimated at 29¢ per pound and average variable costs were estimated at 43¢ per pound.

The Dynamics of Demand for Copper

1. For purposes of analyzing market demand, it is generally accurate to think in terms of a unified market for refined copper, copper scrap, and copper alloy ingot. This is because each type of scrap or alloy ingot can be processed into unalloyed refined copper at a relatively small cost.

2. Demand for refined copper and its equivalent (e.g., copper scrap and copper alloy ingot) is a derived rather than final demand. Semifabricators demand refined copper equivalent not for purposes of final consumption, but for use in the production of semifabricated products which are, in turn, demanded by fabricators and end-users as intermediate inputs in the production of final consumer goods. Semifabricators' demand for refined copper equivalent is thus derived from the demand of fabricators and final consumers.

3. Among semifabricating industries in 1974, wire mills, which use only refined copper, consumed about 47 percent of total supplies of refined copper equivalent. Brass mills, which consume refined copper and scrap in fairly equal proportions, accounted for about 39 percent of total consumption. Ingot makers, who use almost entirely scrap, were the third largest consumers at seven percent. Foundries, consuming predominantly scrap, used about four percent, with powder plants and "other industries" accounting for the remainder.

4. The major industries consuming semifabricated goods are (in order of importance): electrical and electronics products; building construction; consumer and general products; industrial machinery and equipment; transportation, ordnances and accessories.

5. The demand for refined copper equivalent is determined by at least three principal factors: general levels of macroeconomic activity; the prices of refined copper equivalent; and the prices of potential substitute goods for refined copper, such as aluminum and plastics, relative to the price of refined copper.

6. Substitution of aluminum or another material for copper can occur in either the short-run or the long-run. Substitution in the short run involves no major alterations in fixed plant and equipment or changes in product design. For the most part, this type of substitution is limited to residential and nonresidential construction. In most cases, the capital fixity of plant and equipment will limit possibilities for substitution in the short-run. As a result, substitution will only occur when the relative price of a substitute material becomes low enough to justify the capital costs of altering plant and equipment. In economic terms, the long-run own-price and cross-price elasticities will be greater than the short-run price elasticities.

Among substitute materials, it is generally agreed that aluminum has been the most serious competitor to copper, having made the most serious inroads in electrical conductor and heat-exchanger applications. The most important potential instances of long-run substitution are in telephone conductor cable and automobile radiators.

<u>Copper Pricing Mechanisms, Price Formation, and the Two-tier Price System</u>

1. The major institutional arrangements governing copper markets include: two organized exchanges, the London Metal Exchange (LME) and the New York Commodity Exchange (Comex); merchants; and, of course, the major primary producers.

2. The term "outside market" is sometimes used to describe all trade in copper apart from domestic sales made by domestic primary producers. As referred to in this study, the outside market encompasses the secondary industry (including the secondary refiners), sales of U.S. and foreign producers at other than the prevailing domestic producers price, merchants, and transactions in physical copper on the LME and Comex.

3. In spite of a number of different pricing bases in existence, the bulk of refined copper sales during the postwar period have been made directly or indirectly on the basis of one of two distinct price systems. The first is the domestic producers price, a set of nearly uniform price quotations used by the major primary producers. The second is the LME price, spot and forward quotations prevailing on the London Metal Exchange, which has been used by most producers most of the time as a basis for sales outside North America.

In general, LME price movements have been relatively volatile and sensitive to speculative pressures and short-run shifts in supply and demand. By contrast, the producers price has tended to change only slowly, usually lagging significant trends in LME prices by several months.

4. The most significant characteristic of postwar copper markets has been the existence in nine of the 27 years between 1947 and 1974 of a two-price system for refined copper, characterized by a wide divergence between the outside market price for copper (i.e., the LME price) and the domestic producers price. The two-price system developed during periods of rising or excess demand for refined copper and was brought about when participating producers (U.S. and some foreign) chose to ration

their available copper supplies to customers at a price below the level which would have cleared the market. Three distinct periods when the two-price system was in effect can be identified as follows: (1) from late 1954 to mid-1956; (2) from January, 1964 to March, 1966; and (3) from April 1966 to early 1970. During each period, a different combination of foreign producers participated along with U.S. producers.

5. There appears to be no complete, simple, logical explanation or set of explanations for the rationing behavior of the principal U.S. and foreign producers during the periods of the two-price system.

Rationing during periods of excess demand and high copper prices (as reflected in LME prices) is clearly inconsistent with the motive of short-run profit maximization. The producers, however, suggest that they have preferred in the past to forego short-run profit maximization in order to maximize profits in the long-run by avoiding substitution away from copper.

An alternative explanation for producer rationing suggests that partially or fully integrated producers acted as monopolists to limit the availability of refined copper supplies and thereby drive up the market price at which semifabricated and fabricated goods were sold. In other words, it is argued that by regulating supplies, they increased their profits at the fabricating stage while foregoing short-run profit increases at the mining through refining stages. Such behavior, however, could well stimulate long-run substitution as prices rose.

Neither hypothesis explains why different foreign producers participated in the three different two-price systems. Moreover, sufficient quantitative data are unavailable to fully support any of the explanations for the existence of the two-price system.

Financial Characteristics of the Industry and Principal Companies

1. The eleven principal copper producers are publicly-owned companies. The aggregate book value of their corporate assets totaled approximately $17 billion at year-end 1975, while market value of their common stocks totaled about $8 billion.

2. Overall profitability for the producers, in terms of operating margin on sales, has declined from about 23 percent in 1967 to 19 percent in 1974. Average after-tax return on stockholders' equity has been equal to the Federal Trade Commission average for all manufacturing, but has been characterized, on a year-to-year basis, by much greater volatility.

3. The copper industry is capital intensive with typically more than one dollar of assets behind each dollar of annual sales. The major barrier to entry into the industry is the size of capital requirements. At least $500 million (in 1974 dollars) would be required to develop a new integrated copper producing operation from mining through refining at current minimum efficient operating scale (100,000 short tons annually).

4. Firms are typically long-term profit maximizers, with an operative target rate of return on investments. The expected economic lifetime of investments is quite long. Such investment is rendered highly risky because of crucial dependence for success on the price of copper, which has been highly volatile in the past. Consequently, joint ventures, which constitute a means of diversification and pooling of risks, have become quite common in the industry.

5. Several of the major copper producers are involved in the production of lead and zinc, and others are aluminum fabricators. A number of producers participate jointly in foreign copper mining companies, notably in Africa, Canada, and South America; these companies derive 20-25 percent of total sales, and a higher percentage of their after tax earnings, from foreign operations.

6. Capital expenditures by most companies increased sharply in recent years. About 25 percent of total industry capital expenditures have been for pollution abatement, mostly associated with SO_2 control at smelters. About 60 percent of the total for productive investment represents investment in mining and milling capacity. Aggregate capital expenditures have averaged about 12 percent of gross plant in recent years; this is about three times the level of depreciation charges.

7. The cash-flow position of most companies has deteriorated in recent years, with a consequent increase in external financing requirements. While overall debt for the copper producers has approximately doubled during the past five years, equity has increased by less than 35 percent. As a result, debt-equity ratios for most companies have increased significantly. Some companies are believed to have temporarily reached prudent limits to debt in their capital structure, and, as of 1975, awaited higher earnings and stock prices to restore balance and financing flexibility.

<u>Environmental Regulations</u>

Of all the environmental regulations affecting the four segments of the domestic copper industry, air pollution regulations affecting smelters are the most important in terms of cost and potential impact.

The copper industry has traditionally increased smelting capacity via small expansions at existing smelter locations. The construction of smelters in new locations ("grass roots" smelters) or similar major expansions, have been rather the exception and not the rule in the past. The lead time required for planning, engineering, construction, shake-down and start-up for small expansions at existing sites is about three years while that for new grass roots smelters is about seven years. The Clean Air Act requirements (as interpreted by EPA) do not allow small expansions of the type used traditionally by the industry. While there are some uncertainties, the regulations do allow the construction of NSPS calibre smelters in new or existing smelter locations. At the present time, we are not aware of any major smelter construction projects that are under active consideration. Thus, given the time lags in the system, new capacity will not come on-stream until 1984.

The detailed findings from Chapter 8 are summarized below:

1. Small smelter expansions (which could occur prior to 1983) are not possible because emissions from a plant cannot increase above the limit defined by applying "Reasonably Available Control Technology" (RACT). Even if such a RACT limit did not exist the "Modification and Reconstruction Provisions" of the New Source Performance standards would prevent any significant modification of existing reverbs necessary to increase smelting capacity.

2. Existing RACT smelters could expand significantly after 1983 by installing new smelting technology but by operating under the RACT Limit. There is some concern that such expansion might be disallowed under New Source Review. The probability of such disallowance is very low and we assume that this type of expansion will occur after 1983.

3. Existing BACT smelters have a low expansion potential since they cannot use SCS and they are already close to the constant emission control limitations.

4. "Grass roots" smelters for clean concentrates have to use Best Available Control Technology (BACT), such as autogeneous or electric smelting and therefore cannot use SCS. These smelters would meet NAAQS by using tall stacks for dispersing collected emissions. We assume that this type of expansion will occur after 1983. While reverb-based smelters are allowed for smelting impure concentrates, such smelters cannot be built in most locations since SCS is not allowed. This is because SCS is usually necessary to reverb-based smelters for meeting NAAQS. However, there is no demand for smelting capacity of this type.

5. All smelters (reverb-based smelters as well as new smelters based on the Best Available Control Technology) might exceed NAAQS in the vicinity of the smelter as a result of low level fugitive emissions. It it not clear whether SCS can be a useful strategy for dealing with the fugitive problem. This problem could be dealt with by acquiring land in several kilometer radius around a smelter. Such a strategy is probably impossible for existing smelters but could be feasible for new "grass roots" smelters in remote locations. We assume that this potential problem will be resolved without major cost consequences to the industry.

6. While the capacity bottleneck in copper smelting is essentially the result of various environmental regulations, the industry also faces other regulations that affect its production costs and potentially interrupt its planning process. Examples include proposed Occupational Safety and Health Administration (OSHA) regulations on handling of explosives in open pit mines and on the use of engineering controls for abating noise and inorganic arsenic emissions in the work-place environment.

Methodological Approach to the Economic Impact Analysis

1. The general methodological approach adopted in this study to assess the industry-wide economic impact of environmental regulations can be charcterized as the development of a dynamic nonlinear simultaneous-equation

econometric simulation model of the U.S. copper industry. The model is designed, estimated and programmed to simulate the industry's growth and evolution annually over the impact analysis period (1976-1985) under alternative scenarios (baseline conditions, as well as alternative environmental policy scenarios).

2. Very briefly, the model consists of two basic components:

- The Market Clearing Module, and
- The Investment Module.

The Market Clearing Module, which consists of thirteen (13) simultaneous equations, simulates every year the production and pricing behavior of the major producing groups in the industry, the inventory behavior of the major participants in the industry, the demand behavior of the users of copper and balance of trade effects. The market is cleared in each year through materials balancing and price equilibrium equations.

The Investment Module serves as the year-to-year "transit" connecting the solutions of the Market Clearing Module for successive years, by simulating how smelting/refining capacity changes over time. Smelting/refining capacity changes are estimated, then translated into total fixed costs (along with increases in total fixed costs due to mining and milling investment, pollution abatement investment, etc.). These are then built into the cost functions of the primary producers.

Since mining and milling investment decisions typically require profitability considerations extending over quite a long time-horizon (typically 25-30 years), the model treats such investment as exogenous. However, capacity expansion and replacement investment at the smelting and refining level is made endogenous. Pollution abatement investment, as well as pollution-abatement related increases in variable costs enter the model exogenously.

3. Once the model is solved for the entire period (e.g., 1974-1985 or 1974-1990), external checks are performed on the model's results, focusing directly on the industry's overall financial performance. Exogenously specified mining and milling investment behavior is analyzed in terms of various measures of profitability, given the price forecasts. Likewise, overall cash-flow and flow-of-funds (sources vs. uses) analyses are performed, by analyzing financial data computed directly from the model's results, as well as on the basis of detailed historical industry-wide and specific company-by-company financial data. The results of this procedure can, in principle, be internalized.

4. The model has both a linear and a nonlinear version. The nonlinear version of the model, which represents a more reasonable approximation of the variables and relationships being modeled, is by far the more useful analytical system. In the linear case, for example, demand curves may intersect cost or supply functions beyond capacity. By contrast, in the nonlinear case, cost and supply functions appear to model reality much more accurately, beginning to rise at around 86 percent of installed capacity (smelting/refining capacity) and continuing to rise very steeply beyond this region as physical capacity is approached.

5. The structure of the domestic copper industry has been characterized basically in terms of a core group of oligopolistically-behaving primary producers surrounded by a "workably" competitive fringe of secondary refiners, producers/sellers of non-refined scrap, and merchants (i.e., the outside market).

Although the model specifically deals with both the primary producers and with the secondary copper industry (and the interaction between the two sectors), its major focus in directed at the primary producers, with careful attention paid to their discretionary price and output behavior.

6. In a competitive industry or industrial sector, industry-wide price and output levels will be determined at the intersection of supply and demand curves. No member of a competitive sector can affect price; they are all price-takers. Short-run production decisions on the part of a given firm are made by comparing market price with production costs along the marginal cost schedule. In oligopolistic markets,[1] deterministic market solutions, based upon supply and demand functions, are no longer possible (a "supply function," by definition, does not in fact exist in such markets). The reason, is, of course, that members of an oligopolistic industry are price-setters (i.e., they can exercise discretionary pricing) rather than price-takers as under perfect competition.

Given that inevitably a range of possible price and output outcomes can be expected in oligopolistic markets purely on theoretical grounds, we have chosen to "bound" the "solution space" of possible (and most plausible) outcomes analytically in our own modeling work. The pricing

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[1]We should make it clear, for the general reader, that the term "oligopoly" or "oligopolistic" covers a wide spectrum of markets, technically speaking, between the polar conditions of perfectly competitive markets in one extreme and monopolistic behavior in the other.

In our purely technical usage of the terms "oligopoly" or "oligopolistic," we refrain from even remotely rendering any value judgment on the behavior of the firms involved. We are not unaware of the fact that these terms, common as they are among economists as purely technical constructs, have semmingly gained among businessmen a certain pejorative connotation. None is intended by our use of these terms.

strategies or modes of pricing behavior utilized in the model for analyzing the primary producers identify, first, the "most likely" or "normal" pricing behavior of the primary producers in a given year and, second, define reasonably solid bounds around that "most likely" or "normal" pricing behavior.

This approach enables us to examine or measure the industry impacts both at what might be called extreme points and at points "in-between" (principally at the "most likely" solution point, based on average cost pricing behavior). This is what we mean by a parametric approach: we effectively define the parameters (outer boundaries) of possible outcomes and assess the sensitivity of the impact results to variations in behavioral parameters.

CHAPTER 2

PRODUCTION AND POLLUTION CONTROL TECHNOLOGY

A. INTRODUCTION AND SUMMARY

In this chapter, we discuss the conventional technology for producing copper, the pollution control technology which interfaces with the former in order to reduce emissions and new technology which is likely to be less polluting than conventional technology.

The production of copper from primary (virgin) sources, involves four stages of processing: mining--where ore containing 0.6-2% copper is mined; beneficiation or milling--where copper-containing minerals are separated from waste rock to produce a concentrate containing about 25% of copper; smelting--where the concentrates are smelted to produce 98% pure "blister" copper and refining--where blister is refined electrolytically to produce 99.9% pure cathode copper. Subsequently, cathode copper is melted and cast into various shapes for fabrication.

In order to minimize transportation cost, mills are located close to the mines. The concentrates are sufficiently high in value to allow some flexibility in smelter location. Most smelters are located near the mills or on tide water or rail head. Refineries can be located anywhere between smelters and fabricators.

Considerable quantities of copper scrap are recycled by melting and refining by the primary producers, and by the producers of alloyed and unalloyed copper ingot.

The major pollutants at mining and milling stage are solid wastes and water effluents. However, in terms of complexity and cost, the air pollution problems of the smelters are the most important. The smelting technology in the U.S. evolved in a framework of low energy costs and in locations distant from sulfuric acid markets and urban population centers. This smelting technology relies on roasters (optional), reverbs and converters to produce blister copper. Sulfuric acid plants (essentially the only economical method for reducing emissions of sulfur dioxide from smelters) operate efficiently only on concentrated gas streams from fluid bed roasters and converters and not on weak streams from multiple-hearth roasters and reverbs. Thus, in conventional smelting, only about 50-70% of the sulfur in the raw materials is captured as sulfuric acid and the rest emitted to the atmosphere.

In the long run, new pyrometallurgical technology would decrease energy requirements for smelting and also increase sulfur capture to over 90%. However, except for electric smelting, the applicability of these processes to inpure concentrates is unproven. New hydormetallurgical processes for sulfide concentrates are not energy efficient. Their attractiveness derives from the fact that such plants can be built on a much smaller scale than smelters and they convert sulfur in concentrates to form other than sulfuric acid.

B. PRODUCTION TECHNOLOGY

Production of primary copper involves four basic activities: mining, milling, smelting and refining. Refined copper is then fabricated for various end-use markets. The four stages of primary production are:

- mining--where ore containing 0.6-2% copper is mined;
- beneficiation--where the copper-containing minerals are separated from waste rock to produce a concentrate containing about 25% copper;
- smelting--where concentrates are melted and reacted to produce 98% pure "blister" copper; and
- refining--where blister copper is refined electrolytically to produce 99.9% pure cathode copper. Some of the new hydro-metallurgical processes combine the functions performed by smelting and refining.

A generalized flowsheet of copper processing is shown in Figure 1. Because previous ADL reports and the published literature[1] contain detailed information on copper technology, only a brief summary is presented here.

1. Mining

Mines are the source of copper bearing materials found near the surface or deep in the ground. About 85% of the total copper ore mined comes from open pits, where ore is removed from the surface rather than from underground workings; the rest comes from underground mines. Underground mining methods for copper ores involve caving and/or cut-and-fill mining.

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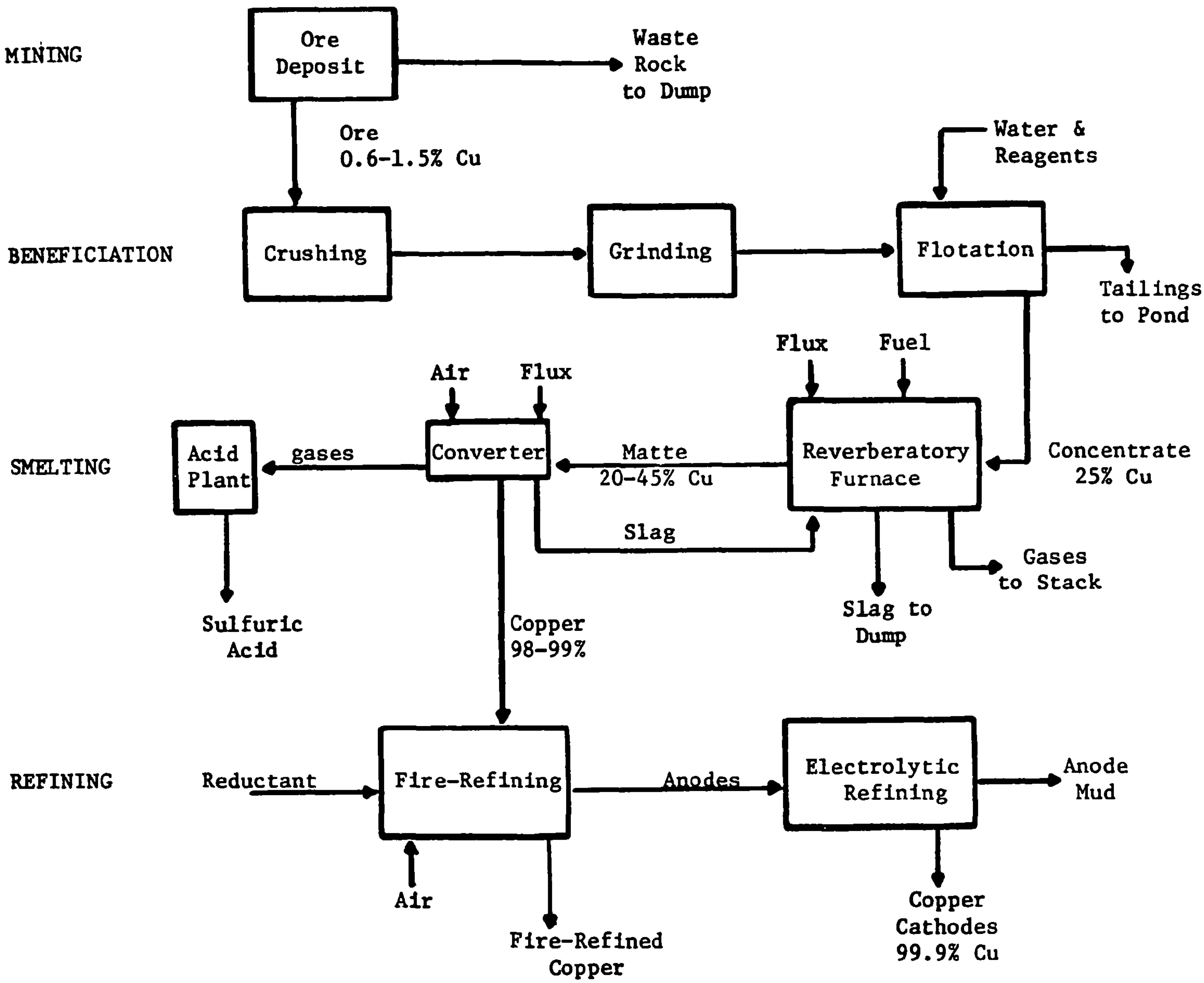
[1] See, for example, two previous reports prepared by Arthur D. Little, Inc. (ADL) for U.S. Environmental Protection Agency (EPA): Economic Impact of Anticipated Pollution Abatement Costs--Primary Copper Industry (1972) and Economic Impact of New Source Performance Standards on the Primary Copper Industry: An Assessment (October, 1974).

FIGURE 1

GENERALIZED FLOWSHEET FOR COPPER EXTRACTION FROM SULFIDE ORES



2. Beneficiation

From a processing viewpoint, copper ores can be classified in three categories: sulfide ores, native copper ores, and oxide ores. Each category requires different beneficiation processes.

A sulfide ore is a natural mixture containing copper-bearing sulfide minerals, associated metals, and gangue minerals (e.g., pyrites, silicates, aluminates) that at times have considerable value (e.g., molybdenum, silver, gold, as well as other metals).

The sulfide ores are treated primarily by crushing, grinding, and froth flotation to produce a concentrate (or several concentrates) of sulfide minerals; worthless gangue is rejected as tailings. Generally, only sulfide ores are amenable to concentration procedures. The output of this benefication process, concentrate, may contain 11-32 percent copper. Mine/mill output is typically defined in terms of recoverable copper content in concentrate form.

In native copper ores copper occurs in metallic form. The Lake Superior district in Michigan is the only major source of ore in this type. Although the reserves of this ore are extensive, they contribute only a small portion of the total U.S. mine production of copper.

Finally, the non-sulfide, non-native ores of copper are termed "oxide" ores, the oxide copper content being measured by and synonymous with solubility in dilute sulfuric acid. An "oxide" copper ore can contain copper oxide, silicate or carbonate minerals and gangue. In the Southwest United States, many deposits have a capping of oxide ore below which is a transition zone of various mixtures of oxidized and sulfide copper minerals and then the primary sulfide deposit. The oxide ores have been treated metallurgically in a variety of ways, the character of the gangue minerals having a very important bearing on the type of metallurgical treatment used. Oxide ores in the U.S. are treated primarily by leaching with dilute sulfuric acid. Copper is recovered in metallic form from leach solution by precipitation on iron scrap (cementation) or by electrowinning from the solution.

Commonly associated with copper are minor amounts of gold, silver, lead, and zinc, the recovery of which can improve mine profitability. Molybdenum, lead and zinc are recovered as sulfides by differential flotation. Minor amounts of selenium, tellurium, and precious metals are extracted in electrolytic refining. On the other hand, arsenic, antimony and bismuth in the ores cause problems in standard pyrometallurgical processing and electro-refining, and thus their presence results in a cost penalty. Nickel and cobalt can interfere with electrolytic refining, but they do not occur in significant amounts with the U.S. copper deposits.

3. Smelting

Because most U.S. copper is extracted from low-grade sulfide ores requiring concentration, current pyrometallurgical practice for recovery of copper is fairly uniform from smelter to smelter and is adapted to treating fine grained sulfide concentrates consisting mainly of copper and iron sulfides and gangue.

Copper's strong affinity for sulfur and its weak affinity for oxygen as compared with that of iron and other base metals in the ore form the basis for the three major steps in producing copper metal from sulfide concentrates; roasting, smelting and converting. About half of the copper smelters roast their charge prior to feeding to the reverberatory (reverb) furnace (calcine smelting), while the other half feed the concentrates directly (green feed or green charge smelting). The subsequent steps consist of melting the charge in the reverberatory furnace to form matte, a mixture of copper and iron sulfides and a slag. The slag is discarded; the matte is oxidized in converters to blister copper.

4. Refining

The blister copper produced by smelting is too impure for most applications and requires refining before use. It may contain silver and gold, and other elements such as arsenic, antimony, bismuth, lead, selenium, tellurium, and iron. Two methods are used for refining copper--fire refining and electrolysis. Electrolytic copper is refined by electrolytic deposition, remelted, and cased in commercial shapes, while fire-refined copper is refined by using only a pyrometallurgical furnace process.[1]

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[1] From the producers' point of view, the distinction between electrolytic and fire refining stems from the nature of the impurities present in the blister copper. If the blister copper contains substantial quantities of the precious metals (e.g., gold, silver, and the metals of the platinum group), it will be electrolytically refined and the precious metals recovered. If, however, the blister copper has a low precious metal content, it will be fire refined. Most of the world copper production of primary or mined copper is electrolytically refined.

Fire refined copper is generally slightly less pure than the electrolytic copper and therefore cannot be used in applications which require high conductivity; in particular. wire mills generally cannot substitute fire refined copper for electrolytic copper. Most electrolytic copper is sold to wire mills and most fire refined copper is sold to foundries and brass mills, but, foundries and brass mills can use electrolytic copper (which is slightly more expensive), and high conductivity fire refined copper (HCFR) can be used at wire mills in place of electrolytic copper.

The process of casting copper gives rise to another set of distinctions arising from the fact that molten copper has a fairly high affinity for oxygen. During the process of casting, cuprous oxide will form is oxygen is available and the copper properties are affected by the amount of curpous oxide present. "Oxygen-free copper" is refined copper cast under a deoxidizing atmosphere that eliminates all cuprous oxide without using metallic or metalloidal deoxidizers. Deoxidized copper is refined copper freed from cuprous oxide through use of metallic of metalloidal deoxidizers. "Tough pitch copper" is electrolytic or fire-refined copper cast in refinery shapes and containing a controlled quantity of oxygen in cuprous oxide. The terms "electrolytic" and "fire refined," when used alone, generally refer to either electrolytic or fire-refined tough-pitch copper without elements other than oxygen present in significant quantities.

The fire-refining process employs oxidation, fluxing and reduction. The molten metal is agitated with compressed air, sulfur dioxide is liberated and some of the impurities form metallic oxides which combine with added silica to form a slag. Sulfur, zinc, tin, and iron are almost entirely eliminated, and many other impurities are partially eliminated by oxidation. Lead, arsenic, and antimony can be removed by fluxing and skimming as a dross. After the impurities have been skimmed off, copper oxide in the melt is reduced to metal by inserting green wood poles below the bath surface (poling). Reducing gases formed by pyrolysis of the pole convert the copper oxide in the bath to copper. In recent years, reducing gases such as natural gas or reformed natural gas have been used. If the original material does not contain sufficient gold or silver to warrant its recovery, or if a special purpose silver-containing copper is desired, the fire-refined copper is cast directly into forms for industrial use. If it is of such a nature as to warrant the recovery of precious metals, fire refining is not carried to completion but only far enough to insure homogenous anodes for subsequent electrolytic refining.

A major portion of U.S. blister output is electrolytically refined. In electrolytic refining, anodes and cathodes (thin copper starting sheets) are hung alternately in concrete electrolytic cells containing the electrolyte which is essentially a solution of copper sulfate and sulfuric acid. When current is applied, copper is dissolved from the anode and an equivalent amount of copper plates out of solution on the cathode. Such impurities as gold, silver, platinum-group metals, and the selenides and tellurides fall to the bottom of the tank and form anode slime or mud.

Arsenic, antimony, bismuth, and nickel enter the electrolyte. The electrolyte has to be treated to prevent the buildup of these impurities since they would have a deleterious effect on cathode purity. After the plating cycle is finished, the cathodes are removed from the tanks, melted, and cast into commercial refinery shapes. Anode scrap is remelted to form fresh anodes. The copper produced has a minimum purity of 99.9%.

C. FORMS OF COPPER

Both electrolytic and fire refined copper are sold in two basic classes of refinery shapes: regular or standard shapes (consisting mainly of horizontally case wirebars, cathodes, ingots, and ingot bars, cakes, slabs and billets). The shapes are largely determined by the requirements of the fabricators' equipment.[1]

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[1]The American Society for Testing Materials (ASTM) defines refinery shapes as follows:

Wire bar: refinery shape for rolling into rod (and subsequent drawing into wire), strip, or shape.

Approximately 3-1/2 to 5 in. square in cross-section, usually from 38 to 54 in. in length and weighing from 135 to 420 lb. Tapered at both ends when used for rolling into rod for subsequent wire drawing and may be unpointed when used for rolling into strip. Cast either horizontally or vertically.

Cake: refinery shape for rolling into plate, sheet, strip, or shape. Rectangular in cross section of various sizes. Cast either horizontally or vertically, with range of weights from 140 to 4,000 lb. or more.

Billet: refinery shape primarily for tube manufacture. Circular in cross-section, usually 3 to 10 in. in diameter and in lengths up to 52 in.; weight from 100 to 1,500 lb.

Ingot and Ingot Bar: refinery shapes employed for alloy production (not fabrication).

Both used for remelting. Ingots usually weigh from 20 to 35 lb. and ingot bars from 50 to 70 lbs. Both usually notched to facilitate breaking into smaller pieces.

Cathode: unmelted flat plate produced by electrolytic refining. The customary size is about 3 ft. square and about 1/2 to 7/8 in. thick, weighing up to 280 lbs.

Copper Powder: finely divided copper particles produced by electrode-deposition.

For analytical purposes, the 40 distinct types of refined copper classified and graded by the American Society for Testing Materials (ASTM) can be collapsed into "refined copper" as a generic category, for two reasons. First, fabricators can to some extent substitute the various types of copper. For example, brass mills and foundries are fairly flexible. Second, copper producers possess the flexibility to produce more of one form and less of another. In the short run, both producers and fabricators have much less flexibility. However, for periods greater than six months there appears little reason to recognize distinctions among various types of refined copper in explaining the behavior of the market for refined copper. Further, market institutions indicate that it is reasonable to work in terms of refined copper, since a considerable degree of flexibility is allowed in substituting one type of copper for another and the producers' price for various types of copper is generally stated in terms of a differential from the price of electrolytic copper wirebars.

D. THE SECONDARY INDUSTRY

The term "primary metal" refers to metal recovered from ores or virgin sources. The term "secondary metal" came into wide use before it had acquired a singular meaning and still carries misleading connotations. It is important to recognize that "secondary" pertains only to origin and not to quality. That is, secondary refined copper is phycially equivalent to a corresponding grade of virgin refined copper. The term means only that the copper was recovered from scrap rather than from copper ore. Secondary copper loses its identity, except statistically, as soon as it is produced. It is not possible, for example, to determine whether a copper wirebar was derived from the scrap charged to a converter, or whether a brass ingot is made from remelted brass scrap or primary alloys.

There are three major categories of scrap users: primary producers, producers of unalloyed copper ingot and producers of alloyed copper ingot. The primary industry will purchase scrap for process reasons (e.g., cooling of converters) and also to supplement the production from primary sources. The producers of unalloyed and alloyed ingots are labelled the secondary copper industry.

The secondary copper industry utilizes a variety of processes to melt and refine copper scrap. Melting units include blast furnaces, reverbatory furnaces and electric furnaces. Refining is achieved via fire-refining or electrolytic refining. Often, product specifications are reached by diluting lower grade secondary copper with purer grades in order to minimize the need for refining.

Copper scrap, as a generic term, refers to a variety of materials. There are five classifications of unalloyed copper scrap and over 30 classifications of copper base or alloyed scrap. Some types of scrap are virtually pure copper, while other types are alloys, or mixtures of alloys with copper contents ranging down to as little as 30 percent. Refinery slags, dross, skimmings and ash, which sometimes have even low copper contents, are regarded as secondary material, although technically they are not scrap copper. Small quantities of copper are also recovered from non-copper-base scrap.

Finally, copper alloy ingot, which refers to alloys of copper and other metals, consists of "yellow brass" and other distinctive types of alloyed copper scrap used by fabricators (primarily by foundries) as a convenient way of arriving at a fabricated product made of a particular alloy. Rather than purchasing pure constituent metals, making the alloy and then fabricating it, a fabricator may find it convenient to purchase one of the many types of copper alloy ingots. These are convenient to supply, as alloy ingot is generally recovered from copper scrap already alloyed with one or more of the desired constituents. Producing an alloy from an alloy usually requires only melting, testing and some dilution.

E. POLLUTION CONTROL TECHNOLOGY

1. Introduction

The major pollutants at the mining and milling stage of production are solid wastes and water emissions. Except for dust emissions, air pollution is not a problem. Of all the environmental regulations affecting the four segments of the domestic copper industry, the air pollution regulations affecting the smelters are the most important. The two pollutants of major concern at this time at the primary copper smelting stage of production are air borne particulates and sulfur dioxide (SO_2). Described below is the process technology required for pollution control.

2. Pollution Control Technology for Conventional Smelting

At conventional copper smelters, both particular and SO_2 pollutants are generated at several individual sources, with distinctive characteristics for the off-gas or emissions at each source. For each of these polluting streams, many factors determine which of the basic abatement methods (or combinations) can best be used. There are two principal methods by which pollution abatement is accomplished: physical removal of the pollutant from the carrying stream before discharge to the environment and subsequent non-polluting disposal of the pollutant, or actual reduction in the amount of pollutant generated by the process. If pollution is defined and measured in terms of concentration levels in the local ambient air (or receiving water bodies), a third abatement method is to increase the amount of final dilution in the local environment.

Figure 2 is a schematic flow diagram of the conventional smelting and refining process. The emission sources of pollutants are shown in four categories: air, solid, water and fugitive. The latter are air emissions that come from diffuse sources. Table 1 shows the magnitude of these streams and the major constituents.

3. Air Pollution

Existing copper smelters have to meet Federal Ambient Air Quality Standards for particulates (50 mg/m^3) and sulfur oxides (80 mg/m^3--primary; annual mean). New copper smelters have to meet New Source Performance Standards in addition. At present there are three methods in use at copper smelters for reducing the sulfur dioxide concentrations in the vicinity of a smelter. These are: the production of sulfuric acid by the contact process from concentrated gas streams; the use of a tall stack to disperse dilute gas streams; and production curtailment. (See Chapter 8 for a discussion of the many regulations on pollution control requirements).

The contact sulfuric acid process is well established for treating SO_2-containing off-gases from metallurgical plants. Modern contact acid plants require at least 4.5-5% sulfur dioxide in the feed gas in order to operate autogenously, i.e., without external fuel. For handling lower concentrations of SO_2 an additional fuel input is required. The acid plant

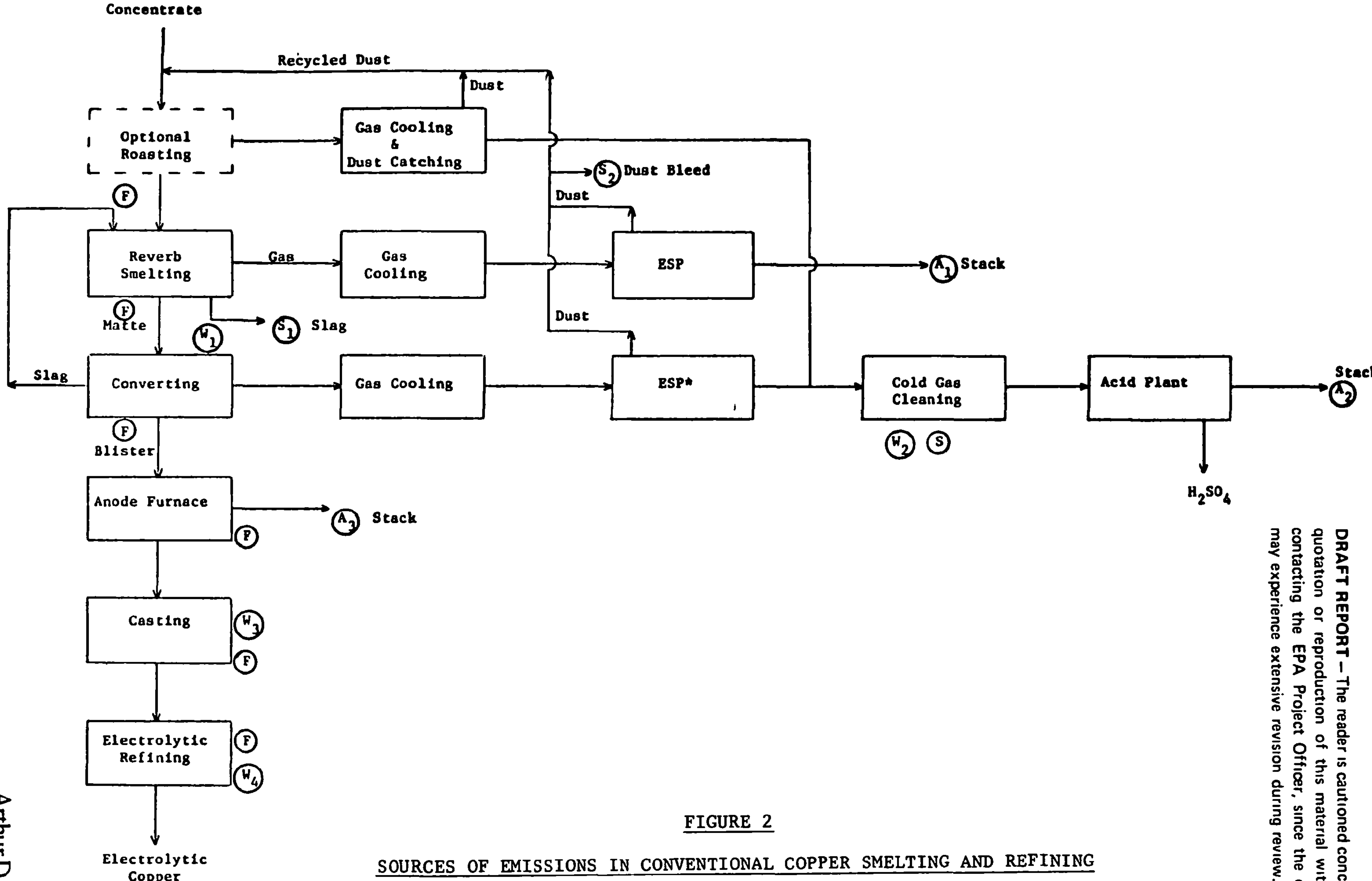

FIGURE 2

SOURCES OF EMISSIONS IN CONVENTIONAL COPPER SMELTING AND REFINING

Effluent Types: (A) - Air; (W) - Water; (S) - Solid Wastes; (F) - Fugitive

*ESP = Electrostatic Precipitator

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TABLE 1

EMISSIONS FROM CONVENTIONAL SMELTING

Stream	Stream Size	Major Constituents
• Air Pollution		
A-1 - Reverb Gas	82,000 SCFM	SO_2: 1-2%; O_2: 5%; Particulates: 50 μg/NM^3
A-2 - Acid Plant Tail Gas	38,800 SCFM	SO_2: 0.2%
A-3 - Anode Furnace Gas	NA	Flue Gas, Some SO_2
• Water Pollution		
W-1 - Slag Granulation	50,000 liters/kkg	TDS, SSS
W-2 - Acid Plant Blowdown	14,000 liters/kkg	TDS, TSS, Acidity
W-3 - Contact Cooling	7,800 liters/kkg	TDS, TSS
W-4 - Black Acid Bleed	700 liters/kkg	Acidity, TDS, TSS
• Solid Wastes		
S-1 - Reverb Slag	3 tons/ton Cu	Iron Silicates
S-2 - Dust Bleed	0.3 tons/ton Cu	Copper Oxides, Minor Elements

size is primarily a function of the volume of gas handled. Hence, for a constant acid output, an acid plant operating on more dilute gases is much larger (and more expensive) than an acid plant operating on more concentrated gases. With the currently used vanadium pentoxide catalysts, the upper level of SO_2 concentration in the feed gas to an acid plant is between 7 and 9%. Gas streams more concentrated than this require dilution.

The tall stack discharges sulfur dioxide at such heights that the gas is diluted when dispersed into the lower atmosphere. It is possible to add preheated air into the stack to achieve additional dispersion and dilution. Because tall stacks can achieve dispersion and dilution when used in conjunction with other means of limiting emissions, there is no simple relationship which can predict ambient concentrations as a function of percent sulfur recovery. Computer modeling has to be used for this purpose. The overall control strategy has to be well defined and local weather patterns have to be considered.

The third method for controlling sulfur dioxide concentrations at ground level is production curtailment when adverse weather conditions prevail. This method has been referred to as "closed loop control" or a Supplementary Control System (SCS) when it is based on the monitoring of sulfur dioxide concentrations at ground level at various sites in the areas surrounding the smelter and using this information to control the smelter operating rate. When ground level concentrations increase as a result of adverse weather conditions, the smelter operation is curtailed to reduce the emission rate.

Most copper concentrates contain more sulfur than copper, e.g., 31% sulfur and 25% copper. About 1 to 2% of the sulfur entering the smelter is lost in the slag and perhaps 3-5% evolves as fugitive emissions. The remaining sulfur is in gaseous effluents from roaster, reverb and converters. Typical sulfur distributions in conventional smelting are:

Sulfur Distribution - Percent

	Calcine Smelting	Green Charge Smelting
Roaster	20	-
Reverb	25	40
Converter	50	55
Slag and Fugitives	5	5
Total	100	100

The conventional smelting process evolved in geographical areas where acid markets were unavailable and all SO_2- containing gas streams were vented to the atmosphere (after particulate control, if necessary). Thus, conventional technology used gas-handling techniques (for example, dilution air for cooling of converter gas) which would not be used if the stream were to be treated for SO_2 recovery. However, streams from the roaster and converted can be handled to minimize air leakage. This results in SO_2 concentrations over 4-5% which is adequate for autogenous (i.e., without using an external heat source) sulfuric acid manufacture--the most cost-effective control technology for removing SO_2 from such streams. The reverb gases are a high volume (up to 100,000 SCFM) and low concentration

(0.5-2% SO_2) stream, not amenable to autogenous sulfuric acid manufacture.

With conventional smelting as well as with the new smelting processes (discussed in the next section), SO_2 control is achieved via an "end-of-pipe" treatment facility, i.e., a sulfuric acid plant. However, changes in processing and in gas handling and gas cooling are necessary for proper interfacing between process units and pollution control units.

In addition to SO_2, the reverb gas contains particulates. The use of electrostatic precipitators permit meeting the particulate emission levels established for copper smelters.

4. Solid Wastes

Slightly more than three pounds of solid waste per pound of copper are generated in a copper smelter. These come in the form of slag and collected flue dust.

- Slag

The converter slage is recycled to the reverb in order to recover its copper content. The slag tapped from the reverbatory furnace (and granulated in some cases) is disposed of as an inert rock. Reverb slag is mainly an iron silicate, containing about 0.5 to 0.9% copper and minor elements in rather dilute form.

- Flue Dust

The flue dust results from entrained particles and condensed effluents in the gas stream. Typically 3 to 6% of the total weight of solids entering the smelter are evolved as dust. Coarse particles are caught in the cooling chambers, while fine particulates are removed by electrostatic precipitators operating slightly above the dew point of the gas stream.

All flue dusts contain entrained copper and they are mostly recycled to the reverbatory furnace. They may also contain volatile impurities in a concentrated form. Excessive impurity build-up by dust recirculation would impair the quality of the blister copper. At times it is economical to process these dusts further in order to recover such metals as zinc, lead, arsenic, etc. Depending on the composition of the feed, a fraction of the dust generated may be diverted and either sold to other specialized smelters which recover the contained metals or stored.

5. Water Pollution

The primary copper industry must control water emissions from three major sources, the mines, the smelters and the refineries. In controlling water pollution it is often necessary to remember that in controlling the air pollution problems, a water pollution problem can be created since some of the most effective air pollution technologies are based on the use of water in scrubbing. Furthermore, the water drainage problem from tailings disposal areas is of considerable concern to the copper industry, but, of course, much less than in the coal mining industry. Although air and water pollution control have been considered separately, it is mandatory that in arriving at solutions to one problem, another one of equal or greater magnitude is not created.

The water pollution regulatory constaints on the copper industry arise mainly as a result of Sections 304(b) and 306 of the Federal Water Pollution Control Act Amendments. Under this Act, the EPA has conducted technical studies which are published as "Development Documents" which form the basis for the Effluent Limitation Guidelines. These guidelines refer to three specific discharge levels.

- Best Practical Control Technology Currently Available (BPCTCA)-- to be met by industrial discharges by 1977.
- Best Available Technology Economically Available (BATEA)--to be met by 1983.
- New Source Performance Standards (NSPS)--to be applied to all new facilities constructed after the promulgation of these guidelines.

In order to achieve the effluent limitations, the recommended treatment technology must remove suspended solids, adjust pH, and remove the specific heavy metals. To perform these functions lime precipitation, settling, and pH adjustment are recommended

Since all of the heavy metals included in the proposed effluent limitations have very low solubility in the alkaline pH range, the addition of lime causes the metal to precipitate out of solution as metal hydroxides and carbonates. The metal precipitates, along with other suspended solids present in the wastewater, are separated from the wastewater stream by means of settling, and are withdrawn as a sludge. Since the wastewater is still at a high pH after this step, it is necessary to lower the pH by means of injecting carbon dioxide gas or other acid into the water. This step is usually performed in a separate basin. Other recommended techniques for improving the effectiveness of the previously mentioned end-of-pipe treatment are reuse of water in other operations; control of mine water drainage by modification of mining techniques, construction of diversion structures, or ditching; and use of solar evaporation to eliminate the discharge of excess water. In a copper smelter and refinery the sources of wastewater are:

- slag granulation (if this is practiced);
- acid plant blowdown (i.e., blowdown from wet scrubbers ahead of the acid plant);
- metal cooling;
- spent electrolyte and washings; and
- storm water commingling with process wastewater.

The Effluent Limitation Guidelines for primary smelters and refineries in net evaporation area is zero discharge of process wastewater pollutants, based on recycle, reuse and solar evaporation. This standard applies to both the 1977 (BPCTA) and for 1983 (BATEA) guidelines. (The applicability of this standard to two particular smelters has been challenged in court).

Zero discharge is to be achieved by neutralization of acidic streams, settling (thickening) of streams containing suspended solids; and cooling of contact cooling water for recycle.

F. NEW PROCESS TECHNOLOGY

The smelting technology in the U.S. evolved in a framework of low energy costs and in loactions distant from sulfuric acid markets and urban population centers. Thus the technology was not aimed at recovering sulfur values as sulfuric acid (as is the case abroad) and was not particularly efficient in its use of energy. Several changes have occurred in the past five years on the economic and regulatory scene which indicate that the currently used technology is no longer applicable for the construction of new smelters. These changes are as follows:

- Energy costs for smelting have increased rapidly. Cheap natural gas, the fuel used by most smelters is not now available to the smelters particularly in peak demand months (winter) and might not be available at all in the future.
- Emissions of SO_2 to the atmosphere have to be controlled. After several years of debate and litigation, all issues relating to SO_2 emissions are yet to be resolved (details in Chapter 8). These issues are as follows:
  - It is generally agreed within EPA and the industry that SO_2 emissions from reverbs cannot be controlled economically, but must be vented from tall stacks. For example, the New Source Performance Standards would allow the use of uncontrolled reverbs only for the smelting of "impure" concentrates (concentrates containing As, Sb, Bi, etc.). About 30% of the feed sulfur is emitted from the reverbs. Emissions from streams containing high concentrations of SO_2 (new smelting furnaces, converter and fluid bed roaster gases) have to be controlled by technology such as sulfuric acid plants. Double absorption plants (or equivalents) are mandatory for new sources. At existing smelters, the combination of uncontrolled reverbs but controlled fluid bed roasters and converters can recover from about 50-70% of the sulfur in the feed in the form of sulfuric acid. New smelting technology can recover a larger fraction (over 90%) of the sulfur in the feed.

- The influence of EPA regulations on different modes of capacity expansion is discussed in Chapter 8.
- Compared to the cost of SO_2 ctonrol, the costs of complying with other existing pollution control legislation, e.g., water and solid wastes, is quite small. However, this situation could change as new standards are proposed for controlling emissions of other substances.

- The acid produced by smelters cannot be economically transported to traditional acid markets and it has to be disposed of (by selling it at a low price) in the general vicinity of the smelter. This resulting availability of low-priced acid in the west has made it possible to use it to make wet process phosphoric acid from low grade western phosphate rock or to use it to leach mine dumps and low grade deposits which cannot be leached economically at higher acid prices for the extraction of the contained copper. An alternative is its neutralization with limestone. This is being indirectly on copper ores high in limestone.

New process technology has evolved in response to various shortcomings of conventional technology and as a result of external constraints. New technology fall into the following major categories:

- New smelting processes (Outokumpu, Mitsubishi, Noranda, electric, etc.),
- Hydrometallurgical processing of sulfide concentrates (Arbiter, Clear, etc.),

- Hydrometallurgical processing of oxide/sulfide ores, mine dumps, etc.

The new smelting processes are more energy efficient and can reduce total energy requirements by 30-50%. They produce a concentrated stream of sulfur dioxide from the smelting unit which can be economically converted to sulfuric acid. The adoption of this technology would avoid the use of reverbs which produce dilute SO_2-containing streams. Sulfure capture would increase from 50-70% for current technology to over 90%. The major shortcoming of the new processes other than electric smelting is that their applicability to impure concentrates (concentrates high is As, Sb, Bi, Pb, Zn, Se, Te, etc.) is unproven. Until this issue is resolved, the new processes would have to be utilized for building large smelters to smelt clean concentrates in regions where acid markets are available. All hydrometallurgical processes, conventional as well as new, offer significant economies of scale, the smallest economic size being approximately 100,000 tons/year of copper.

The hydrometallurgical processes for sulfide concentrates produce cathode copper directly, and release sulfur in the concentrates in forms other than SO_2. It may be feasible to build hydrometallurgical plants sized around 40,000 tons of copper per year at a unit cost which is about the same as the unit cost of a large (over 100,000 tons/year) copper smelter and refinery. The hydrometallurgical processes, in general, are not energy efficient and utilize the same or slightly more energy than conventional smelting and refining which is significantly higher than the energy used by the new smelting processes. The leached solid wastes will require land disposal into areas prepared so as to prevent groundwater leaching of soluble substances and to prevent airborne particulates. Because the plants will probably be located generally in the semi-arid western United States, such a disposal area can be established with some degree of confidence. Overall, these processes are likely to be utilized in locations remote from sulfuric acid markets where a large smelter is not justified.

Sulfuric acid leaching of oxides is not a primary copper recovery process but can be considered as an acid neutralization/disposal technique that also recovers copper from resources previously considered as marginal. Since the typical western U.S. smelter locations are distant from major sulfuric acid markets, the sulfuric acid produced to minimize air pollution has to be utilized for leaching of marginal resources (mine dumps, tailings, oxide ores, etc.) or for making wet process phosphoric acid. The leaching of dumps and surface deposits without contamination of groundwater is possible in the arid west but might not be possible in other parts of the U.S. As a last resort, neutralization with limestone or the reduction of SO_2 streams to elemental sulfur would have to be considered. These options would exert their own impacts.

CHAPTER 3

THE U.S. COPPER INDUSTRY IN WORLD PERSPECTIVE: AN OVERVIEW

A. INTRODUCTION

Although the United States is virtually self-sufficient in copper, the U.S. copper industry does not exist in isolation from the rest of the world. It is possible, therefore, that domestic environmental regulations may have economic effects on the copper industry not only domestically but also internationally. Fundamental questions are raised in this connection. What will be the effect of domestic environmental regulations on the investment behavior of U.S. copper firms internationally? What will be the impact of environmental regulations in terms of the dependency of the United States on imported copper in the future? These questions gain importance particularly in view of the flurry of speculation and debate about the possible emergence of new, OPEC-like cartels following the recent OPEC embargo and oil price increases and the rapid escalation of basic primary commodities prices in 1973 and 1974.[1] Within a broader context, these questions arise in light of the current debate about the "new international economic order," inasmuch as non-fuel primary commodities have remained at the heart of this debate, involving the twin issues of both supply access and prices.

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[1]See, for example, C. Fred Bergsten, "The Threat from the Third World," Foreign Policy, 11 (Summer, 1973), p. 102-124; Stephen D. Krasner, "Oil is the Exception," Foreign Policy, 14 (Spring, 1974), p. 68-84; Bension Varon and Kenji Takeuchi, "Developing Countries and Non-fuel Minerals," Foreign Affairs, 52, 3 (April, 1974), p. 497-510; Raymond F. Mikesell, "More Third World Cartels Ahead?" Challenge (November/December, 1974), p. 24-31; International Economic Policy Association, U.S. Natural Resource Requirements and Foreign Domestic Policy, Interim Report (Washington, D.C.: July 18, 1974).

The issues arising within this broader context are obviously important and require attention in an analysis of the economic effects of domestic environmental regulations.

These broader questions and issues are properly addressed later as part of our impact analysis (Chapter 10). In this chapter, we provide a condensed and selective overview of the international structure of the copper industry, in part as a prelude to an analysis of the international economic implications of domestic environmental regulations affecting the copper industry and also in part to convey an understanding of the international setting in which the domestic copper industry operates. Accordingly, the chapter opens with a review of world copper production and consumption patterns. This is followed by a description of key aspects of the copper industry's worldwide structure. International trade in copper is discussed next, followed by examination of the trade relationships of the United States with the rest of the world.

The principal conclusions emerging from this chapter can be summarized as follows:

1. World production of refined copper in 1974 was approximately 8.9 million metric tons (smelter production about 7.7 million metric tons and mine output about 7.9 million metric tons). The United States accounted for 21.9 percent of refined, 18.4 percent of smelter, and 18.3 percent of mine output.

2. The share of the United States in world refined copper production dropped from 31.7 percent in 1964 to 21.9 percent in 1974. During the same period, U.S. smelter output share dropped from 25.4 percent to 18.4 percent, while U.S. mine output share dropped from 23.8 percent to 18.3

percent.

3. At the mining level, copper output is highly concentrated in a relatively few countries, with the United States still as the largest single producer. Six countries (i.e., the United States, Canada, Chile, Zaire, Zambia, U.S.S.R.) together account for 71.2 percent of total world mine output (1974). This reflects only a slight downward shift in concentration over the previous decade, with the same six countries having accounted for 78.3 percent of total world mine output of copper in 1964.

4. Chile, Zambia, Peru and Zaire, the original four members of CIPEC,[1] together account for about 37 percent of Free World mine production in copper. With recent additions in its membership, CIPEC's participation in internationally traded copper has increased to over 70 percent.

5. Most major copper mining countries are also major smelters. Concentration by country in copper refining, by contrast, displays a different pattern. For example, several leading industrial countries with little or no mine production, and in many cases very little smelter production, are large copper refiners based on imported smelted copper (e.g., West Germany, Belgium-Luxembourg, the United Kingdom, none of which has either mine production or large smelter production; Japan, which accounts for only 1.0 percent of world mine output, accounts for 11.6 percent of world smelter output and 11.8 percent of world refined copper output).

[1] The Conseil Intergouvernemental des Pays Exportateurs de Cuivre (CIPEC), also known as Intergovernmental Council of Copper Exporting Countries.

6. World consumption of refined copper, which tends to be cyclical, was about 8.3 million metric tons in 1974. Of this, U.S. consumption accounted for nearly 2.0 million metric tons or 23.5 percent. The U.S. share of world consumption of refined copper dropped from 28.8 percent in 1963 to 23.5 percent in 1974, reflecting a relatively higher growth in demand for copper in the rest of the world.

7. During the postwar period, there has been a major change in the ownership structure of the world copper industry. In 1947, the four largest private mining companies accounted for about 60 percent of free-world mine output. This declined to 49 percent by 1956 and to less than 20 percent by 1974. Meanwhile, through nationalization, the share of government-owned enterprises in free-world mine output increased, reaching 34 percent in 1974. Moreover, governmental ownership of the copper industry is heavily concentrated in the copper exporting countries--mainly the CIPEC countries.

8. The copper industry is highly concentrated in individual countries. In the United States, three companies (Anaconda, Kennecott, and Phelps Dodge) account for 54 percent of total U.S. mine production (1974) and eight companies account for 87 percent of U.S. mine production. Most of the eight companies also smelt all of their own output. Copper refining in the U.S. is even more concentrated, with six companies (Asarco, Kennecott, Phelps Dodge, Anaconda, Amax, and Newmont) accounting for nearly 90 percent of U.S. refining capacity (1974).

9. A substantial portion of the large firms are vertically integrated from mining to refining. In the United States over half of the output of

domestic copper refiners is sold to subsidiaries, and a substantial portion of the output of Japanese and European refiners is also sold to their affiliates. In the past, a significant portion of the output of the mines owned by private international firms was sold to parent companies or affiliates of the mining firms. However, this pattern has been changing with the nationalization of the private firms in the CIPEC countries and the assumption of the marketing function by the governments of these countries.

10. Copper processing in individual countries or areas is characterized by a relatively high degree of concentration, which suggests an oligopolistic industry structure. However, little can be concluded a priori about possible implications of industry structure for industry behavior and market competition without consideration of other market forces that affect industry behavior. Factors of interest include the extent of vertical integration of smelting and refining firms forward into fabricating, the importance of trade barriers and transportation costs as constraints to international trade, entry conditions facing potential new producers, pricing constraints imposed by secondary metal and the threat of substitution away from copper, and government intervention in markets.

Meanwhile, it is difficult to measure the extent of vertical integration of primary copper producers forward into copper fabricating. As a generalization, primary producers in North America and Japan have important fabricating operations, refiners to Europe are partially integrated forward, and those in other producing countries have very little fabricating capacity.

11. The bulk of the world's copper exports is from the developing countries to Europe, Japan and the United States, with smaller amounts from Canada, South Africa and Australia. The United States and Western Europe also export refined copper, but are net importers of copper overall.

Trade in smelted copper has traditionally flowed mainly from Africa to Western Europe and from Latin America to the United States. Entry of Japan as an important importer and increasing refining of blister in the exporting countries have resulted in greater diversification of trading patterns in recent years and a gradual decline in the absolute importance of trade in unrefined compared with refined metal.

12. Most of the copper exported by the developing countries is sold under contract to smelters, refineries, or fabricators in the developed countries. The pattern of world trade in concentrates tends to be governed by long-term contracts which may call for deliveries over periods up to 15 or 20 years, financial arrangements providing for repayment of loans in concentrates, and ownership ties between the mining and processing companies. Long-term contracts for the sale of concentrates or blister offer important advantages for both the mines and the smelters or refineries with which they are negotiated. By contrast, trade in refined copper is for the most part based on short-term contracts of one-to-twelve month duration. While more competitive, it is also influenced by nonprice factors such as ownership ties, technical assistance and marketing contracts, and long standing buyer-seller relationships. Ownership ties between producing and consuming countries have been declining, and, even where they exist, governments of producing countries have taken a more

active role in marketing and are attempting to diversify their markets. Other nonprice factors, such as strikes, transportation problems, natural disasters in the producing countries, and recessions in the consuming countries, frequently affect the pattern of trade in refined copper.

13. Although the United States has been virtually self-sufficient in copper, except in certain years coinciding with military developments or unusual "demand crunch" periods, the U.S. has been both a leading importer and exporter of copper. This, however, may change sharply in the future, partly as a result of the domestic environmental regulations affecting the U.S. copper industry. The impact of domestic environmental regulations on the U.S. copper industry should therefore be examined with close attention to their international economic implications.

B. WORLD COPPER PRODUCTION AND CONSUMPTION PATTERNS

Analysis of world copper production patterns is somewhat complicated by the role of secondary copper and the difficulty of separating copper of primary origin from that originating from scrap, especially after the latter has been re-refined.

1. U.S. and World Production Trends

World production of refined copper in 1974 was approximately 8.9 million metric tons (smelter production about 7.7 million metric tons and mine output about 7.9 million metric tons), as shown in Table 1. The United States accounted for 21.9 percent of refined, 18.4 percent of smelter, and 18.3 percent of mine output. The share of the United States in world refined copper production dropped from 31.7 percent in 1964 to 21.9 percent in 1974 (Table 2). During the same period, U.S. smelter output share dropped from 25.4 percent to 18.4 percent, while U.S. mine output share dropped from 23.8 percent to 18.3%. U.S. mine output has grown at 2.48 percent per year over the 1964-1974 period (compared to world average of 5.09 percent per year) and at 3.54 percent per year over the 1963-1973 period (compared to world average of 5.08 percent per year).

2. Where Copper is Produced

At the mining level, copper output is highly concentrated in a relatively few countries, with the United States still as the largest single producer (Table 3). Six countries (i.e., the United States, Canada, Chile, Zaire, Zambia, U.S.S.R.) together account for 71.2 percent of total world mine output (1974). This reflects only a slight downward shift in

TABLE 1

WORLD PRODUCTION OF COPPER, 1974[a]
(thousand metric tons)

Country Groups	Mine production (copper content)		Smelter Production		Production of refined copper	
	Amount	Percent (%)	Amount	Percent (%)	Amount	Percent (%)
Total World	7,885.6	100.0	7,733.6	100.0	8,851.5	100.0
United States	1,445.7	18.3	1,424.2	18.4	1,938.3	21.9
Other America	2,042.6	25.9	1,518.6	19.6	1,241.7	14.0
Europe	322.1	4.1	538.1	7.0	1,447.4	16.4
Asia	447.7	5.7	970.4	12.5	1,608.2	12.1
Africa	1,519.1	19.3	1,411.7	18.3	1,051.8	11.9
Australia and Oceania	439.7	5.6	195.6	2.5	189.6	2.1
Communist Block Countries	1,668.7	21.2	1,675.0	21.7	1,914.5	21.6

NOTES: [a]Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), pp. 26-31.

TABLE 2

UNITED STATES AND WORLD COMPARATIVE TRENDS IN COPPER PRODUCTION: 1963-1974
(thousand of metric tons)

Years	Mine Production of Copper (copper content)			Smelter Production of Copper			Production of Refined Copper		
	U.S.	World	U.S. as percent of world	U.S.	World	U.S. as percent of world	U.S.	World	U.S. as percent of world
1963	1100.6	4624.3	23.8	1176.3	4634.8	25.4	1709.5	5399.7	31.7
1964	1131.1	4798.6	23.6	1214.2	4851.4	25.0	1805.7	5739.0	31.5
1965	1226.3	4962.7	24.7	1300.9	5024.4	25.9	1942.1	6058.5	32.1
1966	1296.5	5215.9	24.9	1330.3	5167.0	25.7	1980.7	6322.2	31.3
1967	865.5	5057.6	17.1	782.3	4891.0	16.0	1384.9	6000.5	23.1
1968	1092.8	5456.5	20.0	1148.9	5507.8	20.9	1668.3	6658.6	25.1
1969	1401.2	5951.2	23.5	1438.3	5972.9	24.1	2009.3	7199.8	27.9
1970	1560.0	6387.3	24.4	1489.0	6309.5	23.6	2034.5	7577.8	26.8
1971	1380.9	6473.9	21.3	1360.8	6380.0	21.3	1780.3	7377.8	24.1
1972	1510.3	7071.5	21.4	1533.5	7003.2	21.9	2048.9	8068.0	25.4
1973	1558.5	7591.4	20.5	1582.1	7445.5	21.2	2098.0	8497.3	24.7
1974	1445.7	7885.6	18.3	1424.2	7933.6	18.4	1938.3	8851.5	21.9
Average Annual Compound Growth Rate (Percent)									
1963-1973	3.54	5.08	-	3.01	4.85		2.07	4.64	-
1964-1974	2.48	5.09	-	1.61	4.77	-	0.71	4.43	

NOTES: [a]One metric ton (1,000 kilograms) equals 1.102311 short tons (907.185 kilograms = 2000 pounds avoirdupois, where one pound avoirdupois equals 0.453592 kilogram or 453.5924 grams).

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1963-1973, 61st Edition (Frankfurt am Main, 1974), pp. 26-31; and Metal Statistics 1964-1974, 62nd Edition (Frankfurt am Main, 1975), pp. 26-31.

TABLE 3

WORLD MINE PRODUCTION OF COPPER: FIFTEEN LARGEST PRODUCING COUNTRIES, 1964 and 1974
(copper content)

Country	Amount (thousand metric tons) 1964	Amount (thousand metric tons) 1974	Percent Composition[b] (%) 1964	Percent Composition[b] (%) 1974
United States	1,131.1	1,445.7	23.6	18.3
Canada	441.7	826.2	9.2	10.5
Chile	621.7	902.1	13.0	11.4
Peru	176.4	213.2	3.7	2.7
Zaire	276.6	544.1	5.8	6.9
Zambia	632.3	698.0	13.2	8.9
Republic of South Africa	61.3	179.1	1.3	2.3
Japan	106.2	82.1	2.2	1.0
Philippines	60.5	209.7	1.3	2.7
Australia	106.3	255.6	2.2	3.2
Papua-New Guinea	-	184.1	-	2.3
Yugoslavia	63.2	155.2	1.3	2.0
USSR[a]	650.0	1,200.0	13.5	15.2
Poland	13.4	198.0	0.3	2.5
China, PR and North Korea[a]	83.0	150.0	1.7	1.9
Subtotal	4,423.7	7,243.1	92.2	91.9
World Total	4,798.6	7,885.6	100.0	100.0

NOTES: [a]Estimates.

[b]Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), pp. 26-27.

concentration over the previous decade, with the same six countries having accounted for 78.3 percent of total world mine output of copper in 1964.

Chile, Zambia, Peru and Zaire together account for about 37 percent of Free World mine production in copper.[1] Mines in these countries were initially developed by large foreign countries. In recent years, the governments involved have exerted increasing control over, and participation in ownership of these mines. Chile initiated a "Chilianization" program in 1966 which culminated in complete nationalization of the major producers in 1971. Zambia introduced a "Zambianization" program at the end of 1960 to eventually replace foreign personnel by nations and in 1970, acquired 51 percent ownership of the two major producer groups. Zaire nationalized its one large producer in 1966 and Peru has recently been insisting on increased national participation and expansion of mineral processing. In 1974 the Zambian government terminated both the management and the sale contracts with the Anglo-American group and AMAX, the former majority owners (now 49 percent owners). In that same year the Peruvian government nationalized Cerro de Pasco, the second largest copper producer after Southern Peru Copper Co. (which owns Toquepala and Cuajone). The new copper refinery at Ilo is wholly government-owned and operated. Finally, in 1975

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[1] In 1968, these four countries formed the Conseil Intergouvernemental des Pays Exportateurs de Cuivre (CIPEC), also known as Intergovernmental Council of Copper Exporting Countries. During the November 17-19, 1975 meeting in Lima, Peru, the four founding members accepted Indonesia as a full member and Australia and Papua New Guinea as nonvoting associate members (not subject to CIPEC control directives). The newmembership increases CIPEC participation in internationally traded copper to more than 72 percent. More will be said about CIPEC in the impact analysis section of the report.

the government of Zaire renegotiated its technical assistance and sales agreements with the Belgium firm SGM (an affiliate of Union Miniere) so that operations and sales of Gecamines output are entirely under government control.

The geographical distribution of world copper productive capacity (Table 4) closely parallels the distribution of copper mine output. Among the more striking conclusions that can be drawn here are the following:

- U.S. mine productive capacity (i.e., mine/mill capacity, where the mill capacity effectively serves as the binding constraint) only slightly exceeds the estimated combined capacity of the Sino-Soviet Block countries as a whole,
- about 80 percent of world mine productive capacity is located outside the Sino-Soviet Block countries,
- The CIPEC countries (Chile, Peru, Zambia and Zaire) account for about 29 percent of world capacity and 36 percent of total Free World capacity,
- world capacity has remained practically constant during 1974-1975, reflecting adverse market conditions.

Most major copper mining countries are also major smelters and their shares of smelter output are broadly comparable with their shares of mine output (Table 5). However, Canada and to a much lesser extent, Peru, and Australia have lower shares of world smelter capacity, compared to their shares of world mine capacity, while the reverse is true for Japan and West Germany, in particular. The Philippines exports all of its production in the form of concentrates. However, the degree of concentration in

TABLE 4

WORLD COPPER MINE PRODUCTIVE CAPACITY, BY AREA AND COUNTRY, 1974 AND 1975

Area/Country	Estimated Capacity (thousands of short tons) Dec. 31, 1974	Dec. 31, 1975	Percent Breakdown (%) Dec. 31, 1974	Dec. 31, 1975
North America				
United States	1,920	2,050	20.6	21.6
Canada	1,020	980	11.0	10.0
Mexico	95	100	1.0	1.1
Other	10	10	0.1	0.1
Total	3,045	3,140	32.7	33.0
South America				
Chile	1,000	1,000	10.7	10.5
Peru	245	245	2.6	2.6
Other	15	15	0.2	0.2
Total	1,260	1,260	13.5	13.2
Africa				
Zambia	850	850	9.1	8.9
Zaire	625	625	6.7	6.6
South Africa	200	200	2.1	2.1
South West Africa	35	35	0.4	0.2
Other	80	120	0.9	1.3
Total	1,790	1,830	19.2	19.2
Asia				
Philippines	265	280	2.8	2.9
Japan	85	75	0.9	0.8
Indonesia	80	80	0.9	0.8
Iran	5	5	0.1	0.1
Other	100	110	1.1	1.2
Total	535	550	5.7	5.8
Oceania				
Australia	285	275	3.1	2.9
Papua New Guinea	200	200	2.1	2.1
Total	485	475	5.2	5.0
Europe	365	375	3.9	3.9
TOTAL FREE WORLD CAPACITY	7,480	7,630	80.3	80.2
SINO-SOVIET BLOCK COUNTRIES	1,836[a]	1,880[a]	19.7	19.8
TOTAL	9,316	9,510	100.0	100.0

NOTES: [a]Actual mine production, from World Bureau of Metal Statistics (1974) and Commodities Research Unit Ltd. (1975), as reported in Enginnering and Mining Journal (March, 1976), p. 89.

[b]Components may not sum up to the totals given due to rounding.

SOURCE: Phelps Dodge Corporation; Arthur D. Little, Inc.

TABLE 5

WORLD SMELTER PRODUCTION OF COPPER: FIFTEEN LARGEST PRODUCING COUNTRIES, 1964 AND 1974

Country	Amount (thousand metric tons)		Percent Composition[c] %	
	1964	1974	1964	1974
United States	1,214.2	1,424.2	25.0	18.4
Canada	365.9	537.0	7.0	6.9
Chile	586.7	724.3	12.1	9.4
Peru	152.1	179.8	3.1	2.3
Zaire	276.6	469.9	5.7	6.1
Zambia	638.8	709.3	13.2	9.2
Republic of South Africa	56.3	147.8	1.2	1.9
Japan	280.9	900.0	5.8	11.6
Australia	81.9	195.6	1.7	2.5
Germany, FR	68.3	174.0	1.4	2.3
Spain	21.4	79.0	0.4	1.0
Yugoslavia[b]	49.4	142.2	1.0	1.8
USSR[a]	650.0	1,200.0	13.4	15.5
Poland	23.8	190.0	0.5	2.5
China, PR and North Korea[a]	83.0	150.0	1.7	1.9
Subtotal	4,549.3	7,223.1	93.8	93.4
World Total	4,851.4	7,733.6	100.0	100.0

NOTES: [a]Estimates.

[b]Primary copper only.

[c]Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Akiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), pp. 28-29.

smelting by country is very similar to that in mining, and, as was true for the latter, concentration in copper smelting changed very little over the 1967-1974 period, with the exception of a significant increase in smelter production in Japan.

Concentration by country in copper refining, by contrast, displays a different pattern, as shown in Table 6.[1] For example, several leading industrial countries with little or no mining production, and in many cases very little smelter production, are large copper refiners based on imported smelted copper. The leading examples are West Germany, Belgium-Luxembourg, and the United Kingdom, none of which has either mine production or large smelter production. The United States is the leading producer at all three stages. Japan, which accounts for only 1.0 percent of world mine output, not only accounts for 11.6 percent of world smelter output but also a similarly significant 11.8 percent of world refined copper output. Unlike Western European countries, Japan both smelts and refines most of its copper imports.

3. Where Copper is Consumed

World consumption of refined copper was about 8.3 million metric tons in 1974. Of this, U.S. consumption accounted for nearly 2.0 million metric tons or 23.5 percent. The U.S. share of world consumption of refined copper dropped from 28.8 percent in 1963 to 23.5 percent in 1974, reflecting a

[1] The data in Table 6 must be interpreted with some caution, however, because they include refined copper produced from scrap. Unfortunately, accurate statistics on scrap inputs in refining are not readily available, on a worldwide basis.

TABLE 6

WORLD PRODUCTION OF REFINED COPPER: FIFTEEN LARGEST PRODUCING COUNTRIES, 1964 AND 1974

Country	Amount (thousand metric tons) 1964	Amount (thousand metric tons) 1974	Percent Composition[b] (%) 1964	Percent Composition[b] (%) 1974
United States	1,805.7	1,938.3	31.5	21.9
Canada	370.1	559.1	6.4	6.3
Chile	277.9	538.1	4.8	6.1
Zaire	140.2	254.5	2.4	2.9
Zambia	497.1	678.8	8.7	7.6
Japan	341.7	996.0	6.0	11.3
Australia	101.7	189.6	1.8	2.1
Germany, FR	324.7	423.6	5.7	4.8
Spain	46.7	123.5	0.8	1.4
Belgium-Luxembourg	275.0	378.7	4.8	4.3
United Kingdom	224.9	160.1	3.9	1.8
Yugoslavia	51.9	150.6	0.9	1.7
USSR[a]	750.0	1,350.0	13.1	15.3
Poland	36.6	194.5	0.6	2.2
China, RP and North Korea	110.1	200.0	1.9	2.3
Subtotal	5,354.2	8,133.4	93.3	91.9
World Total	5,739.0	8,851.5	100.0	100.0

NOTES: [a]Estimates.
[b]Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), pp. 30-31.

relatively higher growth in demand for copper in the rest of the world (Table 7). Accordingly, while refined copper consumption in the United States has increased by only 1.90 percent per year during the 1963-1974 period (1.47%/yr. over 1964-1974 and 3.39%/yr. over 1963-1974), world consumption has recorded a substantially higher rate of growth at 3.81 percent per year over the sample period (3.34%/yr. over 1964-1974 and 4.77%/yr. over 1963-1973).

As shown in Table 8, fifteen countries accounted for 88.1 percent of total world refined copper consumption in 1974, while these countries produced only 53.6 percent of total world mine output of copper. When the United States and the U.S.S.R. (two virtually self-sufficient countries) as well as Canada (a major exporter) are excluded, the picture becomes substantially different: while the remaining twelve largest consumers together account for 47.3 percent of total world consumption of refined copper, their combined mine output amounts to only 9.6 percent of the world total.

Although not shown in the accompanying tables, annual copper consumption reported by individual countries tends to be quite cyclical, particularly in the United Kingdom, the United States, and West Germany. Year to year changes of plus or minus ten percent are common and changes exceeding 20 percent have not been unusual. Even though cyclical downturns in some countries tend to be offset by upswings in others and this may serve to smooth the trend in total consumption, copper production generally tends to be more stable over time than overall copper consumption.[1]

[1] It should be noted that the reduced mine production in 1967 was due to a lengthy strike in the United States.

TABLE 7

UNITED STATES AND WORLD COMPARATIVE TRENDS IN REFINED COPPER CONSUMPTION, 1963-1974
(thousand metric tons)

Years	U.S.	World	U.S. as percent of world
1963	1590.0	5519.3	28.8
1964	1690.0	5995.4	28.2
1965	1845.6	6193.2	29.8
1966	2157.8	6444.8	33.5
1967	1797.5	6194.8	29.0
1968	1701.4	6523.3	26.1
1969	1944.3	7148.0	27.2
1970	1854.3	7283.4	25.5
1971	1830.5	7309.9	25.0
1972	2028.6	7944.5	25.5
1973	2218.6	8791.6	25.2
1974	1956.4	8325.4	23.5
Average Annual Compound Growth Rate (Percent)			
1963-1973	3.39	4.77	-
1964-1974	1.47	3.34	-

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1963-1973 and 1964-1974, pp. 32-33.

TABLE 8

REFINED COPPER CONSUMPTION AND MINE PRODUCTION OF COPPER, BY FIFTEEN LARGEST CONSUMING COUNTRIES, 1974

Country	Consumption of Refined Copper[a]		Mine Production of Copper[a]	
	Amount (thousand metric tons)	Percent (%)	Amount (Copper content, thousand metric tons)	Percent (%)
United States	1,956.4	23.5	1,445.7	18.3
Canada	270.1	3.2	826.2	10.5
Japan	831.0	10.0	82.1	1.0
Germany, FR	731.0	8.8	1.7	-
Belgium-Luxembourg	178.2	2.1	-	-
France	414.2	5.0	0.4	-
Italy	308.0	3.7	0.8	-
United Kingdom	496.9	6.0	-	-
Spain	143.9	1.8	44.5	0.6
Brazil	162.0	1.9	6.0	0.1
Australia	121.6	1.5	255.6	3.2
U.S.S.R.	1,170.0	14.1	1,200.0	15.2
Germany, DR	105.0	1.3	18.0	0.2
Poland	150.0	1.8	198.0	2.5
China, PR and North Korea	300.0	3.6	150.0	1.9
Subtotal	7,338.3	88.1	4,229.0	53.6
World Total	8,325.4	100.0	7,885.6	100.0

NOTES: [a]Components may not sum up to the totals given due to rounding.

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics, 1964-1974, 62nd. Edition, (Frankfurt am Main, 1975), various pages.

C. INDUSTRIAL CONCENTRATION

The copper industry's worldwide geographical concentration is paralleled by its industrial concentration.

Orris Herfindahl estimated that in 1947 four mining firms accounted for about 60 percent of world output (excluding the U.S.S.R.) and eight firms accounted for 77 percent of world output. By 1956 these percentages had declined to 49 and 70 percent respectively.[1] All of these companies were privately owned and most of the stock was held by residents of the United States, Canada and the principal Western European countries.

Since 1956 there has been a major change in the structure of the world copper industry. In 1974 the four largest private copper producers--Kennecott, Newmont, Phelps Dodge and Rio Tinto Zinc--had a majority ownership interest in less than 20 percent of the free world mine copper output, and 10 privately-owned companies had a majority interest in less than 35 percent of the free world mine copper output.[2] Eleven other privately-owned companies (see Table 9) are majority owners of an additional 10 percent of the free world copper output.[3]

The majority or wholly-owned government mining enterprises (e.g., in Chile, Peru, Zaire, Zambia, Turkey, India, Uganda) accounted for about 34 percent of the free world mine output in 1974. According to Sir Ronald

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[1] Orris C. Herfindahl, Copper Costs and Prices: 1870-1957, published for Resources for the Future, Inc. (Baltimore: The Johns Hopkins Press, 1959), p. 165.

[2] The ten companies are Anaconda, Asarco, Cyprus, Duval, International Nickel, Kennecott, Mt. Isa, Newmont, Phelps Dodge and Rio Tinto Zinc (RTZ). RTZ controls the Bougainville mine and the Palabora mine (South Africa). Asarco has a 49% equity interest in Mt. Isa.

[3] These companies include Atlas, Falconbridge, Freeport, Hudson Bay, Inspiration, Lornex, Marcopper, Noranda, Rio Tinto Patino, Texas Gulf and White Pine.

TABLE 9

MINE COPPER PRODUCTION OF TWENTY LEADING PRIVATELY-OWNED MINING COMPANIES in 1974[a]
(000 metric tons, copper content)

Companies	Output
U.S. Companies	
Anaconda	179
Asarco[b]	194
Cyprus	100
Duval	120
Freeport[c]	65
Inspiration	51
Kennecott	366
Newmont[d]	215
Phelps Dodge	256
Copper Range	61
Subtotal	1,577
Canadian Companies	
Falconbridge	49
Hudson Bay	49
International Nickel	172
Lornex	58
Noranda	45
Texas Gulf	53
Subtotal	426
Other Companies	
Rio Tinto Zinc (UK)[e]	307
Atlas Consolidated (Philippines)	87
Marcopper (Philippines)	47
Mt. Isa (Australia)	160
Subtotal	601
TOTAL (all 20 companies)	2,604

Summary:

- Total Free World Output 6,064
- Leading 20 private companies as percentage of world output 43.0

NOTES: [a]Includes output of majority-owned subsidiaries. There may be some understatement by reason of absence of knowledge regarding all subsidiaries.

[b]Includes output of Southern Peru Copper Corporation (owned jointly with Phelps Dodge, Newmont and Cerro).

[c]Output of Freeport Indonesia.

[d]Includes Canadian and South African subsidiaries.

[e]Includes output of Bougainville mine and Palobora mine in South Africa.

SOURCE: American Bureau of Metal Statistics Yearbook, 1975.

Prain, in 1970 about 43 percent of copper producing capacity in the non-Communist world was owned in whole or in part by governments.[1] Moreover, governmental ownership of the copper industry is heavily concentrated in the copper exporting countries--mainly the CIPEC countries. In some countries, including Zambia, Mexico and Australia (Mt. Isa), large international mining companies have reduced their equity holdings from a majority to a minority position in recent years.

To summarize, 21 private companies have a majority interest in mines producing about 44 percent of total copper production in the market economies (including Yugoslavia), and another 34 percent is produced by majority-owned government enterprises in eight important copper producing countries. Most of the remaining 22 percent is produced by a fairly large number of privately-owned companies, some of which have a minority government participation. Among the Sino-Soviet Block countries, which account for slightly over 20 percent of total world mine production (see Table 1), 75 percent is produced in the USSR and most of the remainder in Poland, China and Bulgaria.

Copper production is highly concentrated within the leading copper producing countries, as described below.

United States. Copper production in the U.S. is highly concentrated, with three companies--Anaconda, Kennecott and Phelps Dodge--accounting for 54 percent of total U.S. mine production in 1974 and eight companies

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[1] Sir Ronald Prain, Copper, The Anatomy of an Industry (London: Mining Journal Books, 1975).

accounting for 87 percent of U.S. mine production. Most of the eight companies also smelt all of their own output. Copper refining in the U.S. is even more concentrated with six companies--Asarco, Kennecott, Phelps Dodge, Anaconda, Amax, and Newmont--accounting for nearly 90 percent of U.S. refining capacity in 1974. U.S. smelting and refining companies also process a limited amount of foreign concentrates and large tonnages of imported blister copper. The U.S. is currently about 90 percent self-sufficient in copper; it imports substantial amounts of blister copper, mainly from Latin America, and refined copper, mainly from Canada and Latin America. The three largest U.S. mine producers--Anaconda, Kennecott and Phelps Dodge--are vertically integrated into the fabricating stage. Approximately one-third of the copper output of U.S. refineries is sold to downstream affiliates, and U.S. firms export a substantial amount of refined copper.

Canada. There are about 20 important copper mining companies in Canada, with seven companies producing about 56 percent of the total output in 1974. Only about 61 percent of Canada's mine production was smelted in Canada in that year. However, Canada's refining capacity was equal to about 75 percent of her mine output in 1974. Canadian smelting capacity is concentrated in four firms--Falconbridge, Noranda, Hudson Bay and International Nickel. Refining capacity is controlled by two firms--Canadian Copper and International Nickel.

Chile. In Chile the bulk of the copper is produced by COELCO's mines which were nationalized in 1972. Most of Chile's mine output is smelted in Chile and about 60 percent of Chile's output is refined in the country.

Zambia. In Zambia all copper is produced by two mining companies owned 51 percent by the government. Zambia has smelting and refining capacity for nearly all of her mine output.

Zaire. In Zaire the government-owned mining company, Gecamines, produced 92 percent of the mine output in 1974 with a small but growing output produced by the Japanese firm, Sodimiza. Sodimiza ships concentrates, but all of Gecamines' output is smelted and 45 percent is refined in Zaire.

Peru. The Southern Peru Copper Corporation (52 percent owned by Asarco) currently accounts for over half of mine and smelter production in Peru and this proportion is expected to rise to 75 percent when the Cuajone mine begins full operation in 1977. The remainder is produced by government-owned mines and several small private mines. By 1977 about half of Peru's mine and smelter production will be refined in government-owned refineries.

Australia. In Australia 57 percent of the mine copper output in 1974 was accounted for by the privately-owned Mt. Isa mine, and three mines produced 77 percent of total output. (Mt. Isa is owned 49 percent by Asarco). Australia has smelter and refining capacity for nearly 80 percent of its mine output.

South Africa. Nearly 85 percent of South Africa's mine copper is produced by three private firms, owned largely by international mining companies--RTZ, Newmont and U.S. steel. South Africa has smelter capacity for over 80 percent of her mine output, but has refining capacity for less than half of her mine output.

The Philippines. Philippine mine output is produced by six private mining companies, one of which--Atlas--produces about 40 percent of the total. There are no smelters or refineries.

Papua New Guinea. PNG's output is produced solely by the majority foreign-owned firm, Bougainville Copper Ltd. (a subsidiary of Conzinc Rio-Tinto which in turn is a subsidiary of RTZ). All output is shipped abroad in the form of concentrates.

Both Japan and Western Europe have smelting and refining capacity several times their mine output, and import substantial amounts of concentrates and blister copper.

Majority private ownership in copper mines does not carry with it full control over production and marketing. For example, although the majority of Peruvian output is produced by a foreign-owned firm, SPCC, Peru's mineral output is marketed by MINPECO, a government agency.
In all of the CIPEC member countries--Chile, Indonesia, Peru, Zaire and Zambia--the government exercises control over marketing and production in accordance with CIPEC guidelines. (Australia and PNG are Associate Members of CIPEC and are not bound by CIPEC's decisions). In 1974 the original CIPEC members accounted for 38 percent of world mine copper production and about 62 percent of world copper exports. If Indonesia and the new Associate Members of CIPEC are included, these shares rise to 46 and 72 percent respectively.

D. VERTICAL INTEGRATION

A substantial portion of the large firms are vertically integrated from mining to refining. In addition, in 1969 about 25 percent of the refined copper sold on the world market was to affiliates of the copper producers.[1] In the United States over half of the output of domestic copper refiners is sold to subsidiaries, and a substantial protion of the output of Japanese and European refiners is also sold to their affiliates. In the past, a significant portion of the output of the mines owned by private international firms was sold to parent companies or affiliates of the mining firms. However, this pattern has been changing with the nationalization of the private firms in the CIPEC countries and the assumption of the marketing function by the governments of these countries. The buyers of refined copper are usually semi-fabricators of which there are some 500 company groups plus about 100 merchants. Virtually all refiners sell to independent fabricators as well as to their own affiliates.

Data on mine production of copper by company are very limited but most of the larger producing countries have a small number (one to five) of large, integrated mining and smelting firms, and a larger number of small, independent non-integrated mining firms.[2]

[1] This percentage may also have been reduced by recent nationalization.

[2] This part of our discussion draws heavily upon Glen E. Wittur, "Domestic Processing of Mine Output in Canada, with Case Studies on Zinc and Copper Refining," unpublished Ph.D. Thesis, Pennsylvania State University, 1974, Chapter 6.

Similarly, no definitive data are available on the split in mine output between vertically integrated and independent mine producers and it is not possible to draw conclusions on industry concentration at this stage. Integrated firms certainly account for a large majority of production in all major mining countries except the Philippines and, to a smaller extent, Canada and a few smaller producing countries. Independent mines may ship concentrates to domestic smelters and since there are at most only a few smelters in each major producing country. A possible conclusion is that this market is characterized by many competitive sellers facing few buyers. The alternative of exporting concentrates is also available in most countries, however, and this introduces an important competitive element in domestic smelter buying practices. As indicated below, while a number of countries import copper concentrates, major buyers are limited to Japan, West Germany, and to a lesser extent the United States. Japan was a very aggressive buyer of copper concentrates during the 1960's and the international market for copper concentrates was highly competitive during this period. As a result, smelting and refining charges remained at very low levels for most of the decade. Processing charges rose sharply between 1968 and 1972, indicating a considerable change in market circumstances.

The smelting and refining segment of the world copper industry is composed of firms that operate either smelters or refineries, or both. In 1970, some 22 firms with smelters alone operated 23 smelters; 44 firms with both smelters and refineries operated 69 smelters and 63 refineries; and 22 firms with refineries only operated 24 refineries. Neglecting firms with smelters of 30,000 tons or less, eight larger firms operated nine smelters; 32 firms operated 57 smelters and 51 refineries; and three refining firms operated three refineries. By eliminating the smaller producers, many of which operate on scrap, the number of firms is reduced by half and the number of plants by one third.

Considering copper refining only, industry concentration in the leading industrial countries (excluding capacity in foreign countries controlled by firms based in the leading industrial countries) ranges from high to very high. A complication not adequately accounted for in data on industry concentration is the many interrelationships among firms, such as minority ownership, interlocking directionships, joint ventures, and intercompany processing. Charles River Associates (1970a, p. 51-78) document some of these interrelationships between international corporations, but it is difficult to draw conclusions on their importance to industry behavior and performance.

There seems little point in delving very deeply into the copper refining industries in major consuming countries. With the exception of two or three of the larger producers in the United States, most producers in large consuming countries are predominantly custom processors. All but one of the major refining firms in Western Europe, including the United Kingdom, are custom refiners with little or no primary smelting capacity. One West German firm and all but one of the Japanese firms, have both smelters and refineries and import both concentrates and blister. Some Japanese firms also have substantial domestic mine production. However, many of the larger producers outside the industrial countries are associated with producing interests in the industrial countries.

In conclusion, copper processing in individual countries or areas is characterized by a relatively high degree of concentration, which suggests an oligopolistic industry structure. However, little can be concluded a priori about possible implications of industry structure for industry behavior and market competition without consideration of other market forces that affect industry behavior. Factors of interest include the extent of vertical integration of smelting and refining firms forward into fabricating, the importance of trade barriers and transportation costs as contstraints to international trade, entry conditions facing potential new producers, pricing constraints imposed by secondary metal and the threat of substitution away from copper, and government intervention in markets.

Meanwhile, it is difficult to measure the extent of vertical integration of primary copper producers forward into copper fabricating. As a generalization, primary producers in North America and Japan have important fabricating operations, refiners in Europe are partially integrated forward, and those in other producing countries have very little fabricating capacity. In the United States, all of the major primary producers have fabricating subsidiaries. In the mid-1960's, about 35 companies were recognized as important copper fabricators, with most of the larger ones being affiliated with the major primary producers.[1] However, there are also a large number of independent fabricators; in 1966, there were more than 100 wire mills, 60 brass mills, and sever thousand foundries in the United States. Only about one-third of refined copper fabricating capacity is captive to domestic refiners.

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[1] A. D. McMahon, Copper--A Materials Survey (Washington, D. C.: U.S. Bureau of Mines, Information Circular 8225, 1965), p. 253.

The qualitative pattern of vertical integration through refining in Japan is similar to that in the United States, although industry concentration in fabricating is higher in Japan. In the United Kingdom and EEC, the copper fabricating industry is composed predominantly of firms, independent of copper refiners, which purchase refined copper and sell fabricated products to manufacturers. The tendency in recent years however, has been for manufacturers to integrate backwards into fabricating. A recent technological development--continuous casting of copper rod to replace rolling of wire bars--has encouraged some European refiners to extend their operations into production of wire. Substantial excess capacity exists in copper fabricating in both the United Kingdom and original EEC member countries, and the United Kingdom's entry into EEC is said to threaten severe price competition at the fabricating stage.[1]

In the United Kingdom, three major copper fabricating and manufacturing groups of companies have evoled, each of which incorporates some domestic refining capability, but many independent fabricators remain. The largest copper refiner is a subsidiary of the country's leading copper user and the two other large copper fabricators operate small scrap refineries but none ofthe three firms appear to be connected with primary copper producers in other countries.[2]

Hoboken in Belgium, the leading copper refiner in continental Europe, has no fabricating facilities of its own but is associated with a number of metal fabricating firms in Belgium and other European countries. Similarly,

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[1] Metal Bulletin Monthly (August, 1974), p. 11.

[2] Withur, op. cit., p. 331.

the other major producer, Norddeutsche Affinerie in West Germany, has no fabricating facilities but is a member of the Metallgesellschaft Group which is a major metal fabricator in Europe. However, both Hoboken and Norddeutsche have installed continuous rod casting facilities. All of France's copper imports are purchased by Groupement d'Importation et de Repartition des Metaux (GIRM), which distributes metal to its member firms. Two firms associated with Pechiney together fabricate nearly 50 percent of GIRM's copper supply. The five largest fabricators account for nearly two thrids of copper fabricating in France. There exist many other fabricators in Western Europe and, while little information is available on their relative importance, it is apparent that a large independent market exists for refined copper in Europe.[1]

In summary, the structure of the copper consuming industry appears to be broadly similar in all larger industrial countries. In each major copper-using sector (rolling or barss mills, wire mills, and foundries), national industries are characterized by a small number of large firms and a much larger number of medium to small firms. The larger firms in the United States and Japan are in many cases affiliated with primary producers, while some fabricators in the United Kingdom and Continental Europea are affiliated with domestic refiners. The majority of smaller fabricators in all countries appear to be independnet or primary producers. The important point here is that a substantial market for refined copper that is not captive to primary producers, appears to exist in most industrial countries.

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[1] Ibid., p. 332.

E. INTERNATIONAL TRADE IN COPPER

Consistent data on international trade flows in copper are lacking. Nevertheless, a fairly accurate understanding of major trade patterns can be quite readily developed.

The bulk of the world's copper exports is from the developing countries to Europe, Japan and the United States, with smaller amounts from Canada, South Africa and Australia. The United States and Western Europe also export refined copper, but are net importers of copper overall. About 25 percent of world copper exports in 1974 was in the form of concentrates, 16 percent in blister copper and 59 percent in refined copper.[1]

Trade in smelted copper has traditionally followed mainly from Africa to Western Europe and from Latin America to the United States. Entry of Japan as an important importer and increasing refining of blister in the exporting countries have resulted in greater diversification of trading patterns in recent years and a gradual decline in the absolute importance of trade in unrefined compared with refined metal.

Tables 10-12 are organized to convey a summary of world trade patterns in copper. As shown in Table 10, the leading exporters of unrefined copper are Canada, Chile, Peru, Zaire and Zambia, and to a much smaller extent, the United States. These countries, except for Canada and Peru, are also important exporters of refined copper. The list of leading exporters of refined copper also includes such countries as Japan, Germany, (FR), Belgium-Luxembourg, Australia and the United Kingdom. A more detailed view

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[1]Data are from Statistical Bulletin, 1975, CIPEC, Paris, 1976.

TABLE 10

LEADING EXPORTERS OF COPPER, 1974
(metric tons)

Country	Copper ores (copper content), concentrates and matte	Refined Copper
United States	19,944[a]	114,782[a]
Canada	343,846	-[b]
Chile	214,500[c]	487,800[d]
Peru	197,056[e]	38,475
Zaire	157,500	289,100
Zambia	31,946	649,774
Japan	-[b]	279,573
Australia	12,234	70,536
Germany, FR	5,015	82,440
Spain	3,909	5,130
Belgium-Luxembourg	1,004	288,880
United Kingdom	-[b]	35,026

NOTES: [a]21,984 and 126,525 short tons, respectively, as given in U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1974 (April 8, 1975), p. 7.

[b]Data not specifically available; assumed negligible.

[c]Copper content; as reported by Corporacion del Cobre, Chile.

[d]Including both fire refined copper (101,700 metric tons) and electrolytic copper (386,100 metric tons).

[e]Consisting of blister copper (134,364 metric tons) and copper ores (copper content), including copper precipitate (62,692 short tons).

SOURCE: Metallgesellschaft Aktiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), various pages.

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TABLE 11

INTERNATIONAL TRADE FLOWS IN COPPER ORES, BY MAJOR IMPORTING COUNTRY, 1974

Major Importing Country/Origin		Total Volume of Imports[b] (metric tons)	Percent Composition by Origin (%)
JAPAN	TOTAL	3,123,600	100 0
From. Indonesia		161,903	5.2
Phillipines		886,115	28.5
Zaire		87,997	2 8
Chile		183,544	5.9
Canada		1,129,831	36.2
Peru		56,486	1.8
Australia		187,863	6 0
Papua-New Guinea		381,275	12 2
	SUBTOTAL	3,075,014	98 4
GERMANY, FR	TOTAL	571,146	100 0
Norway		24,874	4 4
Spain		24,820	4 3
Indonesia		67,943	11.9
Republic of South Africa		68,112	11 9
Chile		91,397	16 0
Canada		24,751	4 3
Australia		81,714	14 3
Papua-New Guinea		141,675	24 8
	SUBTOTAL	525,286	92.0
SPAIN	TOTAL	128,689	100.0
Irish Republic		27,785	21.6
Cyprus		11,478	8 9
Mauritania		11,329	8 8
Australia		62,590	48.6
	SUBTOTAL	113,182	88 0
UNITED STATES	TOTAL	48,463[a]	100 0
Philippines		12,923	26.7
Canada		18,059	37 3
Peru		6,608	13.6
Honduras		4,169	8 6
	SUBTOTAL	41,759	86 2
SWEDEN	TOTAL	40,360	100 0
Irish Republic		18,411	45 6
Norway		15,343	38 0
Canada		5,405	13 4
	SUBTOTAL	39,159	97 0
BELGIUM AND LUXEMBOURG	TOTAL	32,406	100 0
Italy		2,992	9 2
Sweden		3,021	9 3
Morocco		3,441	10 6
Zaire		5,406	16 7
Canada		3,078	9 5
Mexico		3,066	9 5
Australia		3,928	12 1
	SUBTOTAL	24,932	76 9

NOTES. [a]General imports (copper content), ores, matte, regulus.

[b]Components may not sum up to the totals given due to rounding

SOURCE Metallgesellschaft Aktiengesellschaft, Metal Statistics 1964-1974, 62nd Edition (Frankfurt am Main, 1975), various pages.

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TABLE 12

INTERNATIONAL TRADE FLOWS IN REFINED COPPER,
BY MAJOR IMPORTING COUNTRIES, 1974

Major Importing Country/Origin		Total Volume of Imports[c] (metric tons)	Percent Composition by Origin (%)[c]
UNITED STATES	TOTAL[d]	284,464[c]	100.0
From Canada		107,439	37.8
Chile		60,372	21.2
Japan		66,273	23.3
Yugoslavia		13,465	4.7
	SUBTOTAL	247,549	87.0
GERMANY, FR	TOTAL	440,025	100.0
Belgium-Luxembourg		62,551	14.2
United Kingdom		12,245	2.8
Yugoslavia		11,307	2.6
Poland		32,883	7.5
U.S.S.R		22,724	5.2
Japan		17,905	4.1
Zaire		21,729	4.9
Zambia		80,306	18.3
Chile		87,115	19.8
Canada		23,595	5.4
Australia		11,866	2.7
	SUBTOTAL	384,226	87.3
FRANCE	TOTAL	417,474[a]	100.0
Belgium-Luxembourg		117,468	28.1
Germany, FR		17,142	4.1
Yugoslavia		18,383	4.4
U.S.S.R		16,690	4.0
Zaire		46,778	11.2
Zambia		74,760	17.9
Chile		21,462	5.1
United States		18,013	4.3
Australia		16,807	4.0
	SUBTOTAL	347,433	83.2
UNITED KINGDOM	TOTAL	380,870	100.0
U.S.S.R		11,055	2.9
Zaire		11,725	3.1
Zambia		125,861	33.1
Republic of South Africa		18,246	4.8
Chile		50,428	13.2
Canada		95,274	25.0
United States		18,236	4.8
Australia		14,193	3.7
	SUBTOTAL	345,018	90.6
ITALY	TOTAL	306,673[b]	100.0
Belgium-Luxembourg		21,260	6.9
Zaire		73,513	24.0
Zambia		75,736	24.7
Chile		61,409	20.0
United States		25,682	8.4
	SUBTOTAL	257,600	84.0
JAPAN	TOTAL	230,182	100.0
U.S.S.R		14,556	6.3
Zaire		15,644	6.8
Zambia		139,320	60.5
Chile		42,009	18.3
	SUBTOTAL	211,529	91.9

NOTES [a]Includes unrefined copper of 42,176 metric tons

[b]Includes unrefined copper of 3,418 metric tons.

[c]The data for the United States, believed to be more up-to-date, are obtained from U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1974 (April 8, 1975), p. 6

[d]From all sources

[e]Components may not sum up to the totals given due to rounding.

SOURCE Metallgesellschaft Aktiengesellschaft, Metal Statistics 1964-1974, 62nd. Edition (Frankfurt am Main, 1975), various pages.

of international trade in copper ore and in refined copper can be gained by examining Tables 11 and 12.

Generally speaking, the relative importance of trade increases with the stage of processing, although there is an overall trend towards more trade in concentrates and relatively less in smelted and refined metal.

Trade in concentrates flows mainly from the Philippines, Canada, Peru, and recently the United States, to Japan. Many other small producing countries also export to Japan. Most of the remainder flows from Chile, the United States, and several small exporters to West Germany.

The leading exporters of refined copper all have diversified markets but Belgium and Zaire export mainly to members of the EEC. Zambia's major markets are the United Kingdom, countries in Continental Europe, and since the mid-1960's, Japan. Canada's most important markets are the United Kingdom and the United States, while Chile exports mainly to Continental Europe. United States exports are highly diversified but sales to Europe predominate.

West Germany imports all of its primary copper needs, two thirds in refined form, one quarter in smelted forms, and about one tenth in copper concentrates. It is also one of the leading importers of scrap.

Neither Belgium nor the United Kingdom has very large smelter outputs but the former is a large refiner based on imported blister and some scrap, while the latter is also a large refiner based mainly on scrap plus some imported blister. Belgium, however, exports much of its refinery output while the United Kingdom also requires large net imports of refined copper. Refined imports supply three quarters or more of the United Kingdom's primary copper consumption (smelted imports supply the remainder), and slightly more than half of total copper usage.

Other leading consuming countries in Europe, including France, Italy and the Netherlands, import most of their refined copper requirements in that form, supplemented by small local refined production from scrap. Sweden is an important primary producer but also imports refined metal.

Most of the copper exported by the developing countries is sold under contract to smelters, refineries or fabricators in the developed countries. The pattern of world trade in concentrates tends to be governed by long-term contracts which may call for deliveries over periods up to 15 or 20 years, financial arrangements providing for repayment of loans in concentrates, and ownership ties between the mining and processing companies. Also, smelters are frequently geared to processing particular concentrates.

Long-term contracts for the sale of concentrates of blister have important advantages for both the mines and the smelters or refineries with which they are negotiated. Smelters and refineries in Japan and Europe which lack domestic sources of raw materials want to be assured of raw material supplies; in the case of private or nationalized mines that are not vertically integrated, long-term contracts for the sale of concentrates are frequently important factors in the decision to construct the mine.[1]

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[1]For example, the ability of Bougainville Copper Ltd. (BCL) to negotiate long-term contracts for the sale of concentrates to foreign smelters in 1969 played an important role in the ability of the company to mobilize financing for the mine.

This and the following few points made here are drawn from an unpublished manuscript by Raymond F. Mikesell, entitled "The Nature of the World Market for Copper" (Eugene, Oregon: University of Oregon, June, 1974), pp. 5-6.

By contrast, trade in refined copper is for the most part based on short-term contracts of one-to-twelve month duration. While more competitive, it is also influenced by nonprice factors such as ownership ties, technical assistance and marketing contracts, such as that between Belgium and Zaire, and long standing buyer-seller relationships. Ownership ties between producing and consuming countries have been declining, and, even where they exist, governments of producing countries have taken a more active role in marketing and are attempting to diversify their markets. Other nonprice factors, such as strikes, transportation problems, natural disasters in the producing countries, and recessions in the consuming countries, frequently affect the pattern of trade in refined copper.

The bulk of the world's refined copper is sold directly by the producers to fabricators and semi-fabricators; only marginal amounts are sold through the London Metal Exchange (LME) and the New York Commodity Exchange (Comex).[1]

Fabricators and semi-fabricators also tend to buy refined copper, not obtained directly from producers, from dealers or merchants. Merchants, in turn, deal extensively with independent refineries (not associated with large integrated firms). They may buy scrap for sale to refineries and purchase output from refineries not committed under contract for sale to fabricators or for them to hold as stocks.[2]

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[1] This is a little bit running ahead of the story; more is said on the LME and Comex exchange markets later in the report.

[2] For a discussion of the role of merchants in the copper market, see Ferdinand E. Banks, The World Copper Market: An Economic Analysis (Cambridge, Mass.: Ballinger Publishing Company, 1974), pp. 41-43.

Since the U.S. copper industry is generally more integrated than in the rest of the world, merchants are somewhat less important in the United States than abroad.[1]

[1] *Ibid.*, p. 43.

F. U.S. TRADE PATTERNS IN COPPER

The U.S. is virtually or nearly self-sufficient in copper. As shown in Table 13, the U.S. has experienced what could be called heavy dependence on foreign sources of copper only in such years as 1950, a Korean build-up year, or 1974, an extreme "demand-crunch" year. Otherwise, net U.S. imports have remained well under ten percent of total domestic consumption of refined copper.[1]

Nearly half of U.S. copper imports are in the form of refined copper as shown in Table 14 (from mainly Canada, Japan and Chile)[2] with smaller amounts imported in the form of blister and cement copper, or in the form of ore and concentrate.[3]

Similarly, the bulk of U.S. exports is in the form of refinec copper (Table 15), most of which is destined to such countries as Brazil (23,990 short tons), France, 19,067 short tons), West Germany (11,716 short tons), Italy (26,520 short tons) and the United Kingdom (14,541 short tons).[4]

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[1]These figures would be even less if we defined domestic copper consumption to include directly consumed scrap.

[2]Figures for 1974 were as follows: from Canada 118,431 short tons; Japan 73,053 short tons; Chile 66,549 short tons (Source: U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1974 [April 8, 1975], p. 6).

[3]Although some of this material enters the United States as imports, it is held in "bond" only to be shipped abroad for further processing. This historically has applied especially to unrefined copper "imports" from Chile. Consequently, the import and export statistics, thus subject to some degree of "noise," should not be taken too literally.

In 1974 the major sources of U.S. imports of copper, by type, were as follows (copper content, short tons):

Ore and Concentrate:			Blister		
(from)	Canada	19,917	(from)	Chile	65,093
	Philippines	14,244		Peru	94,686
				Republic of South Africa	37,211

(Source: U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1974 [April 8, 1975], p. 6). [4]1974 figures. Op. cit., p. 7.

TABLE 13

TRENDS IN U.S. COPPER CONSUMPTION AND TRADE, 1950-1975
(short tons)

Years	Total refined consumption	Total imports of refined and unrefined copper (copper content)[a]	Total exports of refined and unrefined copper (copper content)[b]	Net Trade (net imports)	Net trade as Percent of total refined consumption
1950	1,424,434	690,389	154,622	535,767	37.6
1960	1,599,700	524,344	503,733	20,611	1.3
1970	2,043,303	392,480	299,304	93,176	4.6
1971	2,019,507	359,479	214,215	145,264	7.2
1972	2,238,867	415,618	225,165	190,453	8.5
1973	2,437,048	417,434	262,552	154,882	6.4
1974	2,194,168	607,992	189,851	418,141	19.1
1975	1,536,694	324,126	227,273	96,853	6.3

NOTES: [a]Includes refined copper, ore and concentrate, blister and cement copper, matte and scrap.

[b]Includes only refined copper, ore and concentrate, etc. (unrefined copper), and scrap; exclusive of copper semimanufactures or manufactured copper products (e.g., plates, sheets, strips, wire, etc.).

SOURCES: U.S. Bureau of Mines: 1950: Minerals Yearbook, Vol. I, Metals and Minerals (Except Fuels), 1952, pp. 360-371;
1960: Minerals Yearbook, Vol. I, Metals and Minerals (Except Fuels), 1962, pp. 499-509;
1970: Minerals Yearbook, Vol. I, Metals, Minerals and Fuels, 1971, pp. 485-491;
1971-1975: Mineral Industry Surveys, Copper, in 1972, 1973, 1974 and 1975 (separate reports).

TABLE 14

U.S. IMPORTS OF COPPER, BY TYPE, 1971-1975
(Copper content, short tons)

	1971	1972	1973	1974	1975
Refined	163,988	192,380	201,513	313,568	146,807
Ore and Concentrate	30,848	53,653	42,135	53,422	64,879
Blister and Cement copper	156,744	157,430	154,104	207,828	88,949
Matte	440	1,367	746	1,944	9,093
Scrap	7,459	10,788	18,936	31,230	14,398
TOTAL	359,479	415,618	417,434	607,992	324,126

SOURCE: U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1972, 1973, 1974 and 1975 (separate reports).

TABLE 15

U.S. EXPORTS OF COPPER, BY TYPE, 1971-1975
(short tons)

Type	1971	1972	1973	1974	1975
Refined Copper	187,654	181,494	189,396	126,526	172,419
Ore, concentrates, etc. (copper content)	8,126	26,231	30,870	21,983	9,853
Old and scrap	18,435	17,440	42,286	41,342	45,001
Ash and residues	-	9,381	15,087	8,233	6,601
Pipes and tubes	1,249	1,142	7,744	6,738	2,200
Plates, sheets and strips	287	279	474	793	186
Semi-fabricated forms n.e.c.	7,746	6,299	7,431	8,332	9,517
Wire: Bare	1,925	2,767	5,196	5,632	3,720
Insulated	24,590	28,660	40,046	62,514	79,631

SOURCE: U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1972, 1973, 1974 and 1975 (separate reports).

In summary, although the U.S. has been nearly self-sufficient in copper, except in certain years coinciding with military developments or unusual "demand crunch" periods, the U.S. is both a leading importer and exporter of copper. The impact of domestic environmental regulations on the U.S. copper industry should therefore be examined with close attention to their international economic implications, affecting the structure of the world copper industry, international trade patterns, and the role of the United States in the world copper industry.

Chapter 4

INDUSTRY STRUCTURE AND SUPPLY CHARACTERISTICS

A. INTRODUCTION

Chapter 3 presented an overview of the copper industry in an international setting, drawing major attention to the structure of the world copper industry and patterns of international trade. In this chapter, the attention shifts exclusively to the domestic copper industry, with emphasis on its organization and structure, costs of production and related supply characteristics. This discussion, along with other material contained in subsequent chapters on industry background, is intended to provide the necessary informational background for the industry modeling effort for impact assessment purposes. Accordingly, most of this chapter will focus on particular characteristics of the domestic copper industry, including the industry's organization (i.e., primary and secondary producers), the firms involved, the degree of geographical and firm concentration in the industry as well as vertical integration, barriers to entry, and production costs. Our major objective is to lay the groundwork for an exposition of how these characteristics influence the determination of available domestic supplies of refined copper and the formation of copper prices.

Most of the discussion will be concerned with the primary producers segment of the domestic copper industry (i.e., that portion of the industry concerned predominantly with supplying refined copper produced from virgin ore and blister rather than from scrap). We will, however, discuss relevant aspects of the secondary copper industry, as well.

The principal conclusions of this chapter can be summarized as follows:

1. Over the period 1960-1974, about 76 percent, on average, of the total U.S. copper supply was in the form of refined copper processed either from virgin ore or from scrap. Of this, about 80 percent was processed from ore and 20 percent from scrap. The remaining 24 percent, on average, of total copper supplies was in the form of scrap consumed without further refining.

2. Among the semifabricator and fabricator consumers of refined copper, wire mills and brass mills together consumed on average about 83 percent of total copper supplies during the 1960-1974 period. Ingot makers consumed on average about nine percent of total supplies. Foundries used about five percent, powder plants about one percent, and a group of "other industries," such as chemicals and aluminum, about two percent.

3. For the analytical purposes of this study, we have defined the primary and secondary copper sectors on the basis of the pricing behavior of the firms in the domestic copper industry. By this criterion, firms in the primary sector are those which sell the bulk of their refined copper output (mostly from mined copper but also including some refined from scrap), on the basis of a commonly-followed domestic producers price. Firms in the secondary sector, on the other hand, are those which sell their copper output, regardless of its form (i.e., whether refined or scrap) and regardless of its origin (i.e., whether from mined copper--from domestic or foreign source--or refined from scrap), on the basis of one of several "outside market" prices.

4. The primary sector consists of: (1) a core group of seven large fully integrated producers (Anaconda, Kennecott, Phelps Dodge, Inspiration, Magma,[1] Copper Range,[2] and Asarco[4]); and (2) one partially integrated firm (i.e., Cities Service Company, integrated through smelting), two large nonintegrated independent mining firms (e.g., Duval, a subsidiary of Pennzoil Company, and Cyprus[3]), as well as many small independent mining firms. Through a high degree of vertical integration and firm concentration, the core group of primary producers (including Asarco) are able to exercise discretionary pricing behavior in refined copper markets. In 1974, the seven vertically integrated firms (including Asarco) supplied 77.0 percent of domestic mine production of recoverable copper in the United States (79.6 percent in 1973, a peak year). At year-end 1975, these seven firms accounted for over 95 percent of total U.S. smelting capacity and 85 percent of refining capacity.

5. Within the secondary sector, two broad segments can be distinguished. The first comprises a small number of firms processing scrap into secondary refined copper. Amax and Cerro have been the two most important of these during most of the postwar period. These secondary refiners sell their

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[1] Subsidiary of Newmont Mining Corporation.

[2] Of which White Pine Copper Company (mining/milling, White Pine, Michigan), and Quincy Mining Company (smelting/refining, Hancock, Michigan) are subsidiaries.

[3] Of which Cyprus Pima Mining Company and Cyprus Bagdad Copper Company are subsidiaries.

[4] In addition to being, in its own right, a major, fully-integrated primary producer, Asarco also plays a pivotal role in the domestic copper industry as a major custom/toll smelter and refiner.

product at prices (explicitly if in the open market or implicitly if intra-company transfers are involved) which are more reflective of current market prices for scrap than of refined copper prices quoted by the primary producers. They have been responsible for an average of about 12 percent of total refined copper supplied in the U.S. each year between 1950-1974 and have held about 11 percent of domestic refinery capacity during this same period.

The remainder of the secondary industry is comprised of a large number of firms--mostly small and individually unrefined scrap as well as in the trading of refined copper. These include scrap dealers, merchants, ingot makers, and semifabricators (for own-consumption). Firms in this segment buy or sell unrefined scrap directly on the basis of quoted scrap prices.

6. Within the primary copper sector, over 300 mines produce copper in the United States, a majority of which are located in five western states--Arizona, Utah, New Mexico, Montana, and Nevada. Most of the copper smelters in the U.S. are located in these Western states to minimize transportation charges from mine to smelter. About half of domestic refinery capacity, on the other hand, is located on the Atlantic Coast, close to major refined copper consumers. Industry smelting capacity extended only marginally between the early 1950's and 1975; no new smelters were built after 1956. Refinery capacity, however, expanded by about 38 percent over the 1958-1975 period.

7. The U.S. primary copper industry is characterized not only by a high degree of firm concentration and vertical integration at the mining through refining stages of production but also by forward integration beyond

refining. The major domestic producers (particularly Anaconda, Kennecott, and Phelps Dodge) are integrated forward into wire mill and brass mill operations. However, available evidence indicates a significantly lower degree of firm concentration at the semifabricator level than that existing at the mining through refining stages--low enough, at least, to prevent individual semifabricators from having a significant influence on pricing or production decisions within the semifabricating industry as a whole.

Barriers to entry for fully integrated operations appear to be substantial. However, the height or conditions of entry have apparently had little effect in moving the discretionary pricing behavior of the major primary producers, during the past three decades, in the direction of implicit monopolistic pricing behavior, in the face of the continuous threat of long-run substitution from aluminum, among other factors.

8. In the copper industry, costs of mining and milling have traditionally formed the largest proportion of total production costs of refined copper. Smelting and refining costs have represented only a small proportion, with smelters and refineries functioning mainly as "service" operations on fixed and relatively low profit margins.

Overall, real costs of refined copper production, although they have remained stable over a relatively long period (Herfindahl hypothesis), appear to have increased gradually during the 1950's and 1960's. Evidence exists, moreover, suggesting a sharp real increase in some factor costs during the past few years.

Labor productivity in the industry, meanwhile, stagnated through the 1950's and 1960's and registered an actual decline after 1971 in the face of continued degradation of the average ore grades mined in the U.S. This, combined with little prospect for improvements in labor productivity over the next few years, argues for rising production costs in real terms with increases in unit labor costs.

9. We have estimated industry-wide (aggregate) average total costs for producing refined copper (from mining through refining) for the primary producers, in 1974 at 72¢ per pound (at roughly 86 percent of installed capacity). Of that total, average fixed costs were estimated at 29¢ per pound and average variable costs were estimated at 43¢ per pound.

B. COPPER FLOWS THROUGH THE ECONOMY

Figure 1 is a schematic flowsheet of the production and consumption of copper in the United States in 1974, tracing the flow of copper from principal sources (producers of virgin ore and scrap suppliers) through the various stages of processing to consumption by ingot makers, semifabricators, and final end-users.

On the supply side (left-hand side of Figure 1), we can summarize some of the more important facts, with reference to the 1960-1974 period, as follows:

- On average, about 76 percent of total U.S. copper supply was in the form of refined copper processed either from virgin ore or from scrap;[1] of this (i.e., 76 percent), about 80 percent was processed on average from domestic ores and imported blister, while the remaining 20 percent was smelted and/or refined from scrap;
- An average of about 24 percent of total copper supplied was in the form of scrap consumed directly without further refining by semifabricators and end-users.[1]

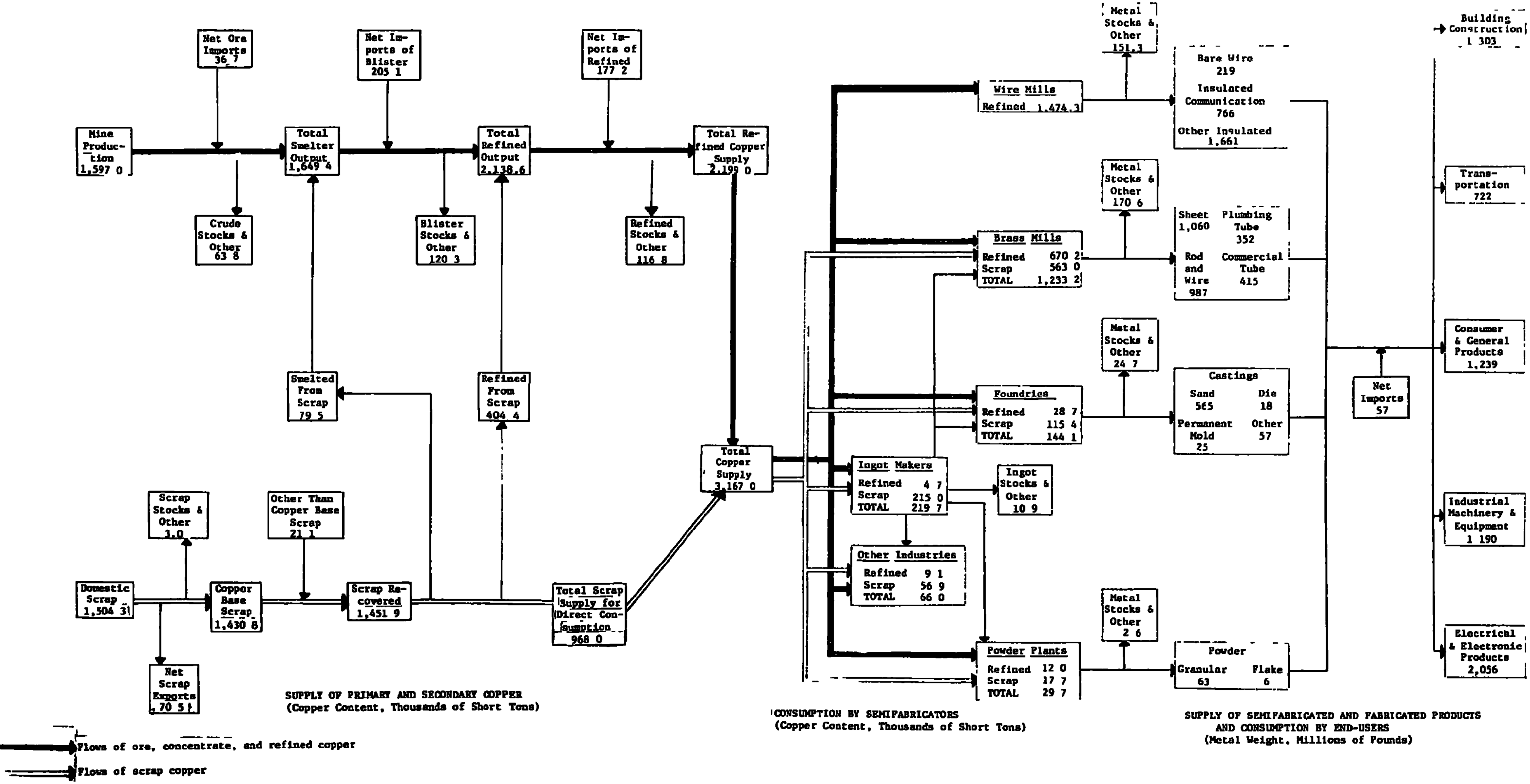
On the demand side (right-hand side of Figure 1), there are six major groups of consumers of refined copper and scrap: four copper semifabricating industries[2]--wire mills, brass mills, foundries, and powder

[1]Approximately 70 percent of the directly consumed scrap was purchased, without any treatment but packaging, by brass mills and foundries; another 22 percent was processed by ingot makers into copper alloy ingot, which was then sold to brass mills and foundries. About 8 percent was consumed directly by powder plants and other industries.

[2]The general task of the semifabricating industries is to alter the shape of copper inputs into products for final end-use. Wire mills, brass mills, and powder mills use mechanical means, while foundries use casting means. Ingot makers produce copper alloy ingot which is then sold to brass mills, foundries, power plants, and other industries using copper.

FIGURE 1

COPPER SUPPLY AND CONSUMPTION IN THE UNITED STATES, 1974



Source Arthur D Little, Inc based on Copper Development Association, Copper Supply and Consumption Annual Data, 1975.

mills; ingot makers; and a group of "other industries" such as chemicals, steel, and aluminum, which consume refined copper and scrap directly.

Wire mills and brass mills together consumed on average about 83 percent of total copper supplies in both refined and scrap forms during the 1960-1974 period.

Wire mills, which use only refined copper, consumed about 46 percent of total copper supplies, on average, while brass mills, which consume refined copper and scrap in fairly equal proportions, accounted on average for about 37 percent of total consumption of copper supplied. Ingot makers, who used almost entirely scrap, consumed on average about nine percent of total copper supplies. Foundries, which consumed predominantly scrap, used on average about five percent of total copper supplied. Powder plants consumed only about one percent of total supplies, while "other industries" were responsible for about two percent of total consumption, the bulk of this in the form of scrap.

TABLE 1

REFINED COPPER PRODUCTION OF U.S.
PRIMARY AND SECONDARY PRODUCERS, 1950-1974
(Thousands of Short Tons)

YEAR	TOTAL REFINED PRODUCTION	PRIMARY PRODUCER REFINED	SECONDARY PRODUCER REFINED
1950	1446.4	1300.8	145.6
1951	1362.5	1247.2	115.3
1952	1320.5	1220.2	100.3
1953	1504.0	1345.6	158.4
1954	1418.4	1249.1	169.3
1955	1562.8	1355.4	207.4
1956	1687.8	1501.3	186.5
1957	1676.1	1467.4	208.7
1958	1579.5	1389.3	190.2
1959	1331.5	1087.9	243.6
1960	1794.6	1565.3	229.3
1961	1813.9	1623.9	190.0
1962	1884.5	1689.4	195.1
1963	1884.4	1648.9	235.5
1964	1990.4	1750.3	240.1
1965	2214.8	1946.6	268.2
1966	2183.3	1905.8	277.5
1967	1526.6	1255.2	271.4
1968	1839.0	1565.4	273.6
1969	2214.9	1951.8	263.1
1970	2242.7	1991.0	251.7
1971	1962.4	1747.6	214.8
1972	2258.5	2006.3	252.2
1973	2312.6	1963.8	348.8
1974	2136.5	1754.4	382.1

Source: Copper Development Association, Inc., Annual Data 1975 and Arthur D. Little, Inc., estimates.

TABLE 2

REFINERY CAPACITY OF U.S.
PRIMARY AND SECONDARY PRODUCERS, 1950-1974
(Thousands of Short Tons)

YEAR	TOTAL REFINED PRODUCTION	PRIMARY PRODUCER REFINED	SECONDARY PRODUCER REFINED
1950	1599.0	1399.0	200.0
1951	1599.0	1399.0	200.0
1952	1647.0	1447.0	200.0
1953	1896.0	1696.0	200.0
1954	1862.0	1656.0	206.0
1955	2070.0	1799.0	271.0
1956	2064.0	1793.0	271.0
1957	2081.5	1810.5	271.0
1958	2108.5	1812.5	296.0
1959	2309.0	2013.0	296.0
1960	2331.0	2017.5	313.5
1961	2341.0	2077.5	313.5
1962	2334.0	2016.5	317.5
1963	2334.0	2016.5	317.5
1964	2334.0	2016.5	317.5
1965	2320.0	2102.5	317.5
1966	2426.5	2112.5	314.0
1967	2527.0	2208.0	319.0
1968	2643.0	2339.0	304.0
1969	2676.0	2372.0	304.0
1970	2676.0	2372.0	304.0
1971	2793.0	2489.0	304.0
1972	2723.0	2419.0	304.0
1973	2850.0	2394.0	456.0
1974	2850.0	2394.0	456.0

Source: American Bureau of Metal Statistics, Yearbook 1954-1975, and Arthur D. Little, Inc., estimates.

C. ORGANIZATION OF THE INDUSTRY: DEFINITION OF THE PRIMARY AND SECONDARY MARKET SEGMENTS AND TYPES OF FIRMS

1. Definition of the Primary and Secondary Market Segments

The domestic copper industry has in the past been segmented into "primary" and "secondary" sectors on the basis of whether the copper product transacted in the market has originated from mined copper (virgin ore) or from scrap. By this definition, based on the source of copper, firms in the primary sector would be those which predominantly transform virgin ore into refined copper, while firms in the secondary sector would be those which either predominantly process scrap copper into the secondary refined copper or prepare it for direct consumption in the form of unrefined copper scrap.

For an economic analysis of the domestic copper industry, such a segmentation of the industry into primary and secondary sectors, on the basis of the source of the copper transacted in the market, is not very useful. First, the pricing behavior of the firms in the industry does not fall neatly into two non-overlapping categories based on whether the copper product transacted is derived from primary or secondary streams. Second, once refined, there is no physical difference between primary and secondary refined copper. Third, the major primary producers do often smelt and refine scrap in their operations, mostly for technological reasons, while at least one major secondary smelter/refiner has processed some blister from virgin ore. Further, there exist merchants, importers or firms which perform a combination of functions involving scrap, refined scrap or toll smelting/refining of mined copper.

We have hence segmented the domestic copper industry into "primary" and "secondary" sectors, for our analytical purposes, on the basis of the pricing behavior of the firms on the sellers' side.[1] By this criterion, the primary sector consists of firms which sell the bulk of their refined copper output (mostly from mined copper but also including some refined from scrap) on the basis of a commonly-followed domestic producers price. Firms in the secondary industry, on the other hand, are those which sell their copper output regardless of its form (i.e., whether refined or scrap) and regardless of its origin (i.e., whether processed from mined copper--from domestic or foreign source--or refined from scrap) on the basis of one of several "outside market" prices.

Within the secondary sector, two broad segments can be distinguished. The first comprises a small number of firms processing scrap into secondary refined copper. The remainder of the secondary industry is comprised of a large number of firms--mostly small and individually owned--engaged in the collection, processing and consumption of unrefined scrap as well as in the trading of refined copper. These include scrap dealers, ingot makers, semifabricators, and merchants. Firms in this segment of the secondary market buy or sell unrefined scrap directly on the basis of quoted scrap prices.

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[1] In the case of a few firms, there is some ambiguity concerning the type of copper input (e.g., mined copper or scrap) <u>predominantly</u> processed by these firms over the past three decades; moreover, where firms process inputs of both blister and scrap, the specific proportions have often reportedly changed over time. In all such ambiguous cases, we have used pricing behavior as the overriding yardstick for classifying firms into either the primary or the secondary industry.

These two segments of the secondary copper sector (or industry) comprise two "workably competitive" markets which together represent a competitive fringe to the domestic primary producers market.

2. Firms in the Primary Copper Sector

The primary sector consists of: (1) a core group of seven large fully-integrated producers (Anaconda, Kennecott, Phelps Dodge, Inspiration, Magma,[1] Copper Range,[2] and Asarco[3]); (2) one partially integrated firm (Cities Service Co., integrated through smelting), two large nonintegrated independent mining firms (Duval, a subsidiary of Pennzoil Co., and Cyprus[4]), and many small independent mining firms.[5]

Since Asarco, which is both a major primary producer and a large custom/toll[6] smelter and refiner, has held a somewhat anamalous position

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[1]Subsidiary of Newmont Mining Corporation.

[2]Of which White Pine Copper Company (mining/milling, White Pine, Michigan), and Quincy Mining Company (smelting/refining, Hancock, Michigan), are subsidiaries.

[3]In addition to being, in its own right, a major, fully-integrated primary producer, Asarco also plays a pivotal role in the domestic copper industry as a major custom/toll smelter/refiner.

[4]Of which Cyprus Pima Mining Company and Cyprus Bagdad Copper Company are subsidiaries.

[5]Including UV Industries, Incorporated (Bayard Operations, New Mexico, 24,167 short tons of recoverable copper output in 1974); Idarado Mining Company, which is 80.1 percent owned by Newmont Mining Corporation (Idarado Mine, Colorado, 2,181 short tons of recoverable copper output in 1974); also including the following (among others): Rancher's Exploration and Development Corporation, Earth Resources Company, El Paso Natural Gas Company, Hecla Mining Company, McAlester Fuel Company, Federal Resources Corporation, Eagle-Picher Industries, Incorporated, Keystone Wallace Resources, Micro Copper Corporation.

[6]Custom smelting/refining: purchasing ores or concentrates from other producers for own-account smelting and refining. Toll smelting/refining: smelting and/or refining (ores, concentrates) for a fee and then returning the resulting metal to the mining company for marketing.

in the domestic copper industry, a brief digression may prove helpful in clarifying our treatment of it for analytical purposes.

Until recently, Asarco differed from other primary producers in four respects:

- The firm was historically not backward integrated into domestic mining and milling operations;
- Asarco processed a large amount of concentrate and/or blister on a toll basis;
- The company frequently used large volumes of scrap as inputs to its refinery operations;
- Asarco's output until 1967 was reportedly sold on the basis of its own "custom smelter" price, an outside market price which frequently deviated from the domestic producers price basis on which the primary producers marketed their output.

In recent years, however, Asarco has made significant expansions, backward into mining and milling and forward into refining. Moreover, as far as the processing of concentrate or blister on a toll basis is concerned, Phelps Dodge and other producers have also carried out this function for independent producers. Asarco, in addition, has reportedly significantly increased over the years the proportion of mined copper and blister used in its smelting and refining operations. Finally, and perhaps most importantly, since 1967 Asarco has followed the producers price quotations in setting the selling price for its own output. For all of these reasons, it is accurate to include Asarco within the primary copper industry along with the other primary producers.

3. Firms in the Secondary Copper Sector

The firms in the secondary copper industry, following our definition of the secondary market, consist of the secondary refiners plus many small, individually-owned firms (scrap dealers, ingot makers, semifabricators engaged in scrap processing for own-consumption, merchants). The classification of these firms in terms of whether they sell refined copper (mostly from scrap, some from mined copper, imports) or unrefined scrap is difficult because of the diversity or multiplicity of functions performed by the latter group of firms.

While there are a number of secondary copper refiners, several of them integrated forward into captive fabricating facilities, Amax and Cerro have been the two most important of these during most of the postwar period. These secondary refiners sell their product at prices (explicit prices if in the open market or implicit prices if intra-company transfers are involved) which are more reflective of current market prices for scrap than of refined copper prices quoted by the primary producers. They have been responsible for an average of 12 percent of total refined copper supplied in the U.S. each year between 1950-1974 and have held about 11 percent of domestic refinery capacity during this same period.

Since 1971 three other refiners, Chemetco, Southwire, and Reading Industries, have gradually come on-stream with substantial secondary refining and, in the case of Southwire, smelting capacity.

Amax, known widely in the industry as the other major custom refiner besides Asarco (approximately 60 percent of the material refined by Amax in 1974 was reportedly done so on a toll or custom basis), is considered a secondary refiner because most of its copper refinery inputs are in the form of scrap and because it sells its output on the basis of its own individually-determined price which, however, reflects prevailing prices on the outside market.

Amax, similar to Asarco, has integrated backward into domestic mining and concentrating operations in recent years (a joint-venture mining project with Anaconda known as Anamax).[1] Concentrate from this operation is toll smelted at Western smelters and a proportion of the resulting blister is refined at Amax's New Jersey refinery. This blister forms only a small proportion, however, of total material processed at Amax's refinery.

Cerro and the other newer secondary refiners are all so classified on the basis that their inputs are mostly if not entirely in the form of scrap. Although most, if not all, of their refined copper output is consumed in their own captive fabricating facilities rather than being sold on the outside market, they, in effect, must charge their own fabricating facilities an inputed price for their refined output reflecting the prevailing price(s) on the outside market.[2] In other words, similar to Amax, they

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[1] Also, in November, 1974 Amax announced an agreement in principle with Copper Range to acquire the assets of Copper Range including its White Pine mining and refining facilities. The proposed merger is currently being challenged by the U.S. Department of Justice. Amax had previously held 19.95 percent of Copper Range's outstanding shares.

[2] In terms of microeconomic theory, as price-takers the secondary refiners will maximize profit by producing refined copper until their marginal cost of producing an additional unit of output is just equal to the prevailing price in the market, in this case the outside market. If they charge their captive fabricators an imputed prices less than the full market price, they will be foregoing revenues (by absorbing costs) which they could obtain by selling the copper on the outside market.

are price-takers in an essentially competitive market.

TABLE 3

ESTIMATED SECONDARY REFINED COPPER PRODUCED BY PRIMARY PRODUCERS AND SECONDARY REFINERS, 1960-1974

	(Thousands of Short Tons)			
Year	Total Production of Refined Copper from Scrap	Copper Refined from Scrap by Secondary Producers	Copper Refined from Scrap by Primary Producers	Percentage of Copper Refined from Scrap by Secondary Producers
1960	291.7	229.3	62.4	78.6%
1961	270.4	190.0	80.4	70.3
1962	289.7	195.1	94.6	67.4
1963	302.0	235.5	66.4	78.0
1964	351.1	240.1	111.0	68.4
1965	445.1	268.2	176.9	60.3
1966	491.3	277.5	213.8	56.5
1967	406.6	271.4	135.2	66.8
1968	416.6	273.6	143.0	65.7
1969	499.1	263.1	236.0	52.7
1970	511.6	251.7	259.9	49.2
1971	400.7	214.8	185.9	53.6
1972	423.2	252.2	171.0	59.6
1973	465.1	348.8	116.3	75.0
1974	496.9	382.1	114.9	76.9

SOURCE: U.S. Bureau of Mines, Minerals Year Book, 1960-1973; Mineral Industry Surveys, Copper Industry in December 1975, (March, 1976), p. 3; Arthur D. Little, Inc., estimates.

D. GEOGRAPHICAL CONCENTRATION AND CAPACITY GROWTH TRENDS IN THE COPPER INDUSTRY

1. Copper Mining

In the United States, over 300 mines produce copper. Copper ore was the principal product of almost 200 mines, and among the others, mostly lead and zinc mines, producer copper was a by-product and co-product. The top five mines each produced more than 100,000 tons of contained metal. The ore is beneficiated (crushed, ground and metal sulfides recovered by flotation) in mills that are located near the mines.

Most of the copper is mined in five western states--Arizona, Utah, New Mexico, Montana and Nevada--(94 percent in 1974) and essentially all of the remainder came from Michigan, Tennessee, and Missouri, as shown in Table 4 for the years 1972, 1973, and 1974.

The major copper mines and their production levels in 1973 and 1974 are shown in Table 5A. Table 5B indicates estimated 1974 reserves of the major producers.[1]

2. Copper Smelting and Refining

Traditionally, smelters have been situated near the mines in order to minimize transportation charges for concentrates. With the major copper mines centered in the Western states, most of the smelting capacity is in that area. In 1974, out of 18 operational smelters (two of these owned and operated by secondary refiners), 13 were located west of the Mississippi.

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[1] It must be kept in mind here that figures on reserves could be quite misleading, since reserves are not static but change with the amount of exploration activity and with the price of copper.

TABLE 4

UNITED STATES MINE PRODUCTION OF RECOVERABLE COPPER
BY MAJOR PRODUCING STATES: 1972, 1973, 1974
(Short Tons)

State	1972 Amount	1972 Rank	1972 Percent	1973 Amount	1973 Rank	1973 Percent	1974 Amount	1974 Rank	1974 Percent
Arizona	908,600	1	55	931,100	1	54	858,783	1	54
Utah	259,500	2	16	257,900	2	15	230,593	2	14
New Mexico	168,000	3	10	208,000	3	12	196,585	3	12
Montana	123,100	4	7	133,000	4	8	131,131	4	8
Nevada	101,100	5	6	95,900	5	5	84,101	5	5
Michigan	67,300	6	4	72,100	6	4	67,012	6	4
Other	37,200	-	2	28,900	-	2	28,797	-	2
TOTAL	1,664,800		100	1,726,900		100	1,597,002		100

Source: American Bureau of Metal Statistics, Yearbook 1973; U. S. Bureau of Mines, Mineral Industry Surveys: Copper Production in July, 1975.

TABLE 5A

MINE PRODUCTION OF RECOVERABLE COPPER IN THE UNITED STATES, 1973 and 1974[a]

Company and Mine	Location	Mine Type	Amount (Short tons) 1973	Amount (Short tons) 1974	Percent Composition (%) 1973	Percent Composition (%) 1974
Kennecott Copper Corporation			471,721	402,213	27.46	25 19
Chino	New Mexico	OP	67,836	60,557	3.95	3 79
Nevada	Arizona	OP	50,012	37,562	2 91	2.35
Ray Mines	Arizona	OP	98,908	74,764	5.76	4.68
Utah	Utah	OP	254,965	229,330	14.84	14.36
Phelps Dodge Corporation			319,358	280,211	18.59	17.55
Morenci	Arizona	OP	119,535	112,790	6 96	7 06
Tyrone	New Mexico	OP	104,011	97,030	6 05	6 08
Ajo (New Cornelia)	Arizona	OP	53,797	43,501	3 13	2 72
Bisbee (Copper Queen)	Arizona					
Lavender Pit		OP	19,387	11,833	1.13	0 74
Underground Mines		UG	22,628	15,057	1 32	0 94
Magma Copper Company (Subsidiary of Newmont Mining Corporation)			158,263	149,645	9.21	9 37
San Manuel	Arizona	UG	22,474	29,437	1.31	1.84
Superior	Arizona	UG	135,789	120,208	7 90	7 53
The Anaconda Company			200,454	190,059	11 67	11 90
Twin Buttes (Anamax Mining Co , under equal partnership with Amax Inc)	Arizona	OP	36,824[c]	20,071[c]	2 14	1 26
Berkeley Pit	Montana	OP	104,474	98,889	6.08	6 19
Anaconda Vein Mines (Leonard, Load Haul Dump, Mountain Con, Steward Mines)	Montana	UG	21,674	17,454	1 26	1.09
Continental East Pit	Montana	OP	1,647	15,676	0 01	0.98
Yerington	Nevada	OP	35,835	37,969	2 09	2 38
White Pine Copper Company (Subsidiary of Copper Range Company)						
White Pine	Michigan	UG	78,506	66,898	4 57	4 19
Cyprus Mines Corporation			107,292	100,268	6 25	6.28
Cyprus Pima Mining Co., Pima Mine	Arizona	OP	88,140	81,889	5 13	5 13
Cyprus Bagdad Copper Company, Bagdad Mine	Arizona	OP	19,152	18,379	1 12	1 15
Asarco Incorporated			73,100	79,200	4.26	4 96
Mission	Arizona	OP	46,600	40,300	2.71	2 52
Silver Bell	Arizona	OP	23,800	23,500	1.39	1.47
San Xavier	Arizona	OP	2,700	5,900	0.16	0.37
Sacaton	Arizona	OP	-	9,500	-	0.59
Inspiration Consolidated Copper Company			65,196	61,238	3 80	3 83
Christmas	Arizona	OP	9,508	6,698	0 55	0 42
Inspiration (Thornton, Live Oak , Red Hill)	Arizona	OP	51,332	49,700	2.99	3 11
Ox Hide	Arizona	OP	4,356	4,840	0 25	0.30
Cities Service Company			33,280	33,855	1 94	2.12
Copperhill	Tennessee	UG	4,025	970	0 24	0.06
Miami (Copper Cities, Diamond H, Pinto Valley)	Arizona	OP	29,255	32,885	1.70	2 06
Duval Corporation (Subsidiary of Pennzoil Company)			131,214	131,843	7 64	8 26
Battle Mountain, Esperanza, Mineral Park	Nevada } Arizona	OP	55,619	52,249	3.24	3 27
Sierrita	Arizona	OP	75,595	79,594	4 40	4.98
AMAX (Anamax Mining Co , under equal partnership with Anaconda)						
Twin Buttes	Arizona	OP	36,824[c]	20,071[c]	2.14	1 26
UV Industries, Incorporated						
Bayard Operations	New Mexico	OP	24,240[c]	24,167	1.41	1.51
Idarado Mining Company (80.1% owned by Newmont Mining Corporation)						
Idarado Mine	Colorado	UG	2,118	2,181	0 12	0.14
SUBTOTAL (of ABOVE COMPANIES)			1,701,566	1,541,849	99.05	96.55
OTHERS (Calculated Residually)[b]			16,374	55,153	0 95	3.45
TOTAL[d]			1,717,940	1,597,002	100 00	100.00

NOTES AND SOURCES: [a]Individual company data have been obtained from the 1973 and 1974 corporate annual reports and from American Bureau of Metal Statistics, Inc. (ABMS), Nonferrous Metal Data 1974, p. 22.

[b]The "Other" category was calculated as the residual of the total less the subtotal for the individual companies reported above. This category includes, for example, Rancher's Exploration and Development Corporation, Earth Resources Company, El Paso Natural Gas Company, Hecla Mining Company, McAlester Fuel Company, Federal Resources Corporation, Eagle-Picher Industries, Incorporated, Keystone Wallace Resources, Micro Copper Corporation and others.

[c]One-half of total Anamax production.

[d]The total is obtained from U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1974 (April 8, 1975) for 1973 data (p. 3) and Copper in 1975 (March 26, 1976) for 1974 data (p 3).

ESTIMATED RESERVES OF MAJOR U.S. COPPER PRODUCERS
(1974)

	Ore Reserves (millions of short tons)	Average Ore Grade	Recoverable Copper (short tons)
naconda	900.0	0.80	5,800,000
namax (Twin Buttes)			
Sulfide	426.0	0.63	2,150,000
Oxide	55.0	1.20	530,000
TOTAL	481.0	0.70	2,680,000
sarco			
Mission	87.1	0.68	475,000
Silver Bell	29.7	0.66	160,000
San Xavier			
Sulfide	152.1	0.51	620,000
Oxide	7.9	1.06	70,000
Sacaton			
Underground	16.7	1.23	165,000
Open Pit	32.7	0.74	195,000
TOTAL	326.2	0.64	1,685,000
Cities Service	350.0	0.44	1,250,000
opper Range	95.0	1.20	910,000
yprus			
Bagdad	300.0	0.49	1,200,000
Pima	200.0	0.49	780,000
Johnson	19.0	0.50	75,000
Bruce	0.2	3.75	6,000
TOTAL	519.2	0.49	2,061,000
uval			
Esperanza	31.2	0.40	100,000
Mineral Park	60.2	0.29	140,000
Battle Mountain			
Copper Canyon	3.7	0.59	17,000
Copper Basin	0.8	0.99	6,000
Sierrita	522.5	0.32	1,350,000
TOTAL	618.5	0.33	1,613,000
nspiration			
Inspiration area			942,778
Christmas			
Underground (operations suspended)			283,802
Open Pit			125,698
Sanchez			142,852
TOTAL			1,495,130

TABLE 5B
(continued)

	Ore Reserves (millions of short tons)	Average Ore Grade	Recoverable Copper (short tons)
Kennecott	3350.0	0.75	20,100,000
Magma	1130.0	0.76	7,050,000
Phelps Dodge	1920.0	0.78	11,900,000

Sources: Corporate Annual Reports, Annual Reports to the SEC, 10-K Forms, and ADL estimates.

The 13 western smelters are operated by five of the six integrated companies (Kennecott, Phelps Dodge, Anaconda, Inspiration, and Magma) who mine a major portion of their respective smelter input, and by Asarco--a major portion of whose input comes from ores mined by other companies.

The ownership of the primary copper smelters and the approximate capacity of each plant in 1975 are shown in Table 6.

Tables 7A and 7B show smelter capacity growth trends for the period 1950-1975.[1] Smelting capacity during the past two and one-half decades has never been as great as it was at the beginning of the 1950's. In spite of an expansion of capacity in the late 1950's and early 1960's, by 1967 capacity had declined to a level only slightly above that existing in 1953. During the following eight years total capacity fluctuated sharply, but by 1975 was only 300,000 tons (or 3.5 percent) greater than that existing in 1953.

Since 1956, no new smelters have been opened by the industry; all expansion has represented additions to existing smelter operations. Changes in total smelter capacity--both additions and curtailments--have been lumpy in nature. The largest was the shutdown of the 1,400,000 short ton Phelps Dodge smelter in Clarksdale, Arizona in 1950. More recently, Asarco expanded its Hayden (Arizona) and El Paso (Texas) smelters in 1968 by 969,000 short tons representing an eight percent addition to total industry capacity.

[1] Growth in smelting capacity of Lake Superior District producers of Lake copper are broken out in Table 7B because capacity figures are reported in tons of product rather than tons of charge material.

TABLE 6

COPPER SMELTING WORKS OF UNITED STATES
(At the End of 1975, Short Tons of Material)

Company	Location	Annual Capacity
Asarco	El Paso, Texas	576,000
Asarco	Hayden, Ariz.	960,000
Asarco	Tacoma, Wash.	600,000
The Anaconda Company	Anaconda, Mont.	750,000
Cities Service Company Copperhill Operations	Copperhill, Tenn.	75,000
Chemetco Inc.	Alton, Illinois	150,000
Inspiration Consolidated Copper Co.	Miami, Ariz.	450,000
Magma Copper Company San Manuel Division	San Manuel, Ariz.	800,000
Kennecott Copper Corporation		
Nevada Mines Division	McGill, Nev.	400,000
Chino Mines Division	Hurley, N.M.	400,000
Ray Mines Division	Hayden, Ariz.	420,000
Utah Copper Division	Garfield, Utah	1,000,000
Phelps Dodge Corporation		
Douglas Smelter	Douglas, Ariz.	700,000
Morenci Branch	Morenci, Ariz.	900,000
New Cornelia Branch	Ajo, Ariz.	250,000
United States Metals Refining Co., a subsidiary of Amax Inc.	Carteret, N.J.	180,000
Total[a]		8,611,000
Quincy Mining Co.	Hancock, Mich.	15,000
White Pine Copper Co.	White Pine, Mich.	90,000
Total[b]		105,000

NOTES: [a]Tons of material.
[b]Tons of product.

SOURCE: American Bureau of Metal Statistics, Inc. (ABMS), Yearbook 1974, and company annual reports.

TABLE 7A

GROWTH OF UNITED STATES COPPER SMELTING CAPACITY[a]

1950-1975

(Short Tons of Material; End of Year Figures)

Year	Copper Smelting Capacity	Change in Copper Smelting Capacity	Change in Copper Smelting Capacity due to new Plants	Change in Copper Smelting Capacity due to Expansion (Contraction) of Existing Plants
1950	9,551,000[b]	-	-	-
1951	9,653,000[b]	102,000	0	102,000[c]
1952	9,653,000[b]	0	0	0
1953	8,318,000	-1,335,000	0	-1,335,000[d]
1954	8,368,000	50,000	0	50,000[e]
1955	8,348,000	-20,000	0	-20,000[f]
1956	8,225,000	-123,000	70,000[g]	-193,000[h]
1957	8,415,000	190,000	0	190,000[i]
1958	8,600,000	185,000	0	185,000[j]
1959	8,600,000	0	0	0
1960	8,600,000	0	0	0
1961	8,700,000	100,000	0	100,000[k]
1962	8,623,000	-77,000	0	-77,000[l]
1963	8,423,000	-200,000	0	-200,000[m]
1964	8,423,000	0	0	0
1965	8,371,000	-52,000	0	-52,000[n]
1966	8,371,000	0	0	0
1967	8,383,000	12,000	0	12,000[o]
1968	9,079,000	696,000	0	696,000[p]
1969	8,689,000	-390,000	0	-390,000[q]
1970	8,704,000	15,000	0	15,000[r]
1971	8,821,000	117,000	0	117,000[s]
1972	8,521,000	-300,000	0	-300,000[t]
1973	8,496,000	- 25,000	0	- 25,000[u]
1974	8,626,000	130,000	0	130,000[v]
1975	8,611,000	- 15,000	0	- 15,000[w]

NOTES:

[a]Excludes producers of Lake Copper.

[b]Includes the capacity of the Phelps Dodge Corporation, United Verde Branch, Clarksdale, Arizona, smelter (1,400,000 short tons of annual capacity) which closed down June, 1950.

[c]Expansion in the capacity of Kennecott Copper Corporation, New Mexico plant at Hurley, New Mexico (from 288,000 to 400,000 short tons), minus the contraction in the capacity of the Kennecott Copper Corporation, Nevada plant at McGill, Nevada (from 450,000 to 440,000 short tons).

[d]Expansion in the capacity of the American Metal Company, Ltd., Carteret, New Jersey smelter (from 200,000 to 265,000 short tons) minus the shutdown of the Phelps Dodge Corporation, United Verde Branch, Clarksdale, Arizona smelter (1,400,000 short tons annual capacity), which closed down June, 1950.

[e]Expansion in the capacity of the American Smelting and Refining Company, El Paso, Texas, smelter (from 300,000 to 350,000 short tons).

[f]Contraction in the capacity of the American Metal Company, Ltd., Carteret, New Jersey, smelter (from 265,000 to 245,000 short tons).

[g]The new San Manuel Copper Corporation, San Manuel, Arizona, smelter, a wholly owned subsidiary of Magma Copper Company.

[h]Expansion in the capacity of the American Smelting and Refining Company, El Paso, Texas, smelter (from 350,000 to 400,000 short tons) minus the contraction in the capacity of the following smelters:

Asarco, Garfield, Utah (from 1,608,000 to 1,440,000 short tons).

Asarco, Tacoma, Washington (from 675,000 to 600,000 short tons).

[i]Expansion in the capacity of the San Manuel Copper Corporation, San Manuel, Arizona, smelter (from 70,000 to 360,000 short tons) minus the contraction in the capacity of the Magma Copper Company, Superior, Arizona, smelter (from 250,000 to 150,000 short tons).

[j]The new Kennecott Copper Corporation, Ray Mines Division, Hayden, Arizona, smelter (400,000 tons annual capacity) minus the contraction in the capacity of the smelting facilities at Garfield, Utah, purchased by Kennecott Copper Corporation from American Smelting and Refining Company (from 1,440,000 to 1,225,000 short tons).

[k]Expansion in the capacity of the following smelters:

Asarco, El Paso, Texas (from 400,000 to 420,000 short tons).

Asarco, Hayden, Arizona (from 300,000 to 360,000 short tons).

Tennessee Copper Company, Copperhill, Tennessee (from 70,000 to 90,000 short tons).

[l]Contraction in the capacity of the American Metal Climax, Inc., Carteret, New Jersey, smelter (from 245,000 to 168,000 short tons).

[m]Shutdown of the Phelps Dodge Refining Corporation, Laurel Hill, New York smelter (200,000 short tons annual capacity).

[n]Expansion in the capacity of the following smelters:

Asarco, Hayden, Arizona (from 360,000 to 420,000 short tons).

Inspiration Consolidated Copper Company, Miami, Arizona (from 360,000 to 450,000 short tons).

Magma Copper Corporation, San Manuel Division, San Manuel, Arizona (from 360,000 to 403,000 short tons).

Kennecott Copper Corporation, Ray Mines Division, Hayden, Arizona (from 400,000 to 420,000 short tons).

Minus the contraction in the capacity of the following smelters:

Kennecott Copper Corporation, Nevada Mines Division, McGill, Nevada (from 440,000 to 400,000 short tons).

Kennecott Copper Corporation, Utah Mines Division, Garfield, Utah (from 1,225,000 to 1,000,000 short tons).

[o]Expansion in the capacity of the American Metal Climax, Inc., Carteret, New Jersey, smelter (from 168,000 to 180,000 short tons).

[p]Expansion in the capacity of the following smelters:

Asarco, El Paso, Texas (from 420,000 to 576,000 short tons).

Asarco, Hayden, Arizona (from 420,000 to 960,000 short tons).

[q]Contraction in the capacity of the Phelps Dodge Corporation smelter at Douglas, Arizona (from 1,250,000 to 860,000 short tons).

[r]Expansion in the capacity of the Phelps Dodge Corporation smelter at Douglas, Arizona (from 860,000 to 875,000 short tons).

[s]Expansion in the capacity of the Magma Copper Corporation, San Manuel Division, San Manual, Arizona, smelter (from 403,000 to 670,000 short tons) minus the permanent shutdown of the Magma Copper Corporation, Superior Division, Superior, Arizona, smelter (150,000 short tons annual capacity).

[t]Contraction in the capacity of the Anaconda Company, smelter at Anaconda, Montana (from 1,000,000 short tons to 750,000 short tons) plus contraction in the Phelps Dodge Corporation, New Cornelia Branch, Ajo, Arizona, smelter (from 300,000 short tons to 250,000 short tons).

[u]The new Chemetco, Inc., Alton, Illinois, smelter (150,000 short tons annual capacity) minus the contraction in the Phelps Dodge Corporation smelter at Douglas, Arizona (from 875,000 short tons to 700,000 short tons).

[v]Expansion in the capacity of the Magma Copper Corporation, San Manuel Division, San Manuel, Arizona, smelter (from 670,000 to 800,000 short tons).

[w]Contraction in the capacity of the Cities Service Company, smelter at

Copperhill, Tennessee (from 90,000 to 75,000 short tons).

SOURCE: Yearbook of the American Bureau of Metal Statistics, Inc., (ABMS), annual yearbook volumes, 1958-1975.

TABLE 7B

GROWTH OF LAKE COPPER SMELTING CAPACITY[a] IN THE UNITED STATES, 1950-1975

(Short Tons of Product; End of Year Figures)

Year	Copper Smelting Capacity	Change in Copper Smelting Capacity	Change in Copper Smelting Capacity Due To New Plants	Change in Copper Smelting Capacity Due To Expansion (Contraction) of Existing Plants
1950	197,000 [b]	---	---	---
1951	197,000 [b]	0	0	0
1952	112,000	-85,000	0	-85,000 [c]
1953	112,000	0	0	0
1954	92,000	-20,000	0	-20,000 [d]
1955	128,000	36,000	36,000 [e]	0
1956	128,000	0	0	0
1957	137,000	9,000	0	9,000 [f]
1958	157,000	20,000	0	20,000 [g]
1959	162,000	5,000	0	5,000 [h]
1960	167,000	5,000	0	5,000 [i]
1961	177,000	10,000	0	10,000 [j]
1962	177,000	0	0	0
1963	177,000	0	0	0
1964	177,000	0	0	0
1965	177,000	0	0	0
1966	202,000	15,000	0	15,000 [k]
1967	132,000	-70,000	0	-70,000 [l]
1968	132,000	0	0	0
1969	135,000	3,000	0	3,000 [m]
1970	135,000	0	0	0
1971	135,000	0	0	0
1972	105,000	-30,000	0	-30,000 [n]
1973	105,000	0	0	0
1974	105,000	0	0	0
1975	105,000	0	0	0

NOTES:

[a]Includes Lake Superior District producers only.

[b]Capacity figure includes the idle capacity of the Copper Range Company, Smelting Department, Houghton, Michigan (85,000 short tons of product annual capacity).

[c]Shut down of the capacity of the Copper Range Company, Smelting Department, Houghton, Michigan (85,000 short tons of product annual capacity).

[d]Contractions in the capacity of the Calumet and Hecla, Inc., Hubbell, Michigan, smelter (from 100,000 to 80,000 short tons).

[e]The new White Pine Copper Company, White Pine, Michigan, smelter.

[f]Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 36,000 to 45,000 short tons).

[g]Expansion in the capacity of the Calumet and Hecla, Inc., Hubbell, Michigan, smelter (from 80,000 to 100,000 short tons).

[h]Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 45,000 to 50,000 short tons).

[i]Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 50,000 to 55,000 short tons).

[j]Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 55,000 to 65,000 short tons).

[k]Expansion in the capacity of the White Pine Copper Company, White Pine, Michigan, smelter (from 65,000 to 90,000 short tons).

[l]Contraction in the capacity of the Calumet and Hecla, Inc., Hubbell, Michigan, smelter (from 100,000 to 30,000 short tons).

[m]Expansion in the capacity of the Quincy Mining Company, Hancock, Michigan, smelter (from 12,000 to 15,000 short tons).

[n]Shut down of the capacity of the Universal Oil Products Company, Calumet Division, Hubbell, Michigan, smelter (30,000 short tons annual capacity).

SOURCE: Yearbook of the American Bureau of Metal Statistics, annual volumes, 1958-1975.

In 1972, reported smelter capacity declined by 300,000 tons (3.4 percent of total industry capacity), as the result of a 250,000 ton contraction of capacity at Anaconda's Montana smelter as well as a 50,000 ton contraction at the Phelps Dodge Ajo smelter.

The major portion of the smelter output of blister copper is electrorefined. Copper electrolytic refineries have traditionally been located near consumers on the Atlantic Coast, but several refineries have been built in the West. The East Coast refineries still account for a major portion--about half--of electrorefining capacity. A smaller portion of smelter output is fire refined, principally in New Mexico and Michigan.

As indicated in Table 8, reported figures on refinery capacity vary (in some cases significantly) depending on the published source of data. The primary copper refineries, their ownership, and the location, type and capacity of each refinery at the end of 1975 are shown in Table 9, based on American Bureau of Metal Statistics data. Table 10 shows capacity growth among domestic refineries over the 1958-1975 period.

Overall, refinery capacity expanded by about 38 percent over the 1958-1975 period. Unlike the fluctuating growth trend in smelter capacity, net changes in refinery capacity have been positive with the exception of two years, 1962 and 1972. The figures in Table 10 indicate how responsive producers have been to general conditions in the business cycle and the demand cycle for copper, with the bulk of refinery capacity expansion occurring in response to business expansion and rising copper demand over the period 1964-1970.

TABLE 8

COPPER REFINERY CAPACITY IN THE UNITED STATES, 1973/1974, BY COMPANY AND LOCATION, AS GIVEN IN DIFFERENT SOURCES

Type, Company, Location	American Bureau of Metal Statistics[a]	Engineering and Mining Journal[c]	Metal Bulletin[j]	
	1973/1974[b] (in tons of 2,000 lbs.)	1973/1974[d] (in tons of 2,000 lbs)	1974[k] (in metric tons)	1974[k] (in tons of 2,000 lbs)[l]
Electrolytic				
The Anaconda Company				
Great Falls, Montana	180,000	180,000	220,000	242,500
Raritan, Perth Amboy, N J	115,000	115,000	100,000	110,200
Asarco				
Baltimore, Md	318,000	312,000	180,000	198,400
Perth Amboy, N J	168,000	168,000	155,000	170,900
Tacoma, Wash	156,000	150,000	141,000	155,400
Cerro Copper & Brass Div of Cerro Corp				
St Louis, Mo	44,000	NA	40,000	41,100
Chemetco, Inc.				
Alton, Illinois	40,000	NA	30,000	33,100
Inspiration Consolidated Copper				
Inspiration, Arizona	70,000	72,000	65,000	71,700
Kennecott Copper Corp				
Garfield, Utah	186,000	192,000[h]	165,000	181,900
Kennecott Refining Corp				
Anne Arundel County, Md	276,000	276,000	250,000	275,600
Magma Copper Company,				
San Manuel, Arizona	200,000	200,000	181,000	199,500
Phelps Dodge Refining Corp.				
El Paso, Texas	420,000	445,000[e]	400,000[e]	400,900[e]
Laurel Hill, L I., N.Y.	72,000	92,000[f]	85,000[f]	93,700[f]
Reading Industries, Inc				
Reading, Penna	20,000	NA	18,000	19,800
Southwire Company, Copper Division				
Carrollton, Georgia	72,000	NA	65,000	71,700
United States Metals Refining Co				
Carteret, N.J , a subsidiary of Amax, Inc.	175,000	215,000[g]	160,000	176,400
TOTAL TANK CAPACITY	2,512,000	NA	NA	NA
Lake and Fire Refining				
Kennecott Copper Corp				
Hurley, New Mexico	103,000	85,000	65,000	71,000
Phelps Dodge Refining Corp.				
El Paso, Texas	25,000	NA[e]	NA[e]	NA[e]
Laurel Hill, L.I., N.Y.	20,000	NA[f]	NA[f]	NA[f]
Quincy Mining Co				
Hancock, Mich.	15,000	NA	11,000	12,100
United States Metals Refining Co				
Carteret, N J , a subsidiary of Amax, Inc.	85,000	NA[g]	75,000	82,700
White Pine Copper Co.				
White Pine, Mich.	90,000	85,000[i]	81,000	89,300
TOTAL LAKE AND FIRE REFINED	338,000	NA	NA	NA
TOTAL REFINED COPPER CAPACITY	2,850,000	NA	NA	NA

NOTES AND SOURCES:

[a]American Bureau of Metal Statistics, Inc. (ABMS) as reported in the Yearbook of the American Bureau of Metal Statistics, 1973 (New York. ABMS, June 1974) p. 28 and Nonferrous Metals Data 1974 (New York ABMS, 1975), p 32.

[b]Figures refer to annual capacity at the end of the year(s) noted, 1973 and 1974 figures are exactly alike in the sources cited.

[c]Engineering and Mining Journal International Directory of Mining, 1973/1974, Section 2A--U.S Mine/Plant Units.

[d]Figures refer to circa 1973/1974; no specific time designations (e.g , mid-1973, etc.) are provided.

[e]Includes data for the El Paso, Texas, furnace refining plant

[f]Includes data for the Laurel Hill, L.I., N.Y., fire refining plant.

[g]Includes data for (at least part) of the Carteret, N J , fire refining (smelting) plant.

[h]Other products produced include selenium, gold, silver, platinum, and palladium.

[i]Listed as smelter capacity (reverbatory matte smelting and converting), the refinery operation described pertain to fire refining, where the major product is listed as high conductivity silver bearing cast copper shapes.

[j]Copper, 1974, a special issue published by Metal Bulletin Limited (London: No date), p. 183.

In addition to the data already listed, this source provides refinery capacity data not given in the other sources cited (for 1973 or 1974), consisting of the following refinery operations:

(1) International Smelting and Refining Co., Raritan, N J. (104,000 metric tons per year = 114,600 short tons).

(2) Hecla/El Paso, Lakeshore, Michigan (36,000 metric tons = 39,700 short tons). Note: This appears to be the same as the Calumet Division, Universal Oil Products Company refinery in Hubbell, Michigan (formerly known as Calumet and Hecla Corp., Universal Oil Products Company, 1968-1971, and simply as Calumet and Hecla, Inc., prior to 1968). This plant was idle in 1970 and 1971 and appears to have been closed down by the end of 1971.

(3) Ranchers, Bluebird (6,000 metric tons = 6,600 short tons).

ita refer to "generally recognized capacity" (see footnote "j," p. 165)

[l]Data converted from metric tons of 2,000 lbs. (i.e., short tons), by using the following relationship:

metric ton = 1000 kilograms

short ton = 907.185 kilograms

Ratio: 1000.000/907.185 = 1.102311

Figures are rounded-off to the nearest hundred

NA: Not available.

TABLE 9

UNITED STATES COPPER REFINERY CAPACITY

(Annual Capacity at End of 1975 in Short Tons of Product)

Company	Location	Annual Capacity, Tons of Product
Electrolytic:		
The Anaconda Company	Great Falls, Mt.	252,000
Asarco	Amarillo, Texas	420,000
"	Perth Amboy, N.J.	168,000
"	Tacoma, Wash.	156,000
Cerro Copper & Brass Division of Cerro Corporation	St. Louis, Mo.	44,000
Chemetco, Inc.	Alton, Ill.	40,000
Inspiration Consolidated Copper	Inspiration, Ariz.	70,000
Kennecott Copper Corporation	Garfield, Utah	186,000
Kennecott Refining Corporation	Anne Arundel County, Md.	276,000
Magma Copper Company	San Manuel, Ariz.	200,000
Phelps Dodge Refining Corporation	El Paso, Texas	420,000
" " " "	Laurel Hill, L.I., N.Y.	72,000
Reading Industries, Inc.	Reading, Pa.	20,000
Southwire Company Copper Division	Carrollton, Ga.	72,000
United States Metals Refining Co. Subsidiary of American Metal Climax, Inc.	Carteret, N.J.	175,000
Lake and Fire Refining:		
Kennecott Copper Corporation	Hurley, N.M.	103,000
Phelps Dodge Refining Corporation	El Paso, Texas	25,000
" " " "	Laurel Hill, L.I., N.Y.	20,000
Quincy Mining Co.	Hancock, Mich.	15,000
United States Metal Refining Co. Subsidiary of American Metal Climax, Inc.	Carteret, N.J.	85,000
White Pine Copper Co.	White Pine, Mich.	90,000
Total		2,909,000

SOURCE: American Bureau of Metal Statistics, Inc., (ABMS), Nonferrous Metals Data, 1975.

TABLE 10

COPPER REFINERY EXPANSION IN THE UNITED STATES, 1958-1975

(Short Ton of Product; End of Year Figures)

Years	Copper Refinery Capacity	Change in Copper Refinery Capacity	Change in Copper Refinery Capacity due to New Plants	Change in Copper Refinery Capacity due to Expansion (Contraction) of Existing Plants
1958	2,108,500	-	-	-
1959	2,309,000	200,500	198,000[a]	2,500[b]
1960	2,331,500	22,500	0	22,500[c]
1961	2,341,500	10,000	0	10,000[d]
1962	2,334,500	- 7,000	0	7,000[e]
1963	2,334,500	0	0	0
1964	2,364,500	30,000	0	30,000[f]
1965	2,420,500	56,000	0	56,000[g]
1966	2,430,500	10,000	0	10,000[h]
1967	2,522,000	91,500	0	91,500[i]
1968	2,643,000	121,000	0	121,000[j]
1969	2,676,000	33,000	0	33,000[k]
1970	2,676,000[o]	0	0	0
1971	2,793,000[o]	117,000	200,000[l]	-83,000[m]
1972	2,723,000	-70,000	0	-70,000[n]
1973	2,850,000	127,000	132,000[p]	- 5,000[q]
1974	2,850,000	0	0	0
1975	2,909,000	59,000	420,000[r]	-361,000[s]

NOTES:

[a]The new Kennecott Refining Corporation, Anne Arundel County, Maryland, refinery.

[b]Expansion in the capacity of the White Pine Copper Co., White Pine, Michigan, refinery (from 45,000 to 50,000 short tons) minus the contraction in the capacity of the Inspiration Consolidated Copper, Inspiration, Arizona refinery (from 47,500 to 45,000 short tons).

[c]Expansion in the capacity of the Lewin-Mathes Co., Division of Cerro de Pasco Corporation, St. Louis, Maryland, refinery (from 25,000 to 42,500 short tons).

[d]Expansion in the capacity of the White Pine Copper Corporation, White Pine, Michigan, refinery (from 55,000 to 65,000 short tons).

[e]Expansion in the capacity of the American Metal Climax, Inc., Carteret, New Jersey, refinery (from 121,000 to 125.000 short tons) minus the contraction in the capacity of the American Smelting and Refining, Tacoma, Washington, refinery (from 114,000 to 103,000 short tons).

[f]Expansion in the capacity of the Inspiration Consolidated Copper, Inspiration, Arizona refinery (from 45,000 to 65,000 short tons) plus expansion in the capacity of the Phelps Dodge Refining Corporation, El Paso, Texas, refinery (from 290,000 to 300,000 short tons).

[g]Expansion in the capacity of the following refineries:

The Anaconda Company, Great Falls, Montana (from 150,000 to 180,000 short tons);

Inspiration Consolidated Copper, Inspiration, Arizona (from 65,000 to 70,000 short tons);

Kennecott Copper Corporation, Hurley, New Mexico (from 84,000 to 103,000 short tons);

minus the contraction in the capacity of the Kennecott Copper Corporation, Garfield, Utah, refinery (from 204,000 to 186,000 short tons).

[h]Expansion in the capacity of the following refineries:

The Anaconda Company, Great Falls, Montana (from 180,000 to 190,000 short tons);

White Pine Copper Company, White Pine, Michigan (from 65,000 short tons to 90,000 short tons);

minus the contraction in the capacity of the International Smelting and Refining Company, Raritan, Perth Amboy, New Jersey (from 240,000 to 215,000 short tons).

[i]Expansion in the capacity of the following refineries:

Asarco, Baltimore, Maryland (from 198,000 to 318,000 short tons);

Asarco, Tacoma, Washington (from 103,000 to 108,000 short tons);

Phelps Dodge Refining Corporation, El Paso, Texas (from 300,000 to 320,000 tons);

minus the contraction in the capacity of the following refineries:

Lewis Mathes Co., Division of Cerro Corporation, St. Louis, Missouri (from 42,500 to 39,000 short tons);

Phelps Dodge Refining Corporation, Laurel Hill, Long Island, New York (from 175,000 to 155,000 short tons);

Calumet and Hecla, Inc., Hubbell, Michigan (from 60,000 to 30,000 short tons).

[j]Expansion in the capacity of the following refineries:

United States Metals Refining Co., Carteret, New Jersey, a subsidiary of American Metal Climax, Inc. (from 150,000 to 175,000 short tons);

Asarco, Tacoma, Washington (from 108,000 to 126,000 short tons);

Kennecott Refining Corporation, Anne Arundel County, Maryland (from 198,000 to 276,000 short tons);

Phelps Dodge Refining Corporation, El Paso, Texas (from 320,000 to 420,000 short tons);

minus the contraction in the capacity of the following refineries:

International Smelting and Refining Co., Raritan, Perth Amboy, New Jersey (from 215,000 to 150,000 short tons);

United States Metals Refining Co., Carteret, New Jersey, a subsidiary of American Metal Climax, Inc. (from 125,000 to 85,000 short tons).

[k]Expansion in the capacity of the Asarco, Tacoma, Washington, refinery (from 126,000 to 156,000 short tons) plus expansion in the capacity of the Quincy Mining Co., Hancock, Michigan, refinery (from 12,000 to 15,000 short tons).

[l]Magma Copper Company, San Manuel, Arizona.

[m]Contraction in the capacity of the Phelps Dodge Refining Corporation, Laurel Hill, Long Island, New York, refinery (from 155,000 to 72,000 short tons).

[n]Contraction in the capacity of the following refineries

The Anaconda Company, Great Falls, Montana (from 190,000 to 185,000 short tons);

International Smelting and Refining Company, Raritan, Perth Amboy, New Jersey (from 150,000 to 115,000 short tons);

Shutdown of Calumet Division, Universal Oil Products Company, Hubbell, Michigan (annual capacity 30,000 short tons at the end of 1971), which was idle in 1970 and 1971.

[o]Includes the "idle" capacity of the Calumet Division, Universal Oil Products Co., Hubbell, Michigan refinery (30,000 short tons annual capacity).

[p]The following new refineries started operations in 1973:

Chemetco, Inc., Alton, Illinois (40,000 short tons annual capacity);

Reading Industries, Inc., Reading, Pennsylvania (20,000 shorts tons annual capacity);

Southwire Company, Copper Division, Carrollton, Georgia (72,000 short tons annual capacity).

[q]Contraction in the capacity of The Anaconda Company, Great Falls, Montana, refinery (from 185,000 to 180,000 short tons).

[r]The new Asarco, Amarillo, Texas, refinery.

[s]Expansion in the capacity of the Anaconda Company, Great Falls, Montana, smelter (from 180,000 to 252,000 short tons) minus the shut down of the following smelters:

Anaconda Company, Raritan plant, Perth Amboy, New Jersey (115,000 short tons annual capacity)

Asarco, Baltimore, Maryland (318,000 short tons annual capacity).

SOURCE: Yearbook of the American Bureau of Metal Statistics, annual volumes, 1958-1975.

Prior to 1971, most of the capacity expansion was in the form of additions to existing plants; no new plants were built in the U.S. during the period 1959-1971. In 1971, however, Magma opened a new 200,000 annual short ton refinery in San Manuel, Arizona. By 1973, three secondary refiners--Chemetco, Reading, and Southwire--had come on-stream with a total capacity of 132,000 annual short tons. Further, in 1975, Asarco began operations at its new 420,000 annual short ton capacity refinery in Amarillo, Texas; at the same time, however, it shut down operations at its 318,000 annual short ton capacity Baltimore refinery.

E. VERTICAL INTEGRATION, CONCENTRATION, AND BARRIERS TO ENTRY IN THE PRIMARY COPPER INDUSTRY

The degree of vertical integration and concentration in an industry as well as the existence of barriers to entry are important considerations in analyzing pricing behavior of firms. The degree of industry concentration provides an indication as to whether or not firms in the industry are capable of exercising discretionary price behavior (i.e., influencing market prices), as opposed to being entirely price-takers. Where concentration is low, there will normally be such a large number of firms and each individual firm's share of the market will be so small that no individual firm would be able to influence prices significantly (i.e., firms are entirely price-takers). Where concentration is high, the pricing and production decisions of any one firm will have some effect on the pricing and output of other firms in the relevant market; consequently, price-output determination by the firms will be interdependent.

Next, the degree of vertical integration is important for two reasons. First, in an industry which is highly integrated, producers' material costs are somewhat insulated from the forces of market demand at intermediate stages of production. This does not mean that producers, in making pricing and output decisions, can ignore market forces, but rather that the relevant demand forces emanate from downstream markets. Second, economies of vertical integration or an existing high degree of integration can constitute an effective barrier to entry into the industry.

The existence of barriers to entry into the industry is important since the absence of barriers to entry can mitigate the effect that a high degree of concentration would normally have on pricing and production behavior of the major producers.

1. Industry Concentration

The U.S. copper industry is indeed highly concentrated, as shown in Table 11. At the mining level, the three largest integrated producers in 1974 accounted for 56.1 percent of total mine production, while the seven integrated producers (including Asarco) together produced 78.3 percent of the total.

At the smelting level, the three largest producers accounted for 53.3 percent of total smelting capacity, while the seven integrated producers (including Asarco) held 94.7 percent of the total.[1]

At the refining level, Anaconda, Kennecott, and Phelps Dodge held 48.9 percent of refinery capacity, while the seven integrated producers combined accounted for 83.8 percent.

As suggested previously, concentration in the semifabricating and fabricating industries has, in the past, varied among different semifabricating industries, but nowhere has it been high enough to allow semifabricators to have a significant influence on pricing or production policies in the industry. The domestic foundry and powder mill industries are highly competitive; in the early 1960's there were approximately 535 foundries in the United States, and the eight-firm concentration ratio

[1]For the copper industry as a whole, concentration ratios at the smelting stage may be slightly overstated in Table 11, since a large number of small secondary smelters/ingot makers are not represented in capacity totals. However, including these figures would not significantly alter the degree of smelting concentration in the entire industry.

TABLE 11

COPPER INDUSTRY CONCENTRATION
AT VARIOUS STAGES OF PRODUCTION, 1974

Company	Mine Production (Short tons of Recoverable Copper)	Smelting Capacity (Short tons of Material)	Refining Capacity (Short tons of Refined Copper)	Percentage of Total Mine Production(%)[a]	Percentage of Total Smelting Capacity(%)[a]	Percentage of Total Refinery Capacity(%)[a]
Anaconda	212,788	750,000	295,000	13.3	8.3	10.3
Kennecott	402,213	2,220,000	565,000	25.2	24.5	19.8
Phelps Dodge	281,338	1,850,000	537,000	17.6	20.5	18.8
Magma	149,645	800,000	200,000	9.4	8.8	7.1
Copper Range	66,623	360,000[a]	90,000	4.2	4.0	3.1
Inspiration	56,336	450,000	70,000	3.5	5.0	2.5
Asarco	81,062	2,136,000	642,000	5.1	23.6	22.5
Seven Integrated Producers' Total	1,250,005	8,566,000	2,399,000	78.3	94.7	83.8
Partially Integrated Producers and Independent Mining Companies	324,288	60,000[b]	15,000	20.3	0.7	0.5
Primary Industry Total	1,574 293	8,626,000	2,414,000	98.6	96.3	84.3
Amax	22,729	180,000	260,000	1.4	2.0	9.1
Cerro	---	---	44,000	---	---	1.5
Chemetco	---	150,000	40,000	---	1.7	1.4
Southwire	---	---	72,000	---	---	2.5
Reading	---	---	20,000	---	---	1.2
Secondary Industry Total	22,729	330,000	436,000	1.4	3.7	15.7
Grand Total	1,597,002	8,956,000	2,850,000	100.0	100.0	100.0

NOTES: [a]Components may not add up to the totals given due to rounding.

[b]ADL estimates. Smelter capacity figures are given in short tons of copper material "feed"; refinery capacity figures represent output of refined copper. Capacity figures in short tons of material "feed" were estimated using an industry-wide average ratio of tons of material input/tons of copper product of 4.0.

SOURCES: American Bureau of Metal Statistics, Yearbook 1974, p. 22; Copper Development Association, Copper Supply and Consumption: Annual Data 1975, p 6-7.

in the foundry industry was only about 25 percent.[1] Concentration in the wire and brass mills was substantially higher, with reported eight-firm concentration ratios between 65 and 81 percent.[2]

2. Vertical Integration

In addition to a high degree of concentration, there is as well a high degree of vertical integration in the primary copper industry, particularly through the refining stage of production. Although most of the major primary producers are vertically integrated through the semifabricating and fabricating stages of production, and it is frequently acknowledged that there is a significant degree of vertical integration in the copper fabricating industry, no recent accurate estimates are available concerning the actual degree of vertical integration at the fabricating stage.

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[1]The number of foundries was reported in U.S. Department of Commerce, 1963 Census of Manufactures, p. 33D-10, p. 33D-20. The concentration ratios were originally reported in Report by the Bureau of the Census for the Sub-committee on Antitrust and Monopoly of the Committee on the Judiciary, U.S. Senate, 89th Congress, 2nd Session, Concentration Ratios in Manufacturing Industry (Washington, D.C.: U.S. Government Printing Office, 1966). See also Charles River Associates, Inc. (CRA), Economic Analysis of the Copper Industry (March, 1970), pp. 58-60; and David McNicol, The Two-Price Systems in the Copper Industry, unpublished doctoral thesis, Massachusetts Institute of Technology (February, 1973), pp. 59-60.

[2]However, effective concentration in the wire and brass mill sectors has likely been significantly lower, for two reasons. First, published ratios were formulated from value-added data which did not discriminate between copper and non-copper-related production of a firm. In several instances, larger fabricators produce non-copper products; to the extent that smaller firms do not do this, the value-added of the larger firms would be overstated, relative to that of the smaller firms, thereby inflating the importance of the large firms in terms on industry concentration. Second, U.S. tariffs on semifabricated copper products have been low; sources of supply for the domestic market have therefore been considerably expanded beyond domestic production, and the effective degree of concentration in the industry thereby lowered.

Data in Table 12 indicates product flow for individual companies from the mining to refining stages of production. The integrated primary producers largely supply their smelters and refineries with company-mined ores. Partially-integrated primary producers and independent miners account for only a modest part of domestic production and most of the output of the major firms is sold directly under long-term contract to either Asarco or Phelps Dodge for smelting and refining.

Past studies of the copper industry have suggested that as much as one-third of refined copper fabricating capacity was captive to vertically-integrated firms, but these estimates apparently included both primary producers and secondary refiners as we have classified them.[1]

The major domestic producers (particularly Anaconda, Kennecott, and Phelps Dodge) are integrated forward into the production of copper wire and brass mill products. David McNicol has estimated that as much as 40 to 50 percent of the domestic copper wire and brass mill industry may have been captive to the major producers during the past 10 to 20 years.[2] There is relatively little, if any, forward integration into other semifabrication industries such as powder mills, ingot makers, and foundries.

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[1] Charles River Associates, Inc. (CRA), Economic Analysis of the Copper Industry, 1970, p. 58.

[2] David McNicol, The Two-Price Systems in the Copper Industry, unpublished thesis, Massachusetts Institute of Technology, February, 1973, p. 60.

TABLE 12

PRODUCT FLOW FOR MAJOR INTEGRATED AND NON-INTEGRATED PRODUCERS IN THE PRIMARY COPPER INDUSTRY

Company	Where Smelted	Where Refined	Sold By
The Anaconda Co., Butte, Mont.	Anaconda, Anaconda, Mont.	Anaconda, Great Falls, Mont.	Anaconda Sales Co.
The Anaconda Co., Yerington, Nevada	The Anaconda Co., Anaconda, Mont.	The Anaconda Co., Anaconda, Mont.	Anaconda Sales Co.
Kennecott Copper Corp.	Own smelters, Garfield, Utah; Ray, Ariz; McGill, Nevada; Hurley, N.M.	Own refineries at Garfield,Utah; Hurley, N.M.Kennecott Refining Corp. at Ann Arundel	Kennecott Sales Corp.
Phelps Dodge Corp.	Own Plants, Douglas, Morenci, and Ajo, Ariz.	Phelps Dodge Ref. Corp.	Phelps Dodge Sales Company Incorporated
Inspiration Consolidated Copper Co.	Own Plant, Miami, Ariz.	Own plant, Inspiration, Ariz. and Raritan Copper Wks.	
White Pine Copper Co.	White Pine, Mich.	White Pine, Mich.	Copper Range Sales Co.
Copper Range Co.	White Pine, Mich.	White Pine, Mich.	Copper Range Sales Co.
Asarco	Own plants.	Own refineries.	Asarco
Duval Corporation	Asarco, Tacoma, Washington, Hayden, Ariz., and El Paso Tex.	Asarco, Perth, Amboy, N. J., Tacoma, Washington Baltimore, Md.	Asarco, Duval Sales Corp
Cyprus Pima Mining Co.	Phelps Dodge Corp., Magma Copper, San Manuel, Ariz.	Phelps Dodge at Laurel Hill, N. Y. Magma Copper, San Manuel, Arizona	Ametalco, Inc.
Cyprus Bagdad Copper Corp.	Phelps Dodge, Ariz., Copper Range, White Pine, Michigan	Phelps Dodge, Laurel Hill, N.Y.Copper Range, White Pine Michigan	Cyprus Mines Corp. Copper Range Sales C
Cities Service Company			
Miami Operations	Inspiration Sm., Miami, Ariz.	Asarco Refineries and Phelps Dodge at Laurel Hill	Cities Service Company Metal Sales Dept.
Copperhill Operations	Own Plant, Copperhill, Tenn.	Southwire	Cities Service Company Metal Sales Dept.
Quincy Mining Co.	Quincy, Mining Co., Hancock, Mich.	Quincy, Mining Co., Hancock, Mich.	Quincy Mining Co.
Anamax Mining Co., Twin Buttes, Ariz.	Inspiration Consolidated Copper Co., Miami, Ariz. Asarco. Hayden, Ariz.	The Anaconda Co., Perth Amboy N.J. Asarco, Perth Amboy,N.J. U.S. Metals Refining Co. Carteret, N.J.	Anaconda and Amax Copper Inc.

SOURCE: American Bureau of Metal Statistics, Inc. (ABMS), Nonferrous Metal Data, 1974.

Little doubt exists, however, that the copper industry is less vertically-integrated in the fabricating stage than in previous stages (i.e., mining through refining), sufficiently so that a very substantial market for refined copper exists outside of the major producer-captive facility supply channels.

3. Barriers to Entry

Barriers to entry for fully integrated operations in the copper industry appear to be substantial. Perhaps the most persuasive evidence of this lies in the lack of new entry by a major integrated producer during the last three decades.

Barriers to entry for nonintegrated operations at the mining and milling level have been less of a constraint; many smaller independent mining and milling facilities have been operating in the industry for years, supporting themselves through factors such as regional markets, lower processing costs due to richer ore bodies, or the use of regional smelters and refineries owned by the major producers for toll or custom smelting and refining of their output.

However, the significance of entry by smaller mines on primary producer behavior is open to doubt. The output of these individual mines is usually an extremely small part of total supplies, and the life of such mines is frequently short. More importantly, the overall size of the independent mining sector relative to mining production by the primary producers has not significantly increased in the recent past.

In his study Barriers to New Competition, J. S. Bain argued that the major barrier to entry into the copper industry was the high absolute cost of obtaining a sufficiently large ore body, although the existence of scale economies as well as high capital costs were important factors as well.[1]

The importance of ore reserves as a barrier to entry is in part related to the competitive advantage derived from vertically integrated operations. A firm contemplating entry at the smelter and/or refinery stage must find some sources of concentrate supplies. It is unreasonable to suppose that an integrated producer in possession of an ore body will want to foster the growth of a competitor by selling concentrate on a large scale. Therefore, a new entrant must either rely on the purchase of concentrate from a number of independent miners or must bear the costs of discovering new ore reserves of sufficient size to support integrated operations.

Once having discovered new ore reserves, a new entrant would still be faced with extremely high capital costs for development of an integrated mine-through-refinery operation. We estimate that minimum efficient scale for an integrated operation would be an estimated productive capacity of approximately 100,000 short tons of copper (Cu content) on an annual basis. Assuming an estimated capital cost of $5,000 per annual short ton of capacity (in constant 1974 dollars)

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[1]See J. S. Bain, Barriers to New Competition (Cambridge, Massachusetts: Harvard University Press, 1956) and O. C. Herfindahl, Copper Costs and Prices: 1870-1957, Published for Resources for the Future, (Baltimore: John Hopkins Press, 1959).

to develop an integrated operation, the total minimum capital cost of an integrated operation would be in the neighborhood of $500 million. Projects of this magnitude almost certainly will be undertaken only by large, well-established firms, or jointly by a group of firms.

F. COSTS OF PRODUCTION

1. Primary Producer Costs

The primary producers are faced with two kinds of costs--variable and fixed costs--at each of the four stages of processing of primary metal--mining, milling, smelting, and refining. In some cases, cost categories as viewed by copper industry management may not necessarily reflect the economists' definition of fixed and variable costs; however, considering such cost categories in these terms will prove important for later analysis of the manner in which production costs and shifts in such costs due to costs of compliance with EPA regulations influence the pricing behavior of the primary producers.

Five relevant categories of annual operating costs or variable costs can be identified: materials; energy and fuels; operating supplies; plant maintenance; and part of sales, administration and overhead.

Fixed costs are defined to include the following: general administration costs (some portion); exploration and research costs; interest expense; property taxes and insurance; depreciation; income taxes; net income (i.e., a desired rate of after-tax return on assets). The first four capital charges are real costs borne by each producer. Costs of depreciation do not represent actual costs, that is, they are not cash charges, but rather are balance sheet items reflecting a cash flow. Net income is treated as a fixed cost by the producers in pricing decisions (i.e., they must insure they receive an increment to revenue at least equal to the opportunity cost of their invested capital).

2. Past Trends in Primary Producer Costs

Accurate estimation of production costs for copper in the United States is a difficult undertaking, both because of the variations in actual costs facing individual producers and because individual producers do not normally disclose detailed cost-of-production data.

However, there is general agreement that:

- Costs of mining and concentrating have traditionally formed, by far, the largest proportion of total production costs of refined copper. Smelting and refining costs have represented only a small proportion of the total cost, with smelters and refineries functioning mainly as "service" operations on fixed and relatively low profit margins.
- Overall, real costs of refined copper production appear to have remained stable or to have increased only gradually during the 1950's and 1960's. There is evidence, however, that real costs have begun to rise sharply in the last few years.
- Labor productivity growth, on the other hand, stagnated through the 1950's and 1960's and productivity has actually registered a slight decline since 1971 in the face of continued degradation of average ore grades being mined in the U.S. The industry, in effect, may have come close to exhausting possible productivity gains from existing technology.

Orris C. Herfindahl in the late 1950's advanced the hypothesis that the long-run price of copper tends to equal the long-run economic cost of copper or the price sufficient to induce continued investment at all stages of production, from exploration to refining.[1] According to Herfindahl's estimates, the long-run economic cost of producing copper in the United States was fairly stable at 25-30 cents per pound between the early 1920's and 1957. Herfindahl argued that copper producers, through technological change, were able to keep pace with real increases in factor costs during this period.

Over the period 1957-1968, as pointed out in a paper by Raymond Mikesell,[2] the deflated average U.S. producers price for refined copper remained reasonably close to the upper range of Herfindahl's estimated long-run cost of copper. After 1968, however, the average producers price in real terms, climbed substantially higher.

Productivity growth in the copper industry, on the other hand, has been relatively stagnant since the early 1960's, with productivity gains lagging behind those experienced by other U.S. industries. Table 13 indicates that output per man-hour at the mining and milling stage rose only slightly between 1963 and 1971 and registered a slight absolute decline in the period after 1971.

The combination of a long-term trend towards escalation in the producers price (in real terms) and stagnant or negative productivity growth suggests that the long-run real economic cost of producing copper has been rising in recent years. In economic terms, producers appear to have begun operating on the sharply rising portion of the industry's long-run average total cost curve, whereas previously they were operating on the relatively flat portion of the curve.

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[1] Orris C. Herfindah, Copper Costs and Prices: 1870-1957, published for Resources for the Future (Baltimore: The Johns Hopkins Press, 1959).

[2] Raymond F. Mikesell, "A Note on Orris Herfindahl's Hypotheses Regarding the Long-Run Price of Copper from the Vantage Point of 1975", unpublished draft paper, (November 7, 1975).

TABLE 13

INDEX OF OUTPUT PER MAN-HOUR SERIES FOR PRODUCTION OR NONSUPERVISORY WORKERS, SIC 1021 (COPPER MINING AND MILLING), 1963-1975
(1967=1.000)

Year	Average employment[a] (thousands)	Average weekly hours[a]	Total average annual man-hours (millions)	Index of man-hours (1967=1.000)	U.S. domestic mine production of recoverable copper[d] (thousands of short tons)	Output index (1967=100.0)	Index of output per man-hour (1967=1.000)
1963	22.7	43.1	50.875	1.291	1213.166	1.272	0.985
1964	22.1	42.9	49.301	1.251	1246.780	1.307	1.045
1965	24.7	43.4	55.743	1.415	1351.734	1.417	1.001
1966	26.2	43.5	59.264	1.504	1429.152	1.498	0.996
1967	19.1	43.0	39.394[c]	1.000	954.064	1.000	1.000
1968	21.3	47.0	48.053[c]	1.220	1204.621	1.263	1.035
1969	26.9	46.3	64.764	1.644	1544.579	1.619	0.985
1970	29.3	44.7	68.105	1.729	1719.657	1.802	1.042
1971	26.8[b]	42.9	59.785	1.518	1522.183	1.595	1.051
1972	30.7[b]	41.6[b]	66.410	1.686	1664.840	1.745	1.035
1973	33.7[b]	42.3[b]	74.126	1.882	1717.940	1.801	0.957
1974	33.8[b]	41.1[b]	72.237	1.834	1593.590[e]	1.670	0.911
1975	28.4[b]	39.2[b]	57.891	1.470	1410.989[e]	1.479	1.000

NOTES AND SOURCES:

[a]U.S. Department of Labor, Bureau of Labor Statistics (BLS), Employment and Earnings, United States, 1909-72, Bulletin No. 1312-9, pp. 10, 11 (for years 1963-1970 only).

[b]BLS, Employment and Earnings:
1971: Vol. 18, No. 9 (March, 1972), pp. 50, 81.
1972: Vol. 19, No. 9 (March, 1973), pp. 50, 81.
1973: Vol. 20, No. 9 (March, 1974), pp. 54, 85.
1974: Vol. 21, No. 9 (March, 1975), pp. 52, 85.
1975: Vol. 22, No. 9 (March, 1976), pp. 56, 89.

[c] To avoid errors due to prolonged strikes in these two years, total annual average man-hours have been computed on a monthly basis before summing up to obtain the annual total.

[d] Data refer to mine production of recoverable copper (copper content) in the form of blister. Source (1963-1973): Copper Development Association, Inc. (CDA), Copper Supply and Consumption, 1955-1974 (New York: CDA, 1975), pp. 8, 9.

[e] 1974: U.S. Bureau of Mines, Mineral Industry Surveys, Copper in 1974 (April 8, 1975), p. 3. 1975: Ibid., Copper in 1975 (March 26, 1976), p. 3.

[f] The indexes of output per man-hour are computed by dividing the output index by the index of total average annual man-hours.

Other evidence exists suggesting a rise in real factor costs in recent years. First, average smelter and refinery charges in the copper industry have escalated dramatically. In the 1960's, the traditional rule of thumb in determining concentrate value was to assume about 9 cents per pound for smelting and refining charges. By 1973, average smelter and refinery charges in the U.S. had risen to nearly 12 cents, and in the ensuing two years the average figure increased to more than 20 cents per pound. This was an increase well in excess of the general rate of inflation in the economy during the 1973-1975 period. Second, as shown in Table 14, the costs of purchased energy in the copper industry have increased substantially faster than the general rate of inflation since 1973.

The industry's productivity problem lies in the lack of development of radically new technologies to take the place of conventional mining practices associated with open-pit mines. The average copper content of the ore mined in the United States declined from about .85 percent in 1957 to .55 percent in 1972.[1] Conventional stripping technology has been unable to offset the increased cost associated with mining lower grade ores.

Several new approaches may be utilized in the future to overcome some of the potential constraints on growth of productivity in the industry. First, newly-developed pit slope engineering techniques may be employed to steepen slopes and thereby decrease stripping ratios, as well as to increase the amount of ore in a given mine which is economically recoverable. In addition, the same design concepts associated with steepening slopes can be utilized for predictable controlled

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[1] Raymond Mikesell, "A Note on Orris Herfindahl's Hypothesis Regarding the Long-Run Price of Copper from the Vantage Point of 1975," unpublished draft paper (November, 1975).

TABLE 14

WHOLESALE PRICE INDEX SERIES FOR MAJOR COMPONENTS OF OPERATING AND MAINTENANCE COSTS, U.S. COPPER INDUSTRY (SIC 1021-COPPER ORES AND SIC 3331-PRIMARY COPPER), 1963-1975

Years	Materials and components, parts, containers and supplies (excl. energy)[a]		Purchased electric power[c]		Purchased fuels[f]	
	(1967=100.0)	(1974=100.0)[b]	(1967=100.0)	(1974=100.0)[b]	(1967=100.0)	(1974=100.0)[b]
1963	94.3	61.2	101.3	62.1	96.1	52.0
1964	94.8	61.5	100.4	61.6	93.8	50.7
1965	96.3	62.5	100.1	61.4	95.6	51.7
1966	99.1	64.3	99.6	61.1	99.6	53.9
1967	100.0	64.9	100.0	61.3	100.0	54.1
1968	102.6	66.6	100.9	61.9	98.6	53.3
1969	106.3	69.0	101.8	62.4	100.1	54.1
1970	110.2	71.5	104.8	64.3	104.3	56.4
1971	113.8	73.8	113.6	69.7	110.0	59.5
1972	117.9	76.5	121.5	74.5	112.7	61.0
1973	129.2	83.8	129.3	79.3	125.6	67.9
1974	154.1[d]	100.0	163.1[d]	100.0	184.9	100.0
1975[d]	171.1[e]	111.0	176.5[e]	108.2	225.9	122.2

NOTES AND SOURCES:

[a]Wholesale price index (WPI) for total manufactured goods.

[b]The base year is shifted from 1967 to 1974, by dividing the series by the 1974 index.

[c]WPI 054-Electric power.

[d]U.S. Department of Labor, Bureau of Labor Statistics, Monthly Labor Review (January, 1976), various tables.

[e]U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Prices and Price Indexes for January through December; average of data for January through December.

[f]WPI 05 (Fuels and related products and power) minus WPI 054 (Electric power) minus WPI 0561 (Crude petroleum). This measurement provides a broad coverage of various types of fuel used by the copper industry, in mining through refining (i.e., included, among others, are natural gas, distillate, and residual fuels).

We have computed this price index series as follows:

Let $\overline{\Delta P} = \Delta P_1 W_1 + \Delta P_2 W_2 + \Delta P_3 W_3$

where

$\overline{\Delta P}$: change in WPI 05 (Fuels and related products and power) between 1967 (1967=100.00) and a given year;

ΔP_1 : change in WPI 054 (Electric power) between 1967 and a given year;

ΔP_2 : change in WPI 0561 (Crude petroleum) between 1967 and a given year;

ΔP_3 : change in "rest of WPI 05" (i.e., WPI 05 minus WPI 054 minus WPI 0561) between 1967 and a given year;

W_1, W_2, W_3 : weights in WPI 05 associated with P_1, P_2 and P_3, respectively; $\sum_{i=1}^{3} W_i = 1.0$

We can solve for $P_3 W_3$ as follows:

$$\Delta P_3 W_3 = \overline{\Delta P} - \Delta P_1 W_1 - \Delta P_2 W_2$$

where $\overline{\Delta P}$, ΔP_1 and ΔP_2 can be computed from the following series on $\overline{P}$, P_1 and P_2:

Years	$\overline{P}$	P_1	P_2
1963	96.3	101.3	98.7
1964	93.7	100.4	98.3
1965	95.5	100.1	98.2
1966	97.8	99.6	98.9
1967	100.0	100.0	100.0
1968	98.9	100.9	100.8
1969	100.9	101.8	105.2
1970	105.9	104.8	106.1
1971	114.2	113.6	113.2
1972	118.6	121.5	113.8
1973	134.3	129.3	126.0
1974	208.3	163.1	211.8
1975	245.1	176.5	245.7

SOURCES:

1963-1973: U.S. Department of Labor, Bureau of Labor Statistics, Handbook of Labor Statistics 1974, Table 129;

1974: U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Prices and Price Indexes, Supplement 1975 (September, 1975), Table 5;

1975: U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Prices and Price Indexes, monthly January through December, 1975, Tables 6.

The weights W_1, W_2 and W_3 are computed as follows:

$$W_1 = 1.728/7.697 = 0.2245$$

$$W_2 = 0.635/7.697 = 0.825$$

$$W_3 = 1.000 - 0.2245 - 0.825 = 0.6930$$

where

1.728 is the weight in the total WPI associated with WPI 054 (Electric power);

0.635 is the weight in the total WPI associated with WPI 0561 (Crude petroleum); and,

7.697 is the overall weight in the total WPI associated with WPI 05 (fuels and related products and power).

SOURCE:

U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Prices and Price Indexes, Supplement 1975 (September, 1975), Table 4.

caving of slopes as an alternative to drilling and blasting under some conditions. Finally, the development of self-propelled crushers and belt-conveyors would eliminate the need for use of trucks in hauling ore and overburden. All of these techniques, however, require substantial, and initially expensive, alterations in traditional mining practices and are unlikely to be adopted in the near future by the industry.

3. ADL Estimates of Primary Producer Costs

As described in greater detail in the Technical Appendix to this report, ADL has made engineering and financial cost estimates of historical and future average variable and fixed costs borne by the primary producers, as part of the construction of an econometric simulation model of the U.S. copper industry to assess the future impacts of environmental regulations and associated compliance costs on the industry.[1]

As suggested earlier in the chapter, variable costs represent costs incurred for inputs which can be varied in the short-term by changing the firm's output; they increase as the firm's output increases, since larger output normally requires increased variable inputs such as labor, raw and intermediate goods, energy, etc.

Fixed costs, on the other hand, represent total obligations over a given unit of time (e.g., year) incurred by a firm for fixed capital inputs which are independent of the level of output. A firm's fixed capital includes plant equipment, and associated depreciation of buildings and equipment, property taxes, rental payments, capitalized maintenance costs, and part of general administration.

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[1]For a number of reasons discussed in the Technical Appendix, our exploratory attempts at an econometric analysis of cost functions facing the primary producers convinced us to use engineering and financial cost estimates.

In making our cost estimates, we have assumed constant returns to scale when firms are operating at between roughly 45-86 percent of installed capacity; beyond this region, diminishing returns to scale are assumed to set in. In other words, in the 45-86 percent range, average variable costs are equal to marginal costs; beyond 86 percent of capacity the average variable and marginal cost schedules (functions) not only rise sharply but also, of course, diverge.[1]

Our estimate of the average variable costs for producing refined copper (over all four stages of production) for the primary producers in 1974 was 43¢ per pound, representing the weighted average of company-specific production cost data for eleven major producers (including both integrated and non-integrated companies.[2]

Where production cost data were not available directly from companies themselves, estimates of average variable costs were made by taking into account differential ore grades, stripping ratios, recovery rates and mining technology. Since smelting and refining processes involve quite

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[1] Refer to the Technical Appendix for more detail.

[2] Based on production cost data for Kennecott, Phelps Dodge, Newmont, Duval, Cyprus Bagdad, Amax, Asarco, Copper Range, Inspiration, Cities Service and Anaconda. The data refer to production costs before credits for by-products (e.g., gold, silver, molybdenum; credits for gold in 1974 have been estimated at about 2.5¢/lb.; total credits in 1974 for all three major by-product metals have been estimated at about 4¢/lb.).

This approach would tend to slightly overstate the average variable costs facing the primary producers in 1974. However, it does make an implicit allowance for ore grade degradation over time. Also as a basis for econometric simulation of future market and investment activity in the industry, the exclusion of by-product credits avoids the assumption that in the future (a) the prices of the by-product metals will remain constant at their 1974 levels(which is not really desirable) or that (b) the prices of the by-product metals will grow at certain rates (which introduces new and unnecessary complications and sources of error in the analysis).

standard technologies with known input requirements, the cost differentials observed were generally reflective of different ore grades and mining costs among the different companies.

Our estimate of the average fixed costs for the primary producers (over all four stages of production) for 1974 was about 29¢ per pound. This figure, if anything, errs on the high side, by one or two cents per pound; it was obtained by cross-checking from a number of different sources historically observed average fixed cost figures for the primary producers.

Fixed costs facing the primary producers in any given year in the future have been estimated by separating out fixed costs due to all sunk costs prior to 1974, new productive investments (both expansion and replacement) over the 1974-1985 period and new pollution abatement investments over the period 1974-1985. This is necessary because total fixed costs will increase as new investment is undertaken in the future; the increase in total fixed costs will correspondingly cause an increase in average fixed costs.

In summary, average total costs for the primary producers in 1974 were estimated at 72¢ per pound.[1] Costs of new capacity expansion have been estimated at $5,000 per annual short ton (in constant 1974 dollars), $1,600 per annual short ton of smelting and refining capacity and $3400 per annual short ton of mining and milling capacity.

[1] Corresponds to the minimum point on the industry's average total cost (ATC) function, at roughly 86 percent of installed productive capacity.

CHAPTER 5

THE DYNAMICS OF DEMAND FOR COPPER

A. INTRODUCTION AND SUMMARY

While the discussion in Chapter 4 concentrated on industry structure and patterns of supply in the domestic copper industry, in this chapter the focus is on patterns of copper consumption and the dynamics of demand for refined copper. We first define explicitly both the relevant market for refined copper and the concept of market demand used in this analysis. Next, we review past patterns of consumption among domestic semifabricators and fabricators. We then discuss the various factors affecting demand levels over the period under analysis, with reference to an econometric analysis of demand for refined copper. Finally, based on econometric analysis, we present some estimates as to the relative sensitivity of demand to changes in various price and income variables identified as having a causal influence on quantities demanded.

Two appendices accompany this chapter. Appendix A presents a review of trends in long-run substitution for copper (primarily from aluminum). Appendix B provides tabulations on interindustrial relationships of copper.

The principal conclusions emerging from this chapter can be summarized as follows:

1. For purposes of analyzing market demand, it is generally accurate to think in terms of a unified market for refined copper, copper scrap, and copper alloy ingot. This is because each type of scrap or alloy ingot can be processed into unalloyed refined copper at a relatively small cost.

2. By accounting definition, total output of refined copper and its equivalent (e.g., unrefined scrap or copper alloy ingot must equal total uses in a given year. The principal categories of use for refined copper and its equivalent are: (1) consumption by semifabricators; (2) net additions to inventories; (3) net exports. Net additions to inventories can be further broken down among various types of users (e.g., stock changes of primary refiners, stock changes of secondary refiners, changes in Federal Government stockpiles, and stock changes of semifabricators).

3. The uses of copper and the demand for copper are not definitionally identical. While "uses" refers to the disposition of copper on hand, demand is an economic concept which refers to the quantities the buyers are willing to purchase at different prices, everything else remaining constant. Demand may be defined to include different use components; however, because we are concerned principally with the dynamics of demand on the part of domestic semifabricators, we have simply defined semifabricated demand to include both semifabricators' consumption and net additions to semifabricators' inventories. The resulting demand series represents the amount of refined copper and its equivalent actually demanded in the market by semifabricators during a given year.

4. Demand for refined copper equivalent is a derived rather than final demand. Semifabricators demand refined copper equivalent not for purposes of final consumption, but for use in the production of semifabricated products which are, in turn, demanded by fabricators and end-users as intermediate inputs in the production of final consumer or producers' goods. Semifabricators' demand for refined copper equivalent is thus derived from the

demand of fabricators which in turn is derived from demand for final products (consumer goods, investment goods--including construction).

5. Among semifabricating industries in 1974, wire mills, which use only refined copper, consumed about 47 percent of total supplies of refined copper equivalent. Brass mills, which consume refined copper and scrap in fairly equal proportions, accounted for about 39 percent of total consumption. Ingot makers, who use almost entirely scrap, were the third largest consumers at seven percent. Foundries, consuming predominantly scrap, used about four percent, with powder plants and "other industries" accounting for the remainder.

The major industries consuming semifabricated goods are (in order of importance): electrical and electronics products; building construction; consumer and general products; industrial machinery and equipment; transportation; ordnance and accessories.

6. The demand for refined copper equivalent is determined by at least three principal factors: general levels of macroeconomic activity; the prices of refined copper equivalent; and the prices of potential substitute goods for refined copper, such as aluminum and plastics, relative to the price of refined copper.

Substitution of aluminum or another material for copper can occur in either the short-run or the long-run. Substitution in the short-run involves no major alterations in fixed plant and equipment or changes in producer design. For the most part, this type of substitution is limited to residential and nonresidential construction. In most cases, the capital fixity of plant and equipment will limit possibilities for substitution in the short-run.

As a result, substitution will only occur mostly over the longer-run when the relative price of a substitute material becomes low enough to justify the capital costs of altering plant and equipment. Consequently, we would expect the long-run own-price and cross-price elasticities to be greater than the short-run price elasticities.

Among long-run substitute materials, it is generally agreed that aluminum has been the most serious competitor to copper, having made the most serious inroads in electrical conductor and heat-exchanger applications. The most important potential instances of long-run substitution are in telephone conductor cable and automobile radiators.

7. Most of the available empirical econometric studies of demand for copper indicate substantial short-run inelasticity (or insensitivity) with respect to price and activity levels. The long-run elasticity estimates are all greater than the short-run elasticities.

Among the various price and income variables affecting quantities demanded, our own econometric analysis indicates that a 1.0 percent increase in the price of copper will lower demand of refined copper equivalent by .47 percent in the short-run and .64 percent in the long-run. Furthermore, a 1.0 percent decrease in the market price of aluminum will stimulate substitution to aluminum, leading to a corresponding decrease in demand for refined copper equivalent of .61 percent in the short-run and .84 percent in the long-run.

We also estimate that a 1.0 percent increase in the production of durable manufactured goods will generate a 1.3 percent increase in refined copper demand in the short-run and a 1.8 percent increase in the long-run.

B. CONSUMPTION PATTERNS AND DYNAMICS OF DEMAND

1. Definition of the Market for Copper

For purposes of analyzing market demand, it is generally accurate to think in terms of a unified market for refined copper, copper scrap, and copper alloy ingot.

As noted at the beginning of Chapter 4, except for wire mills, semifabricators and fabricators use not only refined copper but also various types of scrap and copper alloy ingot in their operations. While there are significant physical differences among these products, and the various types of copper cannot be regarded as perfect substitutes, each type of scrap or alloy ingot can be processed into unalloyed refined copper at a relatively small cost. Therefore, typically the difference between refined copper prices and prices of various types of scrap and copper alloy ingot would be roughly indicative of the added costs to the user of substituting the latter form of copper for the former. Since there are buyers for all possible combinations of products, arbitrage can be fully effective, especially since copper merchants stand ready to trade in virtually all types of copper.

2. Uses of Copper Versus the Demand for Copper

The principal use categories for refined copper and refined copper equivalent (e.g., unrefined scrap or copper alloy ingot) are:

- consumption by semifabricators;
- net additions to inventories;
- net exports.

The category of net inventory additions can be further subdivided into: (a) stock changes of primary refiners; (b) stock changes of secondary refiners; (c) changes in Federal Government stockpiles, and (d) stock changes of semifabricators.

By definition, the total amount of copper supplied by the primary producers, secondary refiners, and scrap suppliers in any year must equal total uses of copper for that year.

The "materials balancing" identity or accounting equation can be represented as follows:

$$QPR + QSR + QSNR = QC + NE + \Delta IGOV + \Delta IF + \Delta IRR + \Delta IRS$$

where QPR represents the quantity of primary refined copper produced, QSR is the quantity of secondary refined copper produced from scrap, and QSNR represents the quantity of unrefined scrap supplied (and used directly); QC is consumption by semifabricators; NE is net exports; ΔIGOV is the change in government stockpiles; ΔIF is the change in semifabricator inventories; ΔIRR represents the change in inventories of primary refiners; and ΔIRS is the change in inventories of secondary refiners.

Table 1 indicates the relative importance of alternative uses of refined copper or refined copper equivalent for selected years from 1954 through

TABLE 1

DISPOSITION OF COPPER SUPPLIES IN THE UNITED STATES FOR SELECTED YEARS BETWEEN 1954-1974
(Thousands of Short Tons of Cu Content)

	1954	1960	1965	1966	1967	1970	1971	1972	1973	1974[a]
Semifabricators Consumption (QC) Reported	1,916.5	2,079.3	2,995.4	3,368.6	3,164.2	2,930.5	2,956.0	3,266.3	3,481.7	3,106.2
(+) Net Additions to:										
o Semifabricators Inventories of Refined and Scrap Ingot (ΔIF)	- 26.0	8.0	9.0	63.0	10.0	64.0	-13.0	-62.0	0.0	75.0
o Refinery Stocks of Refined Copper (ΔIRR)	- 40.6	74.5	15.2	4.9	- 10.7	114.7	- 57.6	54.4	-108.3	145.8
o Refinery Stocks of Scrap (ΔIRS)	- 25.0	- 9.0	- 4 0	3.0	15.0	11.0	- 17.0	-5.0	-4.0	1.0
o Government Stockpiles (ΔIGOV)	199.3	6.0	-122.5	-445.0	- 8.0	0.0	- 1.8	0.0	-33.8	- 182.5
(+) Net Exports of Refined Copper and Scrap (NE)	124.7	438.0	256.1	135.1	130.7	168.9	74.4	29.5	72.6	-108.5
(+) Inventory Accounting Adjustment	11 5	29.4	17.2	- 66.8	- 3.4	- 67.9	- 6.7	37.6	23.9	124.6
= Total Supplies of Primary and Secondary Refined Copper and Scrap (QPR + QSR + QSNR)	2,160.4	2,626.2	3,166.4	3,196.4	3,297.8	3,221.2	2,934 3	3,320.7	3,432.1	3,161.6

NOTES: [a]Preliminary.

SOURCE: Copper Development Association, Copper Supply and Consumption, Annual Data, 1973, 1975.

1974.[1,2] Clearly, consumption by semifabricators dominates among uses of refined copper equivalent. Inventory changes at the semifabricator level have represented only a marginal proportion of total uses. Although in some years net exports and changes in primary producer inventories and government stockpiles have represented a somewhat larger proportion of total uses, their net impact on total quantities demanded has been marginal.

The uses of copper and the demand for copper are not definitionally identical. The term "uses" refers to the disposition of copper on hand into various categories such as consumption, inventory accumulation, etc. Demand, on the other hand, is an economic concept which refers to the quantities the buyers are willing to purchase at different prices, everything else remaining constant.

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[1] U.S. copper production and consumption data developed by the U.S. Bureau of Mines and U.S. Bureau of Domestic Commerce of the Commerce Department inevitably involve inconsistencies due to differences in reporting coverage, etc. In order to reconcile these inconsistencies and obtain a consistent accounting flow of copper from production through consumption, the Copper Development Association adjusts inventory data developed by the Bureau of Domestic Commerce. For purposes of our overall materials balancing equation, we have used the adjusted "apparent change" inventory figures of the Copper Development Association; but in analyzing individual inventory components, we have preferred to use the original U.S. Government data.

[2] It is impossible to obtain an entirely accurate breakdown on inventories of primary and secondary refineries as we have defined them. U.S. Department of Commerce data on refinery stocks of refined copper and scrap reproduced by the Copper Development Association have been used as proxies for stocks held by primary and secondary refiners. Because of the reporting coverage of the Commerce Department's Bureau of Domestic Commerce, some refined copper stocks which we have attributed to the primary producers might logically be attributed to secondary refinery inventories, while some scrap stocks which we have attributed to the secondary refiners might actually be associated with primary refinery inventories. However, these redistributed quantities would without doubt be marginal and use of the Bureau of Domestic Commerce data does not seriously affect the reliability of modeling results obtained.

Data on copper flows are usually collected in terms of production, consumption, and inventories. Therefore, demand must be estimated from these figures, by adjusting either overall production or consumption figures for changes in inventories and/or net exports. How this is precisely accomplished depends on one's analytical objectives. From a theoretical point of view, the choice of approach might be important, but for the objectives of this study, this becomes relatively inconsequential.

When demand is defined as the demand of domestic semifabricators (definition 1), the relevant figure (QD) can be derived from the consumption side as follows:

$$QD = QC + \Delta IF$$

Demand could also be defined, more broadly, to include net exports and changes in government inventories (definition 2):

$$QD^* = QC + \Delta IF + NE + \Delta IGOV$$

These two additional components, when positive, clearly represent additional demand for domestic supplies of refined copper equivalent.

The net result of adjusting semifabricator consumption figures for net exports and government stockpile changes, as well as semifabricators inventory changes, will be as follows: $QD^* > QD$ in years when net exports and government stockpile changes are positive and $QD > QD^*$ when net exports and government inventory changes are negative.

Because we are concerned principally with the dynamics of demand on the part of domestic semifabricators, we have chosen to focus directly on the demand for refined copper equivalent on the part of domestic semifabricators. Aggregate demand figures for the domestic semifabricators

TABLE 2

UNITED STATES SEMIFABRICATOR DEMAND FOR REFINED COPPER AND SCRAP, 1954-1974
(Thousands of Short Tons of Cu Content)

	QC	+	ΔIF	=	QD
1954	1,916.5		-26.0		1,890.5
1955	2,418.7		24.0		2,442.7
1956	2,365.0		7.0		2,372.0
1957	2,106.4		- 2.0		2,104.4
1958	1,974.6		4.0		1,978.6
1959	2,318.6		-39.0		2,279.6
1960	2,079.3		8.0		2,087.3
1961	2,170.0		4.0		2,174.0
1962	2,361.1		5.0		2,366.1
1963	2,565.7		- 8.0		2,557.7
1964	2,775.0		10.0		2,785.0
1965	2,995.4		9.0		3,004.4
1966	3,368.6		63.0		3,431.6
1967	2,850.4		-49.0		2,801.4
1968	2,813.5		-14.0		2,799.5
1969	3,164.2		10.0		3,174.2
1970	2,930.5		64.0		2,994.5
1971	2,956.0		-13.0		2,943.0
1972	3,266.2		-62.0		3,204.2
1973	3,481.7		0.0		3,481.7
1974[a]	3,106.2		75.0		3,181.2

NOTES: [a]Preliminary.

SOURCE: Copper Development Association, Copper Supply and Consumption, Annual Data, 1973, 1975.

industries under definition 1 are presented in Table 2.

3. Patterns of Consumption and Demand Among Domestic Semifabricators and Fabricators

Demand for commodities can be classed broadly into two categories: (1) demand for finished products (i.e., consumer goods); and (2) derived demand for intermediate goods used in the production of finished goods. The demand for refined copper and its equivalent is such a derived demand.

The right side of Figure 1 in Chapter 4 graphically illustrates the fact that semifabricating industries demand refined copper and its equivalent not for final consumption, but as intermediate inputs in the production of semifabricated products. The demand for semifabricated products on the part of fabricators and end-use industries is, in turn, a derived demand, derived from the demand for final goods being produced by fabricators and end-use industries.

While we focus, in the remainder of this chapter, on patterns of consumption and the dynamics of demand for refined copper and its equivalent on the part of semifabricators, it is important to keep in mind the important role played by end-use industry demand for semifabricated products in determining semifabricators' demand for refined copper and scrap.

As indicated briefly at the beginning of Chapter 4, there are six major groups of direct consumers of refined copper and scrap: four copper semifabricating industries--wire mills, brass mills, foundries, and powder mills; ingot makers; and a group of "other" industries such as chemicals, steel, and aluminum.

Ingot makers are, in effect, intermediate processors of refined copper and scrap, producing copper alloy ingot, the bulk of which they sell to

TABLE 3

CONSUMPTION OF COPPER PRODUCTS BY DOMESTIC SEMIFABRICATORS, 1974[a]
(Thousands of Short Tons of Cu Content)

	Refined Copper	Scrap[b]	Total	Percentage of Total
Wire Mills	1,433.4	-	1,433.4	(46.1)
Brass Mills	670.3	563.2	1,233.3	(39.7)
Foundries	28.7	115.4	144.1	(4.6)
Powder Mills	12.0	17.7	29.7	(1.0)
Ingot Makers	4.7	215.0	219.7	(7.1)
Other	2.5	38.5	46.0	(1.5)
Total	2,156.6	949.6	3,106.2	(100.0)

NOTES: [a]Preliminary.
[b]Old and new scrap.

SOURCE: Copper Development Association, Copper Supply and Consumption, Annual Data, 1955-1974.

the other semifabricating industries, principally brass mills and foundries. While ingot makers and other industries are not copper semifabricators as commonly defined, for convenience we shall refer to the aggregate demand schedule of the six consuming groups as the demand for refined copper and its equivalent on the part of semifabricators.

The one characteristic shared by the four semifabricating industries is their use of copper as a basic input. Their production technologies are almost completely different, and their products are not substitutes or complements in any important ways.

Wire mills and brass mills have traditionally been the largest consumers of refined copper and its equivalent accounting for about 86 percent of total consumption in 1974 (refer to Table 3). Wire mills, which use only refined copper, consumed about 47 percent, with brass mills, which consume refined copper and scrap in fairly equal proportions, accounting for about 39 percent. Ingot makers, who used almost entirely scrap, were the third largest consumers at seven percent. Foundries, which consume predominantly scrap, used about four percent of total supplies, with powder plants and "other industries" accounting for the remainder.

Over the last two decades, brass mills have generally accounted for 39-42 percent of total consumption; wire mills, on the other hand, have gradually increased their proportion of total consumption from 37 percent in 1956 to the above-mentioned 47 percent. The proportion of total consumption attributable to ingot makers and foundries has declined somewhat over the last two decades.

TABLE 4

PRODUCTION OF FABRICATED COPPER PRODUCTS, 1966, 1970, 1974
(Thousands of Short Tons)

	1966		1970		1974[a]	
	Metal Content	Percent of Total	Metal Content	Percent of Total	Metal Content	Percent of Total
Wire Mill Products						
Bare Wire	134.5	3.9	113.0	4.0	109.5	3.5
Insulated Communication	323.0	9.4	350.0	12.4	383.0	12.4
Other Insulated	789.5	22.9	701.5	24.9	830.5	26.8
Total	1,247.0	36.2	1,164.5	41.3	1,323.0	42.7
Brass Mill Products						
Sheet	656.5	19.0	441.5	15.7	530.0	17.1
Rod and Mechanical Wire	521.0	15.1	402.0	14.3	493.5	15.9
Plumbing Tube	236.5	6.9	189.0	6.7	176.0	5.7
Commercial Tube	249.0	7.2	224.0	7.9	207.5	6.7
Total	1,663.0	48.2	1,256.5	44.6	1,407.0	45.4
Foundry Products						
Sand Castings	428.0	12.4	310.0	11.0	282.5	9.1
Permanent Mold	23.0	0.7	24.5	.9	12.5	.4
Die Castings	15.0	0.4	11.0	.4	9.0	.3
Other	37.0	1.1	30.0	1.0	28.5	.9
Total	503.0	14.6	375.5	13.3	332.5	10.7
Powder Products						
Granular	30.0		21.5	.7	31.5	1.0
Flake	3.5		2.0	.1	3.0	.1
Total	33.5	1.0	23.5	.8	34.5	1.1
Grand Total	3,446.5	100.0	2,820.0	100.0	3,097.0	100.0

NOTES: [a]Preliminary.

SOURCE: Copper Development Association, Copper Supply and Consumption, 1955-1974.

TABLE 5

U S COPPER CONSUMPTION BY BROAD END-USE CATEGORIES, 1960-1974
(Thousands of Short Tons)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974[a]
Building Construction	478.5	539.5	623.0	648.0	750.5	779.5	780.0	647.5	637.5	711.0	632.0	696.0	749.5	820.5	626.5
Transportation	293.5	297.0	338.5	352.0	398.0	429.5	452.0	351.0	400.5	414.0	333.5	379.0	411.0	459.0	380.0
Consumer and General Products	342.5	358.5	384.0	397.5	469.0	513.5	741.0	752.5	812.5	784.5	601.5	587.0	664.0	702.0	604.0
Electrical and Electronic Products	619.5	604.5	627.0	673.5	752.5	818.0	947.5	797.0	795.0	899.5	835.0	853.5	979.0	1,118.5	1,017.5
Industrial Machinery and Equipment	452.0	446.5	484.0	506.0	556.0	569.5	634.5	519.0	543.0	529.5	484.0	479.5	554.5	586.0	501.0
TOTAL	2,186.3	2,246.0	2,456.5	2,577.0	2,926.0	3,110.0	3,555.0	3,067.0	3,188.5	3,338.5	2,820.0	2,910.0	3,240.0	3,596.0	3,097.0

PERCENTAGE COMPOSITION

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974[a]
Building Construction	21.9	24.0	25.4	25.1	25.6	25.1	21.9	21.1	20.0	21.3	21.9	23.2	22.3	22.3	20.0
Transportation	13.4	13.2	13.8	13.7	13.6	13.8	12.7	11.4	12.5	12.4	11.6	12.7	12.2	12.5	12.1
Consumer and General Products	15.7	16.0	15.6	15.4	16.0	16.5	20.8	24.5	25.5	23.5	20.8	19.6	19.8	19.1	19.3
Electrical and Electronic Products	28.3	26.9	25.5	26.1	25.7	26.3	26.6	26.0	25.0	26.9	28.9	28.5	29.2	30.3	32.5
Industrial Machinery and Equipment	20.7	19.9	19.7	19.7	19.1	18.3	18.0	16.9	17.0	15.9	16.8	16.0	16.5	15.8	16.1
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

NOTES [a]Preliminary

SOURCE 1969-1974 Copper Development Association, Copper Supply and Consumption, 1955-1974, 1960-1968 Charles River Associates, Inc (CRA), Economic Analysis of the Copper Industry (March, 1970), p 12

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As mentioned above, the demand for semifabricated products is a derived demand; "semis" are used as inputs in the production of durable consumer and investment goods. Table 4 provides a breakdown of the various semifabricated products of the four semifabricating industries and gives production levels for 1966, 1970, and 1974 in terms of metal content. Although total output appears to have declined by 10 percent between 1966 and 1974, fluctuations in intervening years not shown make it difficult to discern any secular declining trend. Production of wire mill products increased in absolute terms and as a percentage of the total. Powder mill output remained fairly stable in both absolute and percentage terms, while total production of brass mill products and foundry products declined. Brass and wire mill products account for approximately 85 percent of total production by metal weight for the entire period.

Table 5 presents data on consumption of copper by end-use industries while Figure 1 charts the growth trends evidenced in that consumption. The end-use (fabricating) industrial categories that predominate in the consumption of semifabricated copper are the following in order of importance:

- Electrical and electronics products;
- Building construction;
- Consumer and general products;
- Industrial machinery and equipment;
- Transportation;
- Ordnances and accessories.

The electrical and electronics products industry group has grown to be the principal consumer of copper accounting for somewhat less than one-third of all annual copper consumption. Building construction continues to be a significant consumer of copper for electrical wiring and pipe. The consumer products industry group grew significantly during the late 1960's; however, its use of copper declined after 1969. While part of this decline reflected macroeconomic slowdown, part of it may have reflected substitution of plastics for copper. The industrial machinery and equipment industry and the transportation industry increased their consumption of copper through 1966; however, by 1970, both industries returned to consumption levels found in 1960.

4. Dynamics of Demand

In Table 2, we presented an aggregate demand series for refined copper and its equivalent on the part of domestic semifabricators between 1954-1974. Economic theory and knowledge of the industry suggests that quantities of refined copper and its equivalent demanded during this period were determined by at least three principal factors:

- General levels of macroeconomic activity;
- The prices of refined copper and its equivalent;
- The prices of potential substitute goods for refined copper, such as aluminum and plastics, relative to the price of refined copper.

Other factors, such as the prices of complementary commodities and factors of production, probably had some influence on quantities of refined copper demanded, but there is little *a priori* evidence to suggest a degree of influence substantial enough to require their inclusion as explanatory variables in an analysis of demand for copper.

For the most part, the economic theory behind these variables acting as demand determinants is straightforward. As economic activity and income increase, greater quantities of producers' durable goods and consumer durables using copper inputs will be demanded; this will, in turn, lead to a greater derived demand for copper on the part of semifabricators. Similarly, as copper prices increase, semifabricators and end-users will react by cutting back their consumption in most instances. When prices decrease, in most instances semifabricators and end-users will demand more.

The manner in which fabricators and end-users react to changes in the relative prices of substitute goods is often more complex, however.

There exist a number of substitutes for copper in its various uses. These substitutes include aluminum, stainless steel, zinc and plastics. Each substitute is a competitor to copper in limited situations. For example, aluminum is a substitute for copper mainly in wire products and electrical machinery, given its similarly high conductivity. For consumer products, plastics are the more important substitutes.

Substitution of aluminum or another material for copper can occur in either the short-run or the long-run. Short-run substitution for copper can take place whenever an alternative material can be used without requiring major alterations in fixed plant and equipment, or changes in product design. The major instances of this sort of substitution are probably to be found in residential and nonresidential construction. For example, the leading substitutes for copper drainage pipe are plastic and cast iron pipe. Copper pipe is preferred on technical grounds, but if the price becomes too high or copper is simply unavailable, contractors can readily use plastic or cast iron. Decisions on what sort of pipe to use are made frequently, so substitution is short-run in the sense of requiring no investment and the effects of a change in price probably occurring rapidly.

Short-run substitution can also take place through variations in the copper content of alloy semifabricated products. That is, a consumer who normally uses semis of pure copper or alloys with a very high copper content might switch to alloys with a lower copper content when prices are high. There are also many ways in which the quantity of copper used per unit of output can be reduced.

While it appears that there can occur, in some instances, a noticeable short-run response to changes in price, in many other situations, the capital fixity of plant and equipment will limit the possibilities for substitution in the short run. While copper and its substitutes may exhibit the same required physical properties in use, the capital in place in the using industry cannot generally be used in processing the substitutes for copper. As a result, substitution for copper will occur only when the relative price of a substitute for copper becomes low enough to justify engineering and tooling costs required to alter the capital equipment of the using sector. The full substitution from copper to a competing commodity will occur only in the long run. In economic terms, the long-run own-price and cross-price elasticities will be greater than the short-run price elasticities.

Technological advances can contribute to long run substitution (LRS) in two ways. On the one hand, fabricators and end-users are responsive to technical as well as economic considerations in choosing to use copper versus a substitute. Thus, LRS may be stimulated by changes in the technical and practical feasibility of substitution (i.e., mechanical and physical properties achieved in using a substitute material, safety, ease of handling and storing, size or weight limitations). Technological developments can also alter the relative price ratios at which substitutes for copper may be economical. For example, developments in the last decade in the use of aluminum telephone cables[1] and automobile radiators[2] made aluminum, in theory at least, a realistic substitute at prevailing relative prices.

Long-run substitution has been a serious concern on the part of the copper industry especially since 1947, when the price of copper went above the price of aluminum for the first time. Although the relative price of copper has fallen sharply on occasion in the past (e.g., during 1957 and again during the last half of 1970), the upward trend was resumed shortly thereafter.

Industry observers are not in complete accord on the prevalence and importance of LRS, and comprehensive and detailed quantitative information is unavailable on the degree to which LRS has actually occurred in the industry during the past thrity years. However, it is generally agreed that aluminum has been the most serious competitor to copper, having made the most serious inroads in electrical conductor and heat-exchanger applications.

The most important potential instances of LRS are in telephone conductor cable and automobile radiators. Conductor cable and automotive radiators account for roughly 25-30 percent of total demand for primary copper in the United States. There is also clearly LRS in the demand for copper electric transmission cable, and the possibility of LRS in the demand for several

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[1] American Metal Market, January 4, 1968, p. 1.

[2] American Metal Market, January 11, 1968, and May 25, 1967; Modern Metals, May, 1966, p. 33.

other markets has been mentioned in the trade press. In general, LRS is present in most of the markets for copper wire, and these constitute 60 percent of the demand for refined copper. More detailed information on LRS in specific cases is provided in Appendix A.

During the last two decades, world market prices for refined copper have often experienced substantial and at times violent fluctuations as noted in the next chapter. Producers in the industry have at times voiced fears that, regardless of the relative price of refined copper, a lack of stability in that price over time would by itself stimulate fabricators and end-users to substitute other materials for copper.

It seems unlikely, however, that price fluctuations alone encourage LRS for copper. Most copper consumers base their purchasing plans not on daily price fluctuations occurring on a free market such as the London Metal Exchange (see Chapter 6), but rather on fluctuations of the monthly or quarterly average price. Short-term fluctuations leading to unusually favorable or unfavorable dates for buying can be expected to cancel each other out in the long run, regardless of the general buying practices of most firms. Thus, expectations of future long-term relative price trends are likely to be the most important determinant of LRS, as part of long-term investment planning on the part of user industries.

C. ECONOMETRIC MODELING OF THE GENERAL DEMAND FOR COPPER

To reiterate, the demand for refined copper and its equivalent can be said to be a function of macroeconomic activity levels (driving the activity levels of the end-user industries), the price of refined copper, and the price of substitute products. In an econometric analysis of demand for copper, these would serve as the independent variables.

Demand equations can be specified showing the relationship between the quantity (of copper) demanded and only one of these variables or between quantity demanded and all of these variables simultaneously. In the former case, for example, the relationship between the total quantity demanded and the unit price for refined copper equivalent--assuming other variables are held constant--can be stated as:

$$Q = F(P)$$

or

$$Q = \alpha_o + \alpha_1 P \qquad (1)$$

This equation can be represented graphically by a demand curve (schedule) which indicates the total quantity of refined copper equivalent demanded by a group of users (in this case domestic semifabricators) for various possible changes in price. Thus, in Figure 1 the demand curve indicates that if everything else is held constant and the price of refined copper is P_1, semifabricators will demand Q_1 units of refined copper equivalent. If the price were to fall to P_2, Q_2 would be demanded.

The other factors affecting the quantity demanded are held constant in order to isolate the relationship and quantity. If these factors were included, the relationship in Figure 1 would be:

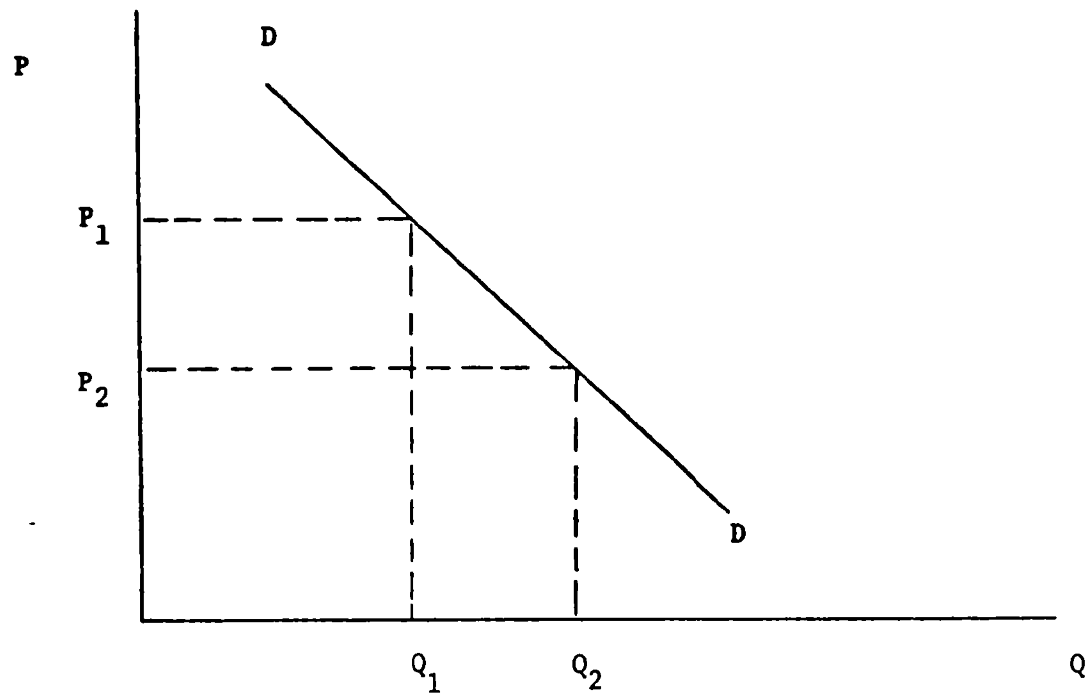

FIGURE 1

$$Q = F(P, P^s, Y) \qquad (2)$$

This equation simply indicates that although price (P) affects the quantity demanded (Q), the quantity demanded is also a function of the prices of substitute commodities (P^s), and the income or activity levels (Y) of the users.

The demand curve suggested by Equation 2 is quite general: it indicates only that the variables are causally related in some way to quantities demanded. In order to introduce greater specificity into the demand equation, it is necessary to look at the production function for semifabricators. This production function is simply a technical relationship indicating the maximum amount of output which can be produced by a producer or industry with each and every set of possible factor inputs (capital, labor, materials). The exact form of the demand schedule for refined copper equivalent, because it is a derived demand, will reflect the relationships expressed in the aggregate production function for semifabricators.[1]

Even given the need to reflect the production function for semifabricators however, the exact form of the equation can still be specified in different ways, each of which involves different assumptions concerning price and income responsive behavior on the part of semifabricators (and, by implication, fabricators and end-users) over time. For example, the demand equation introduced above could be specified in a linear or log-log form.

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[1] Technically speaking, the derived demand schedule will fall out of the first order conditions for cost minimization subject to the production constraint. Derived demand equations are derived for Cobb-Douglas production functions under conditions of perfect and imperfect competition in both factor and product markets. See ADL working paper entitled "Overview of Theoretical and Econometric Foundations of Statistical Cost Analysis" (July 2, 1975).

If a log-log form is used, and the equation is estimated on an annual basis, the nature of the log-log form will cause the estimated price and income elasticities (represented by coefficient estimates associated with each variable) to be constant annually over the entire sample period. This imposed constancy of the elasticity estimates can be undesirable if it is felt that in reality price elasticities change from year to year, given changes in such factors as taste and market conditions. The linear form requires no such assumption, and permits the estimation of differing elasticities as they may change from year to year.

On the other hand, the linear form requires the assumption that, whatever the price level, and absolute increase in price of a certain amount will lead to a corresponding absolute decline in the quantity demanded. Thus, a $1.00 increase in price will lower the quantity demanded bv the same amount whether the initial price is $10 or $100. In reality, one would expect that a $1.00 price increase would lead to a proportionally smaller decline in quantity demanded if the initial price were $100 rather than $10.

The log-log form, on the other hand, allows one to assume that a proportional increase in price from any price level will lead to a corresponding proportional decrease in quantity demanded. In the log-log specification, a $1.00 price increase from a $100 price level would have a proportionally much smaller impact on the quantity demanded than a $1.00 increase from a $10 price level.

Any model of demand applied to a body of data imposes certain structural constraints. If the range of price variation has historically been small, the assumption of a fixed incremental quantity response to an incremental price change (as in the linear form) may not be worrisome. In fact, in such a case, the ability of the linear formulation to estimate differing elasticities over the sample period may be analytically helpful. In light of these considerations, we have chosen to use the linear form of the demand function in our own analysis.[1]

The linear form of Equation 2 can be written as follows:

$$Q = \alpha_0 + \alpha_1 P + \alpha_2 P^s + \alpha_3 Y \qquad (2a)$$

The general demand curve in Equation 2a could be utilized to model the demand for refined copper equivalent for each semifabricating industry (wire mills, brass mills, foundries, powder mills, ingot makers, and other industries) separately or for the group of all semifabricating industries consuming refined copper equivalent. Since a derived demand curve reflects the characteristics of the production function of the consuming industry, a demand curve estimated for the aggregation of the semifabricating industries would reflect an amalgamation of each of the production functions of these industries. If the objective is to estimate the parameters of the individual production functions, such an aggregation would probably generate aggregation errors.[2] However, in order to examine the relationship between aggregate demand for copper and price and activity variables, such a disaggregation is not necessary. Furthermore,

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[1]As discussed in Chapter 6, the Engineering and Mining Journal producers' price series has been used in estimating the demand equations. Changes in the real (i.e., deflated) E/MJ price have been of measurable magnitude. Therefore, the use of the linear form of the demand curve was deemed justified.

[2]See Theil, H., Principles of Econometrics (New York: John Wiley & Sons, 1971), p. 556-573.

attempts in the literature to disaggregate demand analysis to individual semifabricating industries have not proved successful.[1]

One final issue remains: the existence of long-run substitution in demand that characterizes derived demand for copper. The demand equation above represents the short run (in this case, a year). The resultant elasticity coefficients are short-run in nature.

The fact that long-run substitution in demand can require a period of years as changes in capital equipment take place implies that end-users of copper only "partially adjust" to a new copper price level each year. Their equipment will only depreciate so fast each year and because such equipment will not be replaced immediately, the derived demand for copper is more elastic in the short run than in the long run. In the long run, the end-use industries can fully adjust to new factor prices (price changes being assumed once-for-all) through structural and equipment alterations; hence, demand will be more elastic over the long run.

This difference in short-run and long-run elasticities in price responsiveness can be seen graphically in Figure 2. D_L in Figure 2 is the long-run demand schedule of group of copper using industries and D_s is the short-run demand curve. The curves are assumed to be in equilibrium at (Q_1, P_1). If we assume there is a once-for-all price decrease from P_1 to P_2, the long-run desired quantity demanded would be Q_2. However, in the short-run, equipment and structural requirements cannot be altered quickly enough. The copper-using industries would therefore end up operating on a new short-run demand curve $\overline{D}_s$, demanding $\overline{Q}_2$, which represents only partial adjustment

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[1]See Charles River Associates, Inc. (CRA), <u>Economic Analysis of the Copper Industry</u> (March, 1970).

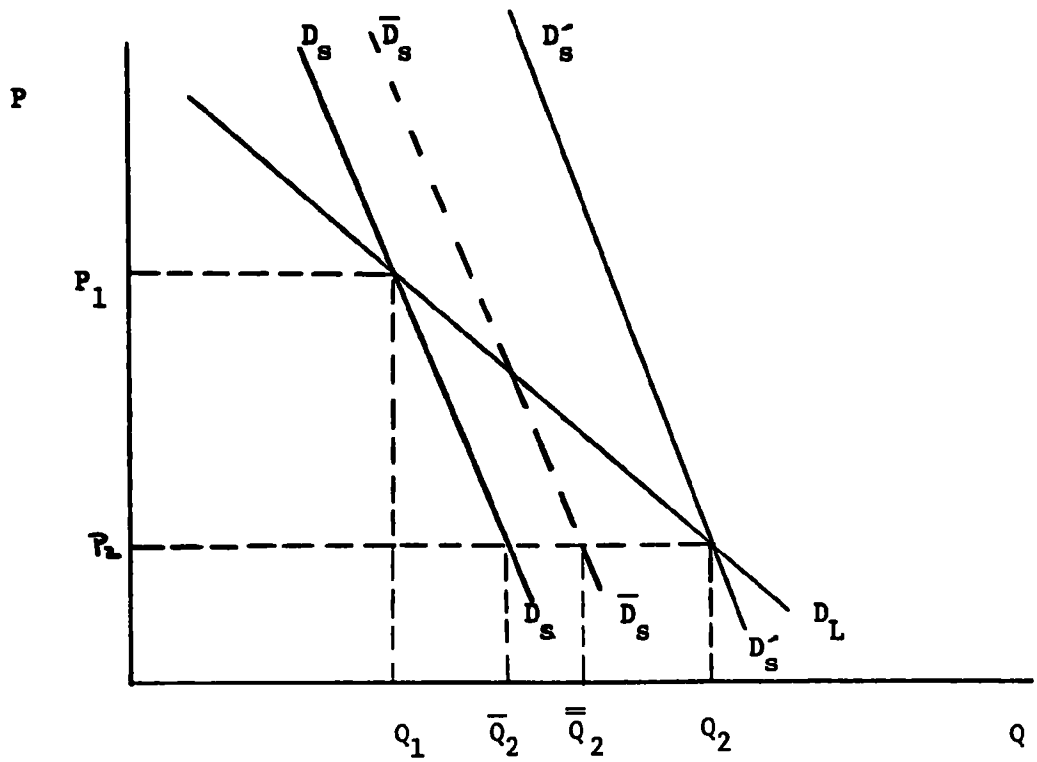

FIGURE 2

to the new price situation.

Eventually, as the copper-using industries continue to adjust by altering plant and equipment, their short-run demand schedule will move outward from $\overline{D}_s$ until it reaches a new short-run demand curve D'_s. Equilibrium is again achieved at (Q_2, P_2) by producers operating at the intersection of the short-run demand curve D'_s and the long-run demand curve D_L.

Using equational form, these concepts can be articulated explicitly.[1]

Equation (3), given below, is similar to Equation (2a) except that it relates the desired quantity demanded Q_t*, by semifabricators, in a given year (rather than the actual quantity demanded Q_t) to prices and activity levels:

$$Q_t^* = \alpha_o + \alpha_1 P_t + \alpha_2 P^S + \alpha_3 Y \quad . \qquad (3)$$

Where the desired quantity demanded and the actual quantity demanded are the same, there is no problem. However, as discussed above, users of copper may not be able to consume Q_t* (the desired quantity) because of technological constraints. Although, in the long-run, they shall move toward Q_t*, they can only adjust partially to that level over the short run. We can represent this latter situation as follows:

$$Q_t - Q_{t-1} = \lambda (Q_t^* - Q_{t-1}), \quad o \leq \lambda \leq 1 \qquad (4)$$

[1] A number of demand formulations have been introduced to take this process into account. They fall under a class of models known as the "adaptive expectations" ("partial adjustment" models). The econometric specification of such models works out to be equivalent to that of a Koyck lagged model. Of course, the stochastic specification will be different for different models. For a discussion of such models, see Henri Theil, Principles of Econometrics (New York: Wiley and sons, Inc., 1971), pp. 258-268.

which means simply that the users of the factor (i.e., copper) adjust the level of their actual demand from year t-1 to year t (estimated as $Q_t - Q_{t-1}$) in some proportion λ of the difference between desired demand (Q_t^*) and actual demand during the preceding period (Q_{t-1}). If no technological constraints existed, $\lambda = 1$ and $Q_t = Q_t^*$. In that case, the short-run and long-run demand responses (and elasticities) would be equivalent.

Using Equation (3) and (4) we can write:

$$Q_t = \alpha_o\lambda + \alpha_1\lambda P_t + \alpha_2\lambda P_t^2 + \alpha_3\lambda Y_t + (1 - \lambda)Q_{t-1} \qquad (5)$$

We can see that in Equation (3), α_1 determines the long-run own price elasticity. If that equation were linear in the logs, α_1 would be that elasticity. In Equation (5), $\alpha_1\lambda$ helps quantify the short-run elasticity, since the equation is specified with <u>actual prices</u> and <u>actual quantity demanded</u>, rather than <u>desired quantity demanded</u>. If Equation (5) were estimated in log-log form, the short-run elasticity would be $\lambda\alpha_1$. Hence, a knowledge of λ indicates the difference between the short-run own-elasticity (e_{SR})[1] and the long-run own-price elasticity (e_{LR}) of demand, as follows:

$$|e_{LR}|\lambda = |e_{SR}| \qquad 0 \leq \lambda \leq 1 \quad .$$

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[1]The difference between short-run and long-run elasticity also applies to cross-price elasticities and to the differential impact of Y in Equation 5.

[2]For a more detailed discussion, refer to the Technical Appendix to this report, Supporting Paper 1, "Econometric Analyses of the Copper Industry: General Theoretical Considerations and Critical Review of Selected Empirical Studies."

D. APPLICATION OF THE GENERAL DEMAND MODEL TO THE COPPER INDUSTRY: SOME RESULTS

Equation (5) introduced a technique for estimating the price effects for both the long-run and the short-run. Furthermore, the impact of production levels of the industries using copper can be estimated. However, in order to estimate these elasticities, proper data series are required.

An aggregate demand series for domestic semifabricators was presented in Table 2. Equation (5) states that the amount of refined copper equivalent demanded by semifabricators is affected by the price of refined copper (P_t), the price of competing substitutes (P_t^s), and the production levels of the consuming industries (Y_t). The price series used for P_t is the deflated EMJ price of copper.

We have focused our analysis of copper substitutes on aluminum because of its overriding importance as a potential competitor to copper. The price series used for P_t^s is therefore the monthly average New York dealers' buying price of new aluminum clippings. Production levels of consuming industries have been represented by the Federal Reserve Board (FRB) index of industrial production (durable manufacturers' production). We could have also utilized production levels (or indices) for the semifabricating and fabricating industries. Other analysts have examined some of these alternatives.[1]

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[1] For example, an index of construction activity was examined by Fisher-Cootner-Baily in "An Economic Model of the World Copper Industry," The Bell Journal of Economics and Management Science, 3, 2 (Autumn, 1972), 568-609.

While the detailed estimation of the sensitivity of the demand for copper to prices and macroeconomic activity is contained in the Technical Appendix to this report, it is useful to present some preliminary estimates from our research of others. Table 6 contains price and activity elasticity estimates for Equation (5). The activity variables utilized in the four studies differ. The aluminum price estimates also differ. These different data series will lead to different elasticity estimates. Further, the long-run elasticity estimates depend crucially upon the estimate of λ. In fact, the major reason for the different long-run elasticity estimates in the four studies is alternative estimates of λ.

There exist technical econometric reasons why some data series are more appropriate than others in estimating price sensitivity. These technical details are examined in the Technical Appendix. However, a cursory examination of Table 6 does confirm some of the insights introduced earlier in this chapter. For example, 17 out of 18 short-run elasticity estimates indicate substantial inelasticity (or insensitivity) with respect to price and activity. The long-run elasticity estimates are all greater than the short-run estiamtes, indicating that the response of demand to relative prices and acitivity is, indeed, more sensitive in the long run. However, about half of the long-run estimates are still in the inelastic range (i.e., less than 1.0). The long-run elasticity estimates of Charles River Associates, Inc. (CRA) are quite high. However, there exist econometric reasons why these estimates may be suspect.[1]

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[1] For details, see the Technical Appendix to this report, Supporting Paper 1, "Econometric Analyses of the Copper Industry: General Theoretical Considerations and Critical Review of Selected Empirical Studies."

TABLE 6

PRICE AND ACTIVITY ELASTICITY ESTIMATES
FROM VARIOUS STUDIES

	Elasticities (At the Mean) Short-Run	Long-Run	Source	Period of Analysis
Own-Price (EMJ Price)	-.47	-.64	ADL (Model)[a]	1950-1973
Cross-Price (Aluminum)	.61	.84		
Activity Variable (FRB Index of Durable Manufacturers)	1.30	1.78		
Own-Price (EMJ Price)	-.21	-.90	Fisher-Cootner-Baily[b]	1950-1958; 1962-1966
Cross-Price (Aluminum)	.24	1.01		
Activity Variable (FRB Index of Industrial Production)	.33	1.40		
Own-Price (EMJ Price)	-.17	-.82	Fisher-Cootner-Baily[b]	1957-1958; 1962-1966
Cross-Price (Aluminum)	.20	.98		
Activity Variable (U.S. Index of Construction Materials)	.15	.73		
Own-Price (EMJ Price)	-.21	-2.88	Charles River Associates, Inc. (CRA)[c]	1950-1967
Cross Price (Aluminum)	.46	6.30		
Activity Variable (FRB Index of Durable Manufacturers	.26	3.56		
Own-Price (EMJ Price)	-.33	-.77	D. McNicol[d]	1949-1966
Cross-Price (Aluminum)	.66	1.57		
Activity Variable (FRB Index of Durable Manufacturers)	.44	1.06		
Own-Price (EMJ Price)	-.12	-.39	D. McNicol[d]	1949-1966
Cross-Price (Aluminum)	.35	1.13		
Activity Variable (FRB Index of Durable Manufacturers)	.32	1.05		

NOTES AND SOURCES:

[a] Refer to the Technical Appendix to this report.

[b] F. Fisher, P. Cootner, M. Baily, "An Economic Analysis of the World Copper Industry," The Bell Journal of Economics and Management Science, 3,2.(Autumn, 1972), 568-609.

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

[d] D. McNicol, "The Two Price Systems in the Copper Industry," Unpublished Ph.D. dissertation, Massachusetts Institute of Technology (February, 1973), pp. 68-69.

The ADL estimates indicate a 1.0 percent increase in the price of copper will lower demand (consumption) of refined copper equivalent by .47 percent in the short run and .64 percent in the long-run. Furthermore, a 1.0 percent decrease in the market price of aluminum will stimulate substitution to aluminum (i.e., a decrease in demand for refined copper equivalent of .61 percent in the short-run and .84 percent in the long-run). The ADL income (activity) elasticities are both greater than unity, indicating that a 1.0 percent increase in the production of durable manufacturers generates a 1.3 percent short-run and 1.79 percent long-run increase in the demand for refined copper.[1]

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[1] It must be mentioned that the two-tiered price system and rationing existed at various times over the historical period. Alternative estimates of demand elasticities for differing sample periods which did not include rationing years, yielded similar estimates for the short-run elasticities. However, the estimate of λ did change since the long-run elasticities differ. Information on rationing is not thorough enough to introduce it effectively into the analysis. None of the analyses in Table 6 appear to have accounted for rationing.

APPENDIX A

LONG-RUN SUBSTITUTION FOR COPPER[1]

This appendix presents detailed information on trends in long-run substitution for copper in markets.

A. CONDUCTOR APPLICATIONS

Aluminum has made significant inroads into copper markets in certain electrical conductor applications, specifically in busbar and switchgear, building wire, communication cable, and power cable. To a lesser degree, aluminum has been substituted, on occasion, for copper in motor and motor control parts and in automotive electrical apparatus and consumer electronics goods.

In the building wire industry, substitution of aluminum for copper has been increasing rapidly since 1964. The amount of substitution is directly related to the conductor size: the larger the conductor, the greater the percentage of aluminum building wire.

Substitution of aluminum for copper in the small building wire sizes is minor because little monetary savings per unit length can be realized in these sizes. In addition, mechanical connectors of aluminum to aluminum or aluminum to copper are a problem, particularly in the smaller wire sizes. Training of electricians on how to make proper connections when installing aluminum building wires has not always been done, and the resultant troubles have caused many building contractors to abstain from the use of aluminum conductor building wire in small sizes.

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[1] The material in this appendix draws heavily on National Materials Advisory Board, Mutual Substitutability of Aluminum and Copper, Report of The Panel on Mutual Substitutability of Aluminum and Copper of the Committee on the Technical Aspects of Critical and Strategic Materials, National Materials Advisory Board prepared for the General Services Administration, (Washington D.C.: April, 1972).

The use of aluminum conductors in the communications industry is minimal at present. However, there is much research activity in this field by both manufacturers and end users because large savings in communication conductor costs are indicated if a number of technical problems can be solved.

The substitution of aluminum for copper in the power-cable field has progressed expeditiously and, in recent years, approximately 40 percent of the insulated power cables and almost 100 percent of the bare conductors have been aluminum. Aluminum has such a weight advantage over copper that aluminum-conductor, steel-reinforced cable has been used for most long-transmission lines for more than a decade. Recently introduced aluminum alloys are being used as conductors on overhead transmission lines.

Copper remains the first choice for automotive wiring at current prices. In areas where space in an existing design is not a problem, the use of the larger sizes of aluminum wire will increase. Examples of such applications are battery cables, air conditioners, clutch coils, alternators, anti-skid devices, horn coils, and some accessory motors.

Copper and aluminum are used widely as electronic consumer items (TV receiver, radios, record players, tape recorders, etc.) For many years the normal electrical conductor in consumer items was an insulated copper wire. However, with the advent of solid-state electronics, a large increase in aluminum usage occurred because of its excellent heat-sink capabilities. With the increasing usage of printed circuits or wiring boards of epoxy glass and epoxy coated steel, and of thin and thick film ceramic units, nickel, gold, silver, tantalum, and rhodium, as well as aluminum have begun competing with copper for this application.

B. HEAT-EXCHANGER APPLICATIONS

Substitution of aluminum for copper in radiators is possible given the fabrication techniques and the available supply of metal in the required sheet and strip forms. Automotive radiators have been built of aluminum in limited quantities and are similar in appearance and heat-transfer characteristics to copper radiators.

All but a small proportion of the motor vehicles currently in service use radiators constructed of copper and copper alloys. Copper has been traditional for this application because of its heat transfer properties, corrision-resistance, ease of fabrication, and ease of joining the various components by conventional "soft" soldering techniques.

Experience has shown that copper radiators are quickly and economically repairable with the use of minimal additional copper. Present repair techniques for aluminum radiators are either unreliable or available only at great expense at a limited number of shops. Most aluminum radiators today are replaced when leaks occur.

The major deterrent to volume production of aluminum radiators seems to be high capital equipment costs plus the unamortized cost of equipment presently used for production of copper radiators. Total cost of industry conversion has been estimated to be more than $200 million.

Currently, more than 90 percent of the primary surfaces in automotive air-conditioner evaporators and condensers are aluminum, and domestic refrigerators and freezers have used all-aluminum evaporators and steel condensers for years. Copper and aluminum are completely substitutable in this area.

Copper tubing is still the predominant primary surface in heat exchangers for commercial refrigerators and freezers, and room, central residential, and commercial air conditioners. Aluminum tubing is used in less than 10 percent of these products. Extensive manufacturing development is necessary before aluminum could be considered completely substitutable for copper in these applications.

Aluminum-alloy tubing in air conditioners has up to twice the wall thickness of copper, but still maintains a weight and cost advantage.

Production processes for most aluminum tube commercial and residential air conditioners and commercial refrigerator and freezer heat exchangers are similar to those for copper tube heat exchangers with the exception of joining or assembly methods. The cost of converting an assembly line for copper-tube heat exchangers to aluminum is relatively low because most of the production equipment could be used with either metal, but not simultaneously.

Additional field experience is required before aluminum will be substituted widely for copper in room-air-conditioner condensers and commercial heat exchangers using water as a secondary refrigerant or as a heating medium. These products account for approximately 25 percent of the total tubing requirements and pose specific corrosion problems to aluminum. Codes now limit the use of aluminum-tube heat exchangers mounted in ducts. However, these codes are being re-evaluated and soldered aluminum-tube heat exchangers may be accepted in the near future.

Aluminum has been tried in five different U.S. power plants. In two cases, failure occurred in about a year; in another instance, failure occurred in five years; and in the other two, condenser tubes lasted ten years. Fresh water was used for cooling in all cases.

There are problems, seemingly insurmountable, that must be overcome to use aluminum in the main condenser of power generating stations. The necessary volume of circulating or cooling water is very great and its quality is extremely variable. To insure against attack of aluminum tubing by water, controls and conditioning equipment not customarily used in electrical generating stations would be required.

Applications Requiring Corrosion Resistance

Copper and aluminum compete directly in many conductivity and heat-exchanger applications, and in some structural applications, but rarely in applications in which corrosion resistance is the prime requisite.

In many applications, copper and aluminum are not mutually substitutable. Even where an overlap exists (valves and fittings for example), a serious decline in copper usage has not occurred.

C. ELECTROPLATING AND COATINGS

Copper has been, and will continue to be, widely used in coatings applied by electroplating and in forms made by electrodeposition. Aluminum coatings by electroplating are not easily applied and currently are in negligible use. In coating applications, copper and aluminum are not interchangeable because the electro-deposition of aluminum requires highly special procedures. In recent years, electrodeposited coatings of aluminum would have cost 6 to 10 times those of copper, technical difficulties would require major changes in equipment.

Recent developments in the thermal decomposition of liquid and vapor phase aluminum organometallic compounds may, however, permit the use of aluminum in coatings for steel and in protective paints in the future.

D. ALLOYING APPLICATIONS AND COATINGS

Copper is essential in all U.S. coins because of the requirements of the large automatic vending machine industry. These machines are designed to accept coins with the properties of coin silver. To match these properties, silver-free coins must contain a high percentage of copper.

Aluminum is not used in any U.S. coins. It is too light in weight to operate coin-operated machines and has less wear resistance than currently used metals in coins. Thus, aluminum is an unlikely candidate for use in this field in the foreseeable future.

E. ORDNANCE AND ACCESSORIES

Although other materials have been employed for certain fuse components, copper alloys continue to be the major ingredient. Periods of critical shortage in copper supplies have prompted efforts to substitute other materials in fuses for several years. Efforts to replace copper with aluminum also have been related to reducing weight.

In recent years, more than 30 different fuses have been used by the U.S. Army. Among standard models, the number of copper and/or aluminum components varies from practically none to a significant proportion. In some, the original functioning requirements were such that other materials (such as steel) were satisfactory for almost all components. In others, aluminum alloys have replaced copper alloys to a certain extent as the result of a gradual substitution program. In still others, especially the recent models developed for entirely new projectiles, aluminum alloys comprise a comparatively large proportion of the materials used. Thus, a part-by-part analysis of the degree to which copper alloys have been or may be replaced by aluminum alloys becomes impractical.

For the manufacture of cartride cases, no commercially available aluminum alloy has proven ideal enough to seriously threaten the use of copper.

APPENDIX B

INTERINDUSTRY RELATIONSHIPS OF PRIMARY COPPER, UNITED STATES, 1967

From	To	Description	($ millions)
38.01	27.01	Industrial Inorganic and Organic Chemicals	12.3
38.01	37.01	Blast Furnaces and Basic Steel Products	25.8
38.01	37.02	Iron and Steel Foundries	6.7
38.01	37.04	Primary Metal Products, n.e.c.	22.8
38.01	38.01	Primary Copper	823.8
38.01	38.02	Primary Lead	.4
38.01	38.03	Primary Zinc	3.8
38.01	38.04	Primary Aluminum	8.5
38.01	38.05	Primary Nonferrous Metals, n.e.c.	67.6
38.01	38.06	Secondary Nonferrous Metals	23.6
38.01	38.07	Copper Rolling and Drawing	871.7
38.01	38.08	Aluminum Rolling and Drawing	23.8
38.01	38.09	Nonferrous Rolling and Drawing, n.e.c.	13.8
38.01	38.10	Nonferrous Wire Drawing and Insulating	426.5
38.01	38.11	Aluminum Castings	9.8
38.01	38.12	Brass, Bronze, and Copper Castings	89.2
38.01	38.13	Nonferrous Castings, n.e.c.	2.5
38.01	40.02	Plumbing Fittings and Brass Goods	17.9
38.01	42.03	Heating Equipment, except Electric	8.5
38.01	42.08	Architectural Metal Work	40.7
38.01	48.05	Printing Trades Machinery	4.4
38.01	48.06	Special Industry Machinery, n.e.c.	4.7
38.01	49.01	Pumps and Compressors	5.9
38.01	49.05	Power Transmission Equipment	6.8
38.01	53.04	Motors and Generators	8.8

SOURCE: U.S. Department of Commerce, Input-Output Structure of the U.S. Economy: 1967, Volume I, Transactions Data for Detailed Industries, A Supplement to the Survey of Current Business, 1974.

INTERINDUSTRY RELATIONSHIPS OF PRIMARY COPPER,
UNITED STATES, 1967
(Continued)

From	To	Description	($ millions)
38.01	53.05	Industrial Controls	6.1
38.01	68.01	Electric Utilities	1.2
38.01	71.02	Real Estate	1.5
38.01	83.00	Scrap, Used and Secondhand Goods	1.5
38.01	88.00	Total Intermediate Output	2,547.8
38.01	93.00	Net Inventory Change	14.1
38.01	94.00	Net Exports	171.8
38.01	97.10	Federal Government Purchases, Defense	-106.3
38.01	97.20	Federal Government Purchases, Others	18.8
38.01	99.02	Total Final Demand	98.3
38.01	99.03	Total Output	2,646.1
38.01	99.04	Transfers-Out	83.9

SOURCE: U.S. Department of Commerce, Input-Output Structure of the U.S. Economy: 1967, Volume I, Transactions Data for Detailed Industries, A Supplement to the Survey of Current Business, 1974.

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING, UNITED STATES, 1967

From	To	Description	($ millions)
38.07	9.00	Stone and Clay Mining and Quarrying	.8
38.07	11.01	New Construction, Residential Buildings (Nonfarm)	138.4
38.07	11.02	New Construction, Nonresidential Buildings	87.8
38.07	11.03	New Construction, Public Utilities	17.7
38.07	11.05	New Construction, All Other	7.6
38.07	12.01	Maintenance and Repair Construction, Residential Buildings (Nonfarm)	34.2
38.07	12.02	Maintenance and Repair Construction, All Other	23.9
38.07	13.01	Complete Guided Missiles	.2
38.07	13.02	Ammunition, Except for Small Arms, n.e.c.	6.2
38.07	13.03	Tanks and Tank Components	.3
38.07	13.05	Small Arms	.5
38.07	13.06	Small Arms Ammunition	100.4
38.07	13.07	Other Ordnance and Accessories	.6
38.07	17.06	Coated Fabrics, Not Rubberized	.3
38.07	20.01	Logging Camps and Logging Contractors	.5
38.07	27.01	Industrial Inorganic and Organic Chemicals	.2
38.07	27.04	Miscellaneous Chemical Products	2.7
38.07	32.04	Miscellaneous Plastics Products	.3
38.07	36.02	Brick and Structural Clay Tile	.1
38.07	37.01	Blast Furnaces and Basic Steel Products	6.0
38.07	38.01	Primary Copper	45.3
38.07	38.04	Primary Aluminum	.7

SOURCE: U.S. Department of Commerce, Input-Output Structure of the U.S. Economy: 1967, Volume I, Transactions Data for Detailed Industries, A Supplement to the Survey of Current Business, 1974.

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING,
UNITED STATES, 1967
(Continued)

From	To	Description	($ millions)
38.07	38.07	Copper Rolling and Drawing	77.1
38.07	38.08	Aluminum Rolling and Drawing	82.5
38.07	38.09	Nonferrous Rolling and Drawing, n.e.c.	13.3
38.07	38.10	Nonferrous Wire Drawing and Insulating	579.9
38.07	38.12	Brass, Bronze, and Copper Castings	11.5
38.07	38.14	Nonferrous Forgings	24.9
38.07	40.01	Metal Sanitary Ware	1.8
38.07	40.02	Plumbing Fittings and Brass Goods	50.2
38.07	40.03	Heating Equipment, Except Electric	24.1
38.07	40.04	Fabricated Structural Steel	2.3
38.07	40.05	Metal Doors Sash and Trim	1.5
38.07	40.06	Fabricated Plate Work (Boiler Shops)	26.7
38.07	40.07	Sheet Metal Work	8.1
38.07	40.08	Architectural Metal Work	4.8
38.07	40.09	Miscellaneous Metal Work	2.7
38.07	41.01	Screw Machine Products and Bolts, Nuts, Rivets, and Washers	93.9
38.07	41.02	Metal Stampings	68.4
38.07	42.01	Cutlery	1.3
38.07	42.02	Hand and Edge Tools Including Saws	3.5
38.07	42.03	Hardware, n.e.c.	35.9
38.07	42.05	Miscellaneous Fabricated Wire Products	14.1
38.07	42.08	Pipe, Valves, and Pipe Fittings	98.1
38.07	42.11	Fabricated Metal Products, n.e.c.	7.1
38.07	43.01	Steam Engines and Turbines	17.2
38.07	43.02	Internal Combustion Engines, n.e.c.	8.7

SOURCE: U.S. Department of Commerce, Input-Output Structure of the U.S. Economy: 1967, Volume I, Transactions Data for Detailed Industries, A Supplement to the Survey of Current Business, 1974.

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING,
UNITED STATES, 1967
(Continued)

From	To	Description	($ millions)
38.07	44.00	Farm Machinery	12.1
38.07	45.01	Construction Machinery	4.1
38.07	45.02	Mining Machinery	1.0
38.07	45.03	Oil Field Machinery	1.6
38.07	46.01	Elevators and Moving Stairways	1.6
38.07	46.02	Conveyors and Conveying Equipment	4.3
38.07	46.03	Hoists, Cranes, and Monorails	2.5
38.07	46.04	Industrial Trucks and Tractors	.7
38.07	47.01	Machine Tools, Metal Cutting Types	2.3
38.07	47.02	Machine Tools, Metal Forming Types	1.0
38.07	47.03	Special Dies and Tools and Machine Tool Accessories	7.3
38.07	47.04	Metalworking Machinery, n.e.c.	6.4
38.07	48.01	Food Products Machinery	1.3
38.07	48.02	Textile Machinery	3.0
38.07	48.04	Paper Industries Machinery	10.0
38.07	48.05	Printing Trades Machinery	2.4
38.07	48.06	Special Industry Machinery, n.e.c.	10.2
38.07	49.01	Pumps and Compressors	11.7
38.07	49.02	Ball and Roller Bearings	3.0
38.07	49.03	Blowers and Fans	4.5
38.07	49.04	Industrial Patterns	.2
38.07	49.05	Power Transmission Equipment	6.0
38.07	49.06	Industrial Furances and Ovens	5.6
38.07	49.07	General Industrial Machinery, n.e.c.	4.2

SOURCE: U.S. Department of Commerce, Input-Output Structure of the U.S. Economy: 1967, Volume I, Transactions Data for Detailed Industries, A Supplement to the Survey of Current Business, 1974.

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING,
UNITED STATES, 1967
(Continued)

From	To	Description	($ millions)
38.07	50.00	Machine Shop Products	30.6
38.07	51.01	Computing and Related Machines	2.9
38.07	51.02	Typewriters	.2
38.07	51.03	Scales and Balances	.2
38.07	51.04	Office Machines, n.e.c.	.9
38.07	52.01	Automatic Merchandising Machines	.2
38.07	52.02	Commercial Laundry Equipment	.3
38.07	52.03	Refrigeration Machinery	135.2
38.07	52.04	Measuring and Dispensing Pumps	1.2
38.07	52.05	Service Industry Machines, n.e.c.	1.6
38.07	53.01	Electric Measuring Instruments	4.3
38.07	53.02	Transformers	17.6
38.07	53.03	Switchgear and Switchboard Apparatus	46.2
38.07	53.04	Motors and Generators	27.7
38.07	53.05	Industrial Controls	6.8
38.07	53.06	Welding Apparatus	9.5
38.07	53.07	Carbon and Graphite Products	.6
38.07	53.08	Electrical Industrial Apparatus, n.e.c.	4.4
38.07	54.01	Household Cooking Equipment	1.4
38.07	54.02	Household Refrigerators and Freezers	1.4
38.07	54.03	Household Laundry Equipment	1.3
38.07	54.04	Electric Housewares and Fans	3.2
38.07	54.05	Household Vacuum Cleaners	.9
38.07	54.06	Sewing Machines	.3
38.07	54.07	Household Appliances, n.e.c.	3.6

SOURCE: U.S. Department of Commerce, Input-Output Structure of the U.S. Economy: 1967, Volume I, Transactions Data for Detailed Industries, A Supplement to the Survey of Current Business, 1974.

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING,
UNITED STATES, 1967
(Continued)

From	To	Description	($ millions)
38.07	55.01	Electric Lamps	.9
38.07	55.02	Lighting Fixtures	9.0
38.07	55.03	Wiring Devices	35.7
38.07	56.01	Radio and Television Receiving Sets	.8
38.07	56.03	Telephone and Telegraph Apparatus	28.1
38.07	56.04	Radio and Television Communication Equipment	6.1
38.07	57.01	Electron Tubes	2.5
38.07	57.02	Semiconductors	1.8
38.07	57.03	Electronic Components, n.e.c.	27.4
38.07	58.03	X-Ray Apparatus and Tubes	.9
38.07	58.04	Engine Electrical Equipment	9.9
38.07	58.05	Electrical Equipment, n.e.c.	4.9
38.07	59.01	Truck and Bus Bodies	3.8
38.07	59.02	Truck Trailers	.6
38.07	59.03	Motor Vehicles and Parts	119.9
38.07	60.01	Aircraft	1.6
38.07	60.02	Aircarft Engines and Parts	2.1
38.07	60.04	Aircraft Equipment, n.e.c.	8.8
38.07	61.01	Shipbuilding and Repairing	14.4
38.07	61.02	Boatbuilding and Repairing	.7
38.07	61.03	Locomotives and Parts	9.1
38.07	61.04	Railroad and Street Cars	2.3
38.07	61.05	Motorcycles, Bicycles and Parts	.2
38.07	61.06	Trailer Coaches	4.4

SOURCE: U.S. Department of Commerce, Input-Output Structure of the U.S. Economy: 1967, Volume I, Transactions Data for Detailed Industries, A Supplement to the Survey of Current Business, 1974.

INTERINDUSTRY RELATIONSHIPS OF COPPER ROLLING AND DRAWING,
UNITED STATES, 1967
(Continued)

From	To	Description	($ millions)
38.07	61.07	Transportation Equipment, n.e.c.	1.0
38.07	62.01	Engineering and Scientific Instruments	1.2
38.07	62.02	Mechanical Measuring Devices	12.7
38.07	62.03	Automatic Temperature Controls	16.6
38.07	63.03	Photographic Equipment and Supplies	1.0
38.07	64.01	Jewelry, Including Costume, and Silverware	19.8
38.07	64.02	Musical Instruments and Parts	2.0
38.07	64.03	Games, Toys, Etc.	.7
38.07	64.04	Sporting and Athletic Goods, n.e.c.	3.2
38.07	64.07	Buttons, Needles, Pins and Fasteners	22.6
38.07	64.12	Miscellaneous Manufactures, n.e.c.	15.0
38.07	65.01	Railroads and Related Services	6.0
38.07	68.01	Electric Utilities	.7
38.07	69.01	Wholesale Trade	2.4
38.07	71.02	Real Estate	4.1
38.07	83.00	Scrap, Used and Secondhand Goods	33.2
38.07	88.00	Total Intermediate Output	2,582.0
38.07	93.00	Net Inventory Change	- .3
38.07	94.00	Net Exports	18.5
38.07	97.10	Federal Government Purchases, Defense	4.5
38.07	97.20	Federal Government Purchases, Other	3.9
38.07	99.02	Total Final Demand	26.6
38.07	99.03	Total Output	2,608.6
38.07	99.04	Transfers-Out	258.9

SOURCE: U.S. Department of Commerce, Input-Output Structure of the U.S. Economy: 1967, Volume I, Transactions Data for Detailed Industries, A Supplement to the Survey of Current Business, 1974.

CHAPTER 6

COPPER PRICING MECHANISMS, PRICE FORMATION AND THE TWO-TIER PRICE SYSTEM

A. INTRODUCTION AND SUMMARY

An adequate understanding of the manner in which supply and demand forces have interacted in the copper industry in the past cannot be attained without a firm grasp of the rather complex set of institutional arrangements which characterize copper markets, the process of price formation among firms in the industry, and, as a directly related matter, the emergence and rationale of the "two-price system" for copper which in the past has been a dominant phenomenon impinging upon the pricing behavior of the domestic primary producers. This chapter therefore focuses on these three closely interrelated subjects.

After a discussion of the various important copper market institutions, their functional bases and the significance of the various price series associated with them, we will review historical trends in prices. This will set the stage for a description and analysis of the pricing behavior of the primary producers within the context of a important characteristic of postwar copper markets, namely, the predominance of the so called "two-price system" for copper. Finally, we will examine the various theoretical explanations that have been advanced for the pricing behavior of the primary producers during periods when the two-price system has been in effect.

The principal conclusions of this chapter can be summarized as follows.

1. The major institutional arrangements governing copper markets include: two organized exchanges, the London Metal Exchange (LME) and the New York Commodity Exchange (Comex); merchants; and, of course, the major primary producers. The LME and Comex are basically hedge and speculative, rather than physical markets. Metal merchants are trading firms which typically trade in all types of copper products as well as in various other metals.

2. The term "outside market" is sometimes used to describe all trade in copper apart from domestic sales made by domestic primary producers. As referred to here, the outside market encompasses the secondary industry (including the secondary refiners), sales of U.S. and foreign producers at other than the prevailing domestic producers price, merchants, and transactions in physical copper on the LME and Comex.

3. In spite of a number of different pricing bases in existence, the bulk of refined copper sales during the postwar period have been made directly or indirectly on the basis of one of two distinct price regimes. The first is the domestic producers price, a set of nearly uniform price quotations used by the major primary producers, and frequently, by Noranda, one the the Canadian producers, for sales in the U.S. The second is the LME price, spot and forward quotations prevailing on the London Metal Exchange, which has been used by most producers most of the time as a basis for sales outside North America.

4. Within the U.S. during the past three decades, about 76 percent of average annual consumption has been transacted at the domestic producers price; about 12 percent on average has been marketed by the principal

secondary or custom refiners at their own established prices reflecting the prevailing price for scrap and the remaining 12 percent has consisted on average of imports and merchant copper sold at a price identical to or close to the LME price. Because movements in the price of domestic scrap tend to follow closely movements in the LME price, however, an average of 24 percent of refined copper consumption can be said to have been marketed at prices closely reflecting movements in the LME prices.

5. The significant aspects of the pricing behavior of the copper industry during the postwar period can thus be adequately described by focusing on the history of the LME and domestic producers prices. In general, LME price movements have been relatively volatile and sensitive to speculative pressures and short-run shifts in supply and demand. By contrast, the producers price has tended to change only slowly, usually lagging significant trends in LME prices by several months.

6. The most significant characteristic of postwar copper markets has been the existence in nine of the 27 years between 1947-1974 of a two-price system for refined copper, characterized by a wide divergence between the outside market price for copper (i.e., the LME price) and the domestic producers price. The two-price system developed during periods of rising or excess demand for refined copper and was brought about when participating producers (U.S. and some foreign) chose to ration their available copper supplies to customers at a price below the level which would have cleared the market. Three distinct periods when the two-price system was in effect can be identified as follows: (1) from late 1954 to mid-1956; (2) from January, 1964 to March, 1966; and (3) from April 1966 to early 1970. During each period, a different combination of

foreign producers participated along with U.S. producers.

7. There appears to be no complete, simple, logical explanation or set of explanations for the rationing behavior of the principal U.S. and foreign producers during the periods of the two-price system. All of the proposed explanations are either logically inconsistent or are unable to explain certain "anomalous" behavior on the part of the producers.

Rationing during periods of excess demand and high copper prices (as reflected in LME prices) is clearly inconsistent with the motive of short-run profit maximization. Since the major producers themselves commonly cite the fear of long-run substitution for copper by end-users if copper prices are allowed to rise too high or are too volatile, the explanation might lie in an analysis of longer-term motives. Here, the producers suggest that they have preferred in the past to forego short-run profit maximization in order to maximize profits in the long-run by avoiding substitution away from copper.

8. The long-run substitution explanation for rationing is supported by evidence that producers have at times rationed markets selectively--fully supplying semifabricator customers with a high propensity for long-run substitution, such as wire mills, while rationing severely customers with a low propensity for long-run substitution, such as brass mills. Such behavior occurred only at certain times during the periods of the two-price systems, however; at other times, markets were apparently rationed across-the-board.

9. A second explanation for producer rationing suggests that partially or fully integrated producers acted as monopolists to limit the availability of refined copper supplies and thereby drive up the market price at which semifabricated and fabricated goods were sold. In other

words, it is argued that by regulating supplies, they increased their profits at the fabricating stage while foregoing short-run profit increases at the mining through refining stages. Such behavior, however, could well stimulate long-run substitution as prices rose.

Neither hypothesis explains why different foreign producers participated in the three different two-price systems. Moreover, sufficient quantitative data are unavilable to fully support any of the explanations for the existence of the two-price system.

A. COPPER MARKET INSTITUTIONS AND REFINED COPPER PRICES

Although there are many distinguishable copper prices and the institutional arrangements of the copper markets are complex, we can briefly identify the following major institutional arrangements governing the copper markets: two organized exchanges, the London Metal Exchange (LME) and the New York Commodity Exchange (Comex); merchants; and the major (primary) sellers themselves.

The LME and Comex are basically hedge and speculative, rather than physical markets. Their principal function is hence to provide hedging facilities for both producers and fabricators rather than as markets for spot sales for physical deliveries. Comex's trading rules virtually preclude its use as a physical market. However, the LME can be, and sometimes is, used as a physical market, but even in Europe its role as a physical market is very limited.

Metals merchants, meanwhile, are trading firms which typically trade in all types of copper products, as well as in various metals, and organize the refining of numerous small lots of material (i.e., scrap, secondary blister, and the output of small mines and smelters).

As indicated earlier, the term "outside market" is sometimes used to describe all trade in copper apart from sales made by the producers. The outside market encompasses the secondary industry (including the secondary refiners), some of the smaller foreign producers, merchants, and transactions in physical copper on the LME and Comex.

The great bulk of refined copper sales by the major producers are handled through their own subsidiary sales agencies. Some sales agencies handle not only the refined output of their parent companies, but also copper refined by several other domestic and foreign primary producers, and it is not uncommon for the output of a small primary producer to be sold through the sales agency of a larger producer. Sales by these agencies represent current orders by buyers for future physical delivery of copper at an agreed upon price.

While a number of price bases have been employed at different times during the post-World War II period in the buying and selling of refined copper, the bulk of refined copper sales have been made directly or indirectly on the basis of one or two distinct price regimes:

- The domestic producers' price, a set of nearly uniform price quotations used by the major U.S. primary producers and, for a good part of the postwar period, by Noranda, one of the Canadian producers, for sales in the U.S.; and
- The LME price, spot and forward quotations prevailing on the London Metal Exchange, used by most producers most of the time as a basis for sales outside North America.

Practically the whole of the world's mine production which is traded internationally is sold at prices based on the LME. The actual price is not necessarily the daily spot quotation, nor the forward price, nor yet an average of the two, but in most cases it is arrived at by application of a formula which is related directly to Exchange quotations.[1]

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[1] Sir Ronald Prain, Copper: The Anatomy of an Industry (London: Mining Journal Books Limited, 1975), p. 95.

Within the U.S., refined copper has been bought and sold on average in the following proportions during the postwar period:

- About 76% of average annual consumption has been sold by U.S. primary producers at the domestic producers' price;
- About 13% of average annual consumption has been marketed by the principal secondary or custom refiners at their own established price generally reflecting the prevailing price for copper scrap plus operating margins;
- The remaining 11% of consumption on an average annual basis has consisted of imports from foreign producers and the LME, and copper handled by U.S. metals merchants, mostly sold at the LME price or a price closely reflecting that price.

Because movements in the price of domestic scrap tend to follow closely movements in the LME price, however, an average 24% of refined copper consumption in the U.S. can be said to have been marketed on the basis of LME prices.

1. The Copper Exchanges: The LME and Comex[1]

Of the two exchange markets on which copper is quoted, the LME is certainly the more important in terms of volume of transactions, physical deliveries, and influence on world copper prices generally. As has already

[1] The discussion presented here draws upon the following principal sources:
(1) Raymond F. Mikesell, "The Nature of the World Market for Copper," unpublished paper (Eugene, Oregon: University of Oregon, June, 1974);
(2) Ferdinand E. Banks, The World Copper Market: An Economic Analysis (Cambridge, Mass.: Ballinger Publishing Co., 1974), pp. 41-49;
(3) Charles River Associates, Inc. (CRA), Economic Analysis of the Copper Industry (March, 1970), Chapters 5 and 6.
(4) Sir Ronald Prain, Copper: The Anatomy of an Industry (London: Mining Journal Books Limited, 1975), Chapters 7 and 8.

been noted, producers' prices outside the United States tend to follow LME quotations rather closely and long-term contracts employ a variety of formulas for pricing copper related to LME prices. Although there is frequently a price differential of several cents per pound for the same type of copper between the two markets as a consequence of the time and cost of shipping copper, government trade controls, and other factors, arbitrage transactions between the Comex and the LME tend to limit the amount of the differential. There are a number of important differences in the two markets that require explanation.

The London Metal Exchange (LME)

The LME dates from 1882, although copper and other metals had been quoted in London much earlier. During World War II and the immediate post-war period, when the government controlled the price of strategic metals, the exchange was closed; but it reopened in 1953, and since that time a steady increase in activity has been noted.

The LME deals exclusively in nonferrous metals--copper, lead, zinc, tin and silver. Two copper contracts are traded on the LME: one for electrolytic wirebar, and one for electrolytic cathode.[1] Cathodes normally trade at a discount under wirebar, reflecting conversion costs. Contracts may be traded for "spot", "ninety days", and any market day in between. The minimum contract is for 25 long tons and dealings are

[1]LME permits trading in electrolytic wirebars, cathodes, and fire refined ingot or ingot bars. HCRF wirebar may be delivered for electrolytic wirebars at a discount, but with this exception substitutions are not permitted.

conducted in multiples of 25 tons. Dealings on the LME are not simply paper transactions. Purchasers can always obtain delivery of metal on the day agreed upon (and in the case of spot transactions, the following day) at any of the registered LME warehouses at the seller's option. Copper for delivery on contract terms is held in warehouses in London, Birmingham, Liverpool, Manchester, Hull, or Glasgow in the United Kingdom; Rotterdam in the Netherlands; Hamburg in Germany; and Antwerp in Belgium. Insistence on delivery has remained paramount and is reflected in the fact that contracts may not contain any force majeure provisions.

Trading on the LME takes place through representatives of member firms who are seated in a circle around the exchange floor and who made bids and offers to each other across the ring. Deals are made when a bid or offer is accepted and contracts are issued promptly. Dealers may hold a position in the metal traded on any market day between the current day and three months forward, with the final day for liquidation being the last market day before the contract matures. Dealing members accept the responsibility of honoring their own contracts. (This differs from the Comex where the Clearing Association has responsibility for honoring transactions). Two rings operate daily, Monday through Friday. Trading commences at noon and at 3:45 p.m. Copper, like the other metals on the exchange, is traded for a period of five minutes with two-five minute sessions. During each trade period or ring, one five-minute session is devoted to copper wirebar and the other to cathode. Closing prices in the noon session become the official prices and form the basis for the major share of long-term contracts on which LME quotations are based.[1] No official prices are announced as a result of the afternoon session. Dealings outside the market ("kerb" dealings) are permitted both in the morning and in the afternoon, and trading is allowed outside regular market hours.

The LME price, although it is determined by a small number of transactions daily, is important as it has been used as a transaction price by a number of major producers. During the postwar period, with the exception of five and one-half years, it has been the policy of the Anglo-American Corporation (AAC) and Rhodesian Selection Trust (RST), both of whose properties are in Zambia, to sell at the LME price.[2] Union Miniere du

[1] The LME Price quotes daily are based either on the last transaction entered into or on the closing bids and offers made during the short period in which dealings occur, and these prices reflect business done in what are usually only small tonnages of copper. Yet these same quotations are used as a basis for pricing infinitely greater quantities of metal which are sold directly by producers to fabricators outside the Exchange. In other words, producers and fabricators use the LME quotations in much the same way as one might use an official stock exchange quotation for a private share deal, and the transaction in no way represents physical copper actually being dealt in across the floor of the Exchange. (See Prain, op. cit., p. 95).

[2] The African producers have departed from the policy of selling at the LME price on two occasions. First, during the period 1955-1957, RST sold at announced producer prices, while AAC, UMdHK, the Canadian producers and Chile sold at a common producers' price.

In the period 1964-1966 RST and AAC sold at a common producer price. Union Miniere, the other major African producer, sold at an announced price. In 1958, Sir Ronald L. Prain stated that the UMdHK price followed the Metals Week weighted average export refinery price more closely than the LME price (see Sir Ronald L. Prain, "Copper Pricing Systems;" address to the Organization for European Economic Co-operation, Paris, June 25, 1958, reprinted in, Selected Papers of Sir Ronald Lindsay Prain, Vol. II [London: B. T. Batsford], p. 15).

Furthermore, during the two years prior to the "second producers' price experiment" AAC and RST had supported the LME price at a fixed level. These periods are discussed in more detail below. The Korean War must also be excluded here, as in this period the maximum domestic producers' price was set by the government (see Charles River Associates, [CRA], op. cit., p. 122).

Haut Katanga (UMdHK), whose properties are in Zaire, has also generally sold at a price closely related to the LME price. Also, sales of Canadian and Chilean copper made outside the United States have usually been based on the LME prices.

The New York Commidity Exchange (Comex)

The Comex copper contract are for 25 short tons of either electrolytic wirebar, high conductivity fire-refined copper (HCFR), Lake Copper, electrolytic cathode, or 99.88 percent fire-refined copper, all specified according to American Society for Testing Materials (AFTM) standards.[1] Electrolytic cathodes and high conductivity fire-refined (HCRF) copper may be substituted at fixed differentials.

Price movements on Comex have a daily limit of 2 cents per pound for all trading months except the spot months. This limitation,

[1] Trading on the Comex is done by floor brokers working in a ring through bid and offer procedures daily from 9:45 a.m. to 2:10 p.m. At the end of the day purchases and sales on the Comex are "cleared" through the Clearing Association composed of commission houses and trading firms. The Association guarantees fulfillment of all contracts handled by its members. This procedure differs from that of the LME which is a market of "principals" (i.e., the participating brokers underwrite the performance of each contract).

All members of the Clearing Association maintain guarantee funds and fixed original margins within the Association. Trading takes place for delivery in seven specified months—January, March, May, July, September, October and December.

Delivery on Comex contracts may be made on any day during these months, at the seller's option, to any registered Comex warehouse. Warehouses are located in Chicago, St. Louis, and Franklin Park in Illinois; El Paso, Texas; Reading, Pennsylvania, New York City; and Tacoma, Washington. A semi-fabricator who purchased a contract on Comex might receive fire refined copper in Tacoma on May 31, while it wanted electrolytic wirebars in New York on May 1.

together with the system of trading for delivery in seven selected months and at any day during the month at the seller's option, is designed to prevent the price from being disproportionately affected by a few large transactions. However, this system complicates the use of Comex as a hedging medium and as a basis for establishing prices for contracts outside the market. It also complicates the problem of comparing LME and Comex spot and forward prices and or arbitrage between the two exchange markets. However, formulas have been adopted to compare the prices in the two markets in a manner which will eliminate to the maximum degree possible the distortions arising from the different trading and delivery arrangements.

On the Comex, cathode trades at a discount of one-eighth of a cent a pound below electrolytic wirebar, and the lower grades of fire-refined copper at a discount of a quarter of a cent per pound. Since the cost of casting cathode into wirebar is generally more than one-eighth of a cent a pound and the actual market value of lower grade fire-refined is less than one-fourth of a cent per pound discount from electrolytic wirebar, it is to the producers' advantage to deliver these lower grades against Comex contracts. Hence, the Comex warehouses contain mainly the lower grades of copper. Such grades serve as a source of direct supply to brass mills and foundries. Other U.S. fabricators tend to purchase wirebar from merchants, whose prices fluctuate at a premium above the Comex quotations. By pricing their copper in close relation to Comex prices, both merchants and consumers are able to employ the Comex for hedging purchases and sales for future delivery against price changes.

In summary, Comex is considerably less important in world copper markets than is the LME. Like LME, Comex is basically a hedge and speculative market, but Comex is even less of a physical market than LME, and the Comex price is not generally used for sales on the "outside" market. Arbitrage between the LME and Comex generally keeps the prices close together.

2. The Merchant Market[1]

Generally merchants buy and sell copper outside the principal producer-consumer channels. Merchant copper traded in the U.S. is related to the Comex price. Merchants for the most part do not invest in production facilities, but they can and will hold or finance stocks. In the United States, where there is more integration in the copper industry, merchants may be experiencing somewhat less scope for their activity than in Europe. For one thing, Comex has a smaller physical turnover than the LME, and although its facilities for hedging and speculating are quite as developed as those to be found in London, it is not especially oriented toward the international market.

Merchants tend to make extensive use of independent refineries. They also buy a great deal of scrap for refineries handling secondary materials. Many of the physical deliveries on the LME result from the transactions of merchants; and by the same token they carry out arbitrage operations on a worldwide basis. They are usually busiest when the demand for copper is highest, since during these periods more copper than ever

[1] See Banks, op. cit., pp. 41-43.

will come from the smallest mines (i.e., mines that under normal circumstances are only marginal producers and possibly have not committed their production to any given refinery) or scrap. There are also the periods when buyers or sellers are most likely to misjudge requirements and thus need the service of merchants.

U.S. merchants are able to sell in European markets; but for the most part American producers frown on these operations, and it is believed that they have taken steps to see that their regular customers do not succeed in transferring any large amount of the excess copper to merchants and thus to the "free" market.

3. The U.S. Producers' Price

Since shortly after World War II, the major U.S. primary producers have, in effect, used a common basis for determining the price at which they sell refined copper to affiliated and independent fabricators within the U.S. This domestic producers' price has represented a common set of price quotations for delivery of wirebars, ingots, and ingot bars to any consuming destination within the continental United States.[2] Cathodes have until recently been available at a slight discount, indicating the

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[1]On this point it is interesting to note that some producers, before 1961, reserved a portion of their output for sales to merchants. These transactions were later largely terminated (mostly at the insistence of the copper companies operating in Africa) on the grounds that sales of this type contributed to destablizing the market, and many producers inserted "no resale" clauses in their contracts. It is probably true that similar no resale clauses are still employed by many American producers (see Banks, op. cit., p. 43).

[2]The domestic producers' price was quote delivered Connecticut Valley until July, 1950. Kennecott thereafter quoted its price as delivered anywhere within the continental United States; the other major producer did not follow suit until January, 1954.

absence of melting and casting costs. Cakes and billets, on the other hand, have sold at premiums which cover additional casting costs. In 1973, however, two major producers began referring to their cathode price as the standard producers' price in response to the use of the cathode price by the Cost of Living Council in setting ceilings on refined copper prices in the U.S.

Metals Week (formerly E/MJ Metal and Mining Markets) publishes a daily weighted average producers' price quotation based on U.S. mine production and current selling prices of U.S. producers, reduced to a delivered wire-bar basis.[1] An f.o.b. refinery quotation is also published, which represents the producers' delivered price quotation minus a standard shipping cost. This Metals Week price, or its weekly or monthly arithmetic average, published in Engineering & Mining Journal (E/MJ) is often referred to when speaking of the domestic producers' price for refined copper.[2] U.S. producers usually sell on the basis of the price prevailing on the date of shipment, regardless of when the buyer placed his order. Some sales, however, are made at the average weekly or monthly price quotation as published in E/MJ or American Metal Market; other sales may be made at a firm price prevailing on the date of the sale.

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[1]Prior to 1971, the "E/MJ domestic refinery price" represented a weighted average of the U.S. producer price and the LME price, with the U.S. producers' price getting more than 97.5% of the weight.

[2]An additional producers' price quotation is published daily in the American Metal Market; the monthly arithmetic average of these quotations is published annually in Metal Statistics. The E/MJ price reportedly reflects the prices at which copper is actually traded in the U.S. somewhat more accurately than the U.S. producers' price series; moreover, Fisher-Cootner-Baily have indicated in a past econometric study of the world copper industry that modeling results they obtained using the E/MJ price were uniformly better and more reasonable than those obtained using the U.S. producers' price series. (Franklin M. Fisher, Paul H. Cootner, Martin N. Baily, "An Econometric Model of the World Copper Industry," The Bell Journal of Economics and Management, 3, 2 [Autumn, 1972]).

During the 1947-1974 period, approximately 76% on average of U.S. fabricators' total annual consumption of refined copper was purchased at the domestic producers' price; excluding the strike years of 1959 and 1967-1968, this average figure would rise to about 78%. About 73% of total annual production of refined copper was sold at the producers' price on average; this figure is slightly lower than the consumption figure because it excludes that proportion of domestic annual production by Kennecott and Anaconda which was refined from Chilean copper and re-exported abroad to be sold at prevailing international prices.

The Outside Market and U.S. Secondary Refiners

The term "outside market" has often been used to denote all trade in copper in the U.S. other than sales of the major U.S. producers. The term has been so applied because of the dominant role played by the major producers in providing the bulk of refined copper supplies to U.S. fabricators.

Although refined copper within the U.S. could be bought on the outside market at a number of different prices during this period, including the London Metal Exchange spot and forward price, the Comex price, the E/MJ export refinery price, the U.S. merchants or dealers' price, and the custom smelter price, the two most important prices bases at which the bulk of outside market sales of refined copper quoted were the LME Price and the price set by custom refiners.

Asarco, Amax, and Cerro have been widely recognized as the principal custom refiners in the U.S. secondary copper industry during the postwar period. While the secondary character of most if not all of Amax's and

Cerro's refined copper production is beyond dispute (i.e., nearly all of their refined copper is produced from scrap), the same is not true for Asarco, which has over the years reportedly used an increasing proportion of primary ore and blister as inputs in its smelting and refining operations.

The ambiguity of Asarco's position in the copper industry is reflected in its pricing policies as well. Prior to August, 1967, Asarco sold at least some proportion of its output at a "custom smelter" price published in both <u>Metals Week</u> and <u>Engineering and Mining Journal</u>. After August, 1967, Asarco suspended the practice of quoting a custom smelter price, and generally followed producers' price quotations in its sales. Asarco executives and other industry observers have privately indicated that prior to 1967, less than 50% of Asarco's output was actually sold at the custom smelter price.

Given the ambiguity of Asarco's position prior to 1967, and the fact that Asarco has behaved essentially as a primary producer since 1967, we have classified Asarco as a primary producer in this study and have included Asarco's output in the figures for total primary refined copper production in the U.S. sold at the producers' price during the postwar period.

With Asarco thus excluded, Amax and Cerro have accounted for at least 75% of U.S. secondary refined copper production from scrap in most years since 1946, with the remainder divided among a number of small secondary refiners. These two firms can thus be considered "representative" of the U.S. secondary copper industry.

Amax and Cerro sold their refined copper output on their own individual pricing basis. We have estimated that refined copper sold on this basis accounted for an average of about 13% of total annual domestic production of both primary and secondary refined copper in the U.S. during the post-war period; sales by Amax and Cerro accounted for roughly 12% of total annual consumption of refined copper during the period.

Because both custom refiners have depended heavily on the copper scrap market for material inputs in the production of refined copper, the profitability of their operations has been dependent on maintaining flexible pricing policies which enable them to respond to fluctuations in the price of copper scrap.

A recorded historical price series for sales by Amax and Cerro is unavailable; in lieu of this, we have developed an estimated price series based on the dealers' buying price for #2 heavy copper scrap[1] and estimated annual operating margins for the two customer refiners which reflect commercial costs, operating costs, and gross profits before taxes. This is a "fictitious" price series in the sense that it does not necessarily represent actual prices charged by these custom refiners at any one point in time, but rather an approximate estimate of their average pricing behavior over the study period.

The Outside Market: Foreign Producers, the LME and Metals Merchants

The remaining 11% of annual U.S. refined copper consumption has generally come from one of three sources: directly purchased imports from foreign producers, sales on the London Metal Exchange, or purchases from U.S. metals merchants. With the exception of refined copper exported

[1] Dealers' buying price for #1 heavy copper scrap prior to 1956.

from Noranda in Canada to the United States (which has usually been sold at the domestic producers' price), imported refined copper and merchant copper has generally been sold in the U.S. on the basis of the price prevailing on the London Metal Exchange or at a price closely reflecting that price.

The major producers have refrained from selling copper in large quantities on the LME not only because their customers often require non-standardized grades and shapes of copper to suit their specific needs, but also because the Standard Contract on the LME requires physical delivery of the copper in European warehouses, a requirement which is economically prohibitive for selling copper to customers in other parts of the world.

Moreover, the major producers normally insist on the inclusion of a force majeure clause in their sales agreements; such clauses are not permitted under the LME contract system.

B. HISTORY OF REFINED COPPER PRICES

The history of refined copper prices since World War II is complicated, because of the number of different pricing bases in existence and the variety of influences of both a market and administered nature leading to changes in these different prices over time. However, in spite of the number of different prices in effect over the study period, most refined copper sales by the major U.S. and foreign producers were made directly or indirectly on the basis of either the domestic producers' price or the LME price (spot or forward quotation). Although the refined copper output of U.S. secondary refiners such as Amax and Cerro was sold at prices reflecting the price of scrap, a good deal of the movement in copper scrap prices occurred either in response to or in anticipation of movements in the LME price. The significant aspects of pricing behavior in the postwar copper industry can thus be adequately described by focusing on the history of the LME and domestic producers' prices.

Table 1 provides average annual figures for the E/MJ domestic refinery price, the LME spot price, the price for #2 heavy copper scrap (#1 heavy copper scrap prior to 1956) and the secondary refinery price, all in 1974 dollars.

As a general rule, LME Price movements have been relatively volatile and sensitive to speculative pressures and short-run shifts in copper demand and supply. By contrast, the producers' price has tended to change only slowly, usually lagging signficant trends in LME Prices by several months.

The essential facts concerning price movements and the pricing behavior which underlay them can be fairly easily grasped by dividing the entire study period into a number of smaller periods on the basis of changing supply and demand conditions in the copper industry and the particular response of copper producers to those changing conditions.

- 1947-1953: A period marked by government controls of both prices. The LME price was administered by the British Government until August, 1953. A price ceiling on the domestic producers' price was in effect from January, 1951 to February, 1953 in response to Korean War requirements.
- November, 1953-July, 1956: The period of the first so-called "two-price system" for refined copper. A sudden and excessive increase in the demand for copper led to a rapid rise in the LME

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TABLE 1

PRICES OF REFINED COPPER AND COPPER SCRAP, 1947-1974
(Average Annual ¢/lb. in Constant 1974 Dollars)

Year	EM/J Domestic Refinery Price	LME Spot Price	Secondary Refinery Price	#2 Heavy Copper Scrap Price
1947	52.44	58.74	57.94	40.43
1948	50.08	54.81	55.24	39.33
1949	42.39	48.36	46.04	30.58
1950	45.35	47.72	80.42	37.72
1951	47.13	53.63	90.22	41.54
1952	46.88	62.67	85.24	36.81
1953	54.59	60.99	86.11	42.51
1954	55.57	58.53	64.65	45.93
1955	67.77	79.36	77.04	60.77
1956	71.03	69.75	68.90	53.62
1957	48.36	44.78	54.10	32.84
1958	41.20	39.70	48.91	28.12
1959	49.29	47.14	53.04	35.65
1960	50.62	48.69	50.79	33.42
1961	47.50	45.64	52.04	34.58
1962	48.63	46.63	52.47	34.30
1963	48.63	46.65	53.54	35.27
1964	50.20	69.10	56.51	40.81
1965	54.32	90.97	73.66	53.50
1966	54.90	104.93	87.52	67.79
1967	56.81	76.15	68.58	49.26
1968	60.09	80.42	67.14	47.04
1969	65.58	91.46	78.48	59.16
1970	76.56	84.77	70.92	52.34
1971	65.32	62.58	60.42	35.02
1972	62.12	59.58	72.43	47.88
1973	68.67	94.26	84.24	58.57
1974	76.65	93.10	79.89	54.88

SOURCE: E/MJ Domestic Refinery Price: Metals Week, Engineering & Mining Journal.
LME Spot Price: American Bureau of Metal Statistics Yearbook.
Secondary Refinery Price: Arthur D. Little, Inc.
#2 Heavy Copper Scrap Price: Metal Statistics.

price; the domestic producers' price, on the other hand, was kept substantially below the market-clearing level by U.S. producers, who rationed their customers. One foreign producer, RST, also sold copper at substantially below the LME price.

- July, 1956-early, 1964: Except for a brief period of rising demand in 1958-1959, a period of generally slack world demand for refined copper characterized by decline or relative stability in both the domestic producers' price and LME prices and general equilibrium between the two price series (with LME prices maintained below the domestic producers' price, reflecting the differential cost of tariffs and transport).
- Early 1964-Late 1970: The period of the second and third "two-price systems," characterized by excess demand for copper, a very dramatic increase in the LME Price, and a wide differential between the LME price and the producers' price, which was again kept well below the market-clearing level.

  The second and third two-price systems are distinguished principally by the difference in the group of firms which participated in selling copper below the free or open market price. During the second two-price system between January, 1964 and March, 1966, all of the major foreign producers joined U.S. producers in selling at essentially the domestic producers' price.[1] Between April, 1966, and late 1970, during the third two-price system, the major

[1]Foreign copper was sold at a slight premium (generally 1.5¢/lb) reflecting U.S. tariff and transportation charges.

foreign producers returned to selling at the LME price,[1] while U.S. producers continued to sell at the domstic producers' price.

- Late 1970-early 1973: A period of slack demand and declining or fluctuating prices in which LME price quotations were generally below the producers' price. U.S. price controls on refined copper were instituted in August, 1971, but the producers price remained below the established price ceiling until April, 1973.
- Early 1973-Late 1974: A period of great instability in world copper markets characterized initially by a sharp increase in world demand and prices and ultimately by a similarly sharp decline in both demand and prices. Some increase in the producers' price was permitted by the U.S. government in December, 1973; price ceilings were formally abolished in May, 1974. Controls on the domestic producers' price remained in effect through April, 1974.

C. THE TWO-PRICE SYSTEM AND PRICING BEHAVIOR OF THE PRIMARY PRODUCERS

With respect to the pricing behavior of the primary U.S. and foreign producers, probably the most significant characteristic of postwar copper markets has been the existence in nine of the 27 years between 1947-1974 of a two-price system for refined copper, characterized by a wide divergence between (1) the free or outside market price for refined copper as represented by the LME price and (2) the price at which domestic U.S. producers and some of the major foreign producers sold their output.

[1] Noranda returned to selling within the U.S. at the domestic producers price in 1968.

The two-price system developed during periods of rising or excess demand for refined copper and was brought about when participating producers chose to ration their available copper supplies to customers at a price below the level which would have cleared the market.

As noted above, there were actually three two-price systems in effect during three different periods: (1) from November, 1954 to July, 1956; (2) from January, 1964 to March, 1966; and (3) from April, 1966 to early 1970. Each of these was distinguished principally by differences in the foreign producers who participated along with U.S. producers.

During periods when the two-price system was not in effect, either a general equilibrium existed between the LME price and the domestic producers' price, or government controls were in effect on either one or both prices.

<u>The First Two-Price System (November, 1954-July, 1956)</u>

The first two-price system was set off by a sudden increase in world copper demand at the end of 1954. Between October, 1954 and April, 1955, the LME price ranged from 4¢ to 11¢ above the domestic producers' price. Although U.S. producers raised their price twice, in January, 1955, and again in March, rationing by the producers during these months was reported in the trade press as the LME price still remained 5¢/lb. above the producers' price in April.

Then, in May, 1955, RST initiated what has been frequently called in Europe the first "producers' price experiment," when it announced that it would sell refined copper at a price approximately in balance with the then prevailing domestic producers' price--about 10¢/lb. below the existing

LME price. The announced purposes of this policy were to stabilize the price of copper and keep the price low enough to prevent long-term substitution away from copper.

During this period, Noranda adopted the policy of selling in the U.S. at the domestic producers' price and abroad at the LME price. All of the other major foreign producers continued to sell directly or indirectly on the basis of LME prices. Although the producers' price was subsequently increased somewhat, rationing by RST and the major U.S. producers continued until mid-1956, when declining demand for copper led to a rapid decline in the LME price which eventually undercut the producers' price. In October, 1957, RST returned to its earlier policy of selling at the LME spot price on the date of delivery.

Slack Demand and Support of the LME (July, 1956-January, 1964)

The demand for copper both worldwide and in the U.S. was generally slack during the 1957-1964 period. In the recession year of 1958, both the LME Price and the producers' price were lower than they had been in nearly a decade. Although demand increased somewhat in 1959 and again in early 1960, producers continued to operate at substantially below capacity.

Most notable between late 1961 and mid-1963 was an attempt by two of the African producers, RST and AAC, to prevent the LME price from slipping below equilibrium with the producers' price by cutting back on production and shipments. The result was, in effect, a single, stable world price for copper, as UMdHK and the Canadian producers continued to sell at the supported LME Price.

The Second and Third Two-Price Systems (January, 1964-Late 1970)

The second two-price system developed in January, 1964 in response to a sudden, unanticipated surge in worldwide copper demand and the LME price. The two Zambian producers--AAC and RST--had insufficient inventories to alleviate upward demand pressures; however, rather than follow the LME upward, AAC and RST initiated what came to be known as the second "producers' price experiment." The LME price was allowed to rise, and both U.S. producers and the Zambian producers began rationing their customers at a selling price well below the world free market price. UMdHK, INCO, and Noranda adopted the Zambian producers' price.[1] Excluding tariff and transport differentials, the major producers thus continued to sell at essentially a common world producers' price during the January, 1964 to March, 1966 period.

This second two-price system or "producers' price experiment" was seriously weakened by pressure from the Chilean government on Anaconda and Kennecott to increase the price at which they sold copper refined from blister imported from Chile.[2] The Chilean government was anxious to maximize short-term revenues in a period of expanding world copper demand.

Following several smaller increases, the second two-price system collapsed in early April, 1966, when Anaconda and Kennecott were forced to increase the price of their Chilean copper from 42¢/lb. to 62¢/lb. (the monthly average LME spot price in April, 1966 was 86¢/lb.). The foreign

[1] Noranda continued to sell in the U.S. at essentially the domestic producers price.

[2] The bulk of this copper was reexported for sale on the international market after being refined in the U.S.

producers refused to follow this increase, AAC, RST, INCO, and Noranda began selling at the LME three months forward price on the date of delivery, while UMdHK resumed its traditional policy of selling at an announced price which closely followed the LME price.

A third two-price system maintained only by the U.S. producers in the U.S. market was in effect more or less continuously from April, 1966 until late, 1970. Noranda sold at the LME price until August, 1968; thereafter it sold in the U.S. at the domestic producers' price and abroad at the LME price.

The third two-price system was interrupted by a strike in the domestic copper industry from August, 1967 to April, 1968. During much of this period, the domestic producers' price was suspended. Demand reportedly fell off early in 1967 because fabricators had already accumulated very large inventories in anticipation of the strike. At other times, however, demand for copper remained excessive, as reflected by the wide differential between the LME price and the price at which domestic fabricators were obtaining rationed supplies.

<u>Declining Demand and the End of the Third Two-Price System (Late 1970-1974)</u>

LME prices fell off dramatically in mid-1970 as refined copper supplies exceeded demand for the first time since 1964. This was due more to simultaneous recessionary trends in several of the developed nations than to any spectacular increase in productive capacity among the major U.S. and foreign producers.

The return of the LME price to a level below the domestic producers' price marked the end of the third two-price system. Until early 1973, the market was nearly in equilibrium as measured by the differential between LME and producers' prices; substantial incrased capacity which had been developed by the primary producers in response to the excess demand conditions of the late 1960's was sufficient to absorb growth in demand during this period. Although U.S. price controls were in effect, the producers' price remained below the effective price ceiling.

Between early 1973 and early 1974, a sudden sharp increase in demand led to a record increase in the LME. This was followed by an equally sharp decline in the LME price during the remainder of 1974. Price movements during this period were a direct reflection of simultaneous boom and recessionary cycles which developed in the world's major economies: unsettled economic conditions as well as international monetary instability led to wide-scale hoarding the speculation which exaggerated price movements during this period. Prices of the U.S. primary producers remained under government control until May, 1974; thereafter, producers increased their prices only to be met by a plummeting LME price which forced down the domestic producers' price.

D. EXPLANATIONS FOR THE TWO-PRICE SYSTEM

At least on the surface, rationing by the major copper producers during periods of excess demand and high copper prices seems totally inconsistent with the motive of profit maximization. The major producers themselves have revealed little in detail about their motives: the common rationale cited by the producers is the fear of long-run substitution for copper by end-users if copper prices are allowed to rise too high or are too volatile.

The May, 1970, report of the Houthakker Subcommittee on Copper to the Nixon Administration's Cabinet Committee on Economic Policy cited three principal explanations advanced by the industry for the second and third two-price system.[1]

In the first explanation, some industry sources argued that the persistent post-1964 gap between the LME price and the domestic producers' price was simply a matter of delayed recognition of a long-run secular rise in the equilibrium copper price on the part of producers used to ignoring short-run demand fluctuations. Producers were, in effect, continually trying to catch up with what looked like a short-run increase in the LME Price during this period.

The second and third explanations were justifications for rationing on the basis that high and volatile outside market prices were nonreflective of actual long-term trends in demand, but were rather caused by strikes, government intervention, and other short-run pressures on the market. Following the LME price under these circumstances would have invited unjustified substitution away from copper.[2]

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[1] Report of the Subcommittee on Copper to the Cabinet Committee on Economic Policy, May, 1970, pp. 9-10.

[2] Fisher-Cootner-Baily have argued that producers, in addition to fearing long-run substitution, may resist a short-run rise in the producers' price out of fear that independent miners and new entrants to the industry may take the price rise as a signal of a long-run rise in demand in the market. These independents would then open new mines and/or step up production in response to the higher price, leading to a long-run oversupply of copper and depressed prices during a subsequent period of dampened demand. They cite little evidence in support of this hypothesis, however. Fisher-Cootner-Baily, "An Econometric Model of the World Copper Industry," op. cit., p. 573.

Long-Run Substitution as an Industry Problem

Long-run substitution (LRS) has been a concern in the copper industry since 1947, when the price of copper went above the price of aluminum for the first time. Industry observers are not in complete accord on the prevelance and importance of LRS, but it is generally agreed that LRS is an important consideration in some of the markets for copper but not in others.

The most important instances of LRS are in telephone conductor cable and automobile radiators. Both of these require technological changes and are, as yet, largely potential areas of substitution. Conductor cable and automobile radiators account for roughly 25% to 30% of total demand for primary copper in the United States. There is also clearly LRS in the demand for copper electric transmission cable, and the possibility of LRS in the demand for several other markets has been mentioned in the trade press. In general, LRS is present in most of the markets for copper wire, and these constitute 60% of the demand for refined copper.

The defining characteristic of LRS for copper is the need for new investment to effect the substitution. Investment may simply be a matter of purchasing existing types of equipment or may require technological innovation. In either case, it is a high-cost move which is likely to be undertaken only in the face of consistently high and/or fluctuating copper prices which indicate that substitution will be justified in the long run on a cost basis. Similarly, the substitution process is unlikely to be reversed unless copper prices fall sufficiently below former levels to both cover the costs of reinvestment in copper-using equipment and provide significant long-run savings.

Excess Demand and the Producers' Dilemma

David McNicol in his study of the two-price system[1] argues that in the face of a sudden unanticipated surge in demand for the refined copper, producers have three alternatives:

- They can choke off demand by letting refined copper prices rise freely, in the process stimulating LRS (and, by implication, a loss of long-run profits);
- They can maintain the price at a level below that which they believe will stimulate LRS and still continue to supply the entire market demand by stepping up output; or
- They can maintain the price at a level below that which will stimulate LRS and ration their production at existing levels, at the same time expanding long-run capacity to bring down the equilibrium price level.[2]

The first alternative implies an unacceptable loss of substantial long-run profits. Under the second alternative--assuming the producers

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[1] David McNicol, The Two-Price Systems in the Copper Industry, unpublished Ph.D. thesis, Massachusetts Institute of Technology, February, 1973.

[2] Short-run production planning in the copper industry is generally done on a five to six months' basis. Orders for semi-fabricated products are usually placed a month in advance of delivery and the processing of refined copper from mine output typically involves a three-month period.

Expanding capacity in an existing mine generally requires eighteen months to three years; however, this involves effectively shortening the life of the mine.

Although there is generally a ten to fifteen year lag between the decision to bring a major copper deposit into production and the beginning of production, the major producers typically have one or more mining projects through the "exploration" stage of development. From that point, the development period is generally the same as that required to expand capacity in an existing mine.

Thus, for planning purposes, the short run involves at least a period of 6-18 months from a given date, and possibly as long as three years, while the long run would prevail at some point between 18 and 36 months in the future and would continue into the indefinite future.

have the capacity to meet existing demand in the short-run--McNicol argues it is entirely possible that producers will have to operate so near to capacity that their short-run marginal costs will rise above the mamimum price level at which they can sell and still avoid LRS.

Rationing would appear to be the desirable alternative. However, the problem with explaining rationing as a producer response to the threat of long-run substitution is that, as the rationing process is usually described by the producers, rationing would be a self-defeating process.[1]

The key to preventing long-run substitution lies not in keeping down the price of the producers' refined copper per se, but in preventing an unacceptable rise in the price of semifabricated and fabricated copper goods, since substitution decisions will be made at this latter stage of the manufacturing process.

Yet according to McNicol as soon as producers begin to ration semi-fabricators these semifabricators will either be unable to supply the demand of their fabricator customers for semifabricated inputs, or they will have to turn to the outside market to obtain their remaining refined copper needs to meet the fabricators' demand. In both cases, the price of fabricated goods will rise: in the former instance, because of excess demand for fabricated output; in the latter instance, because semifabricators will price their output along their new or shifted (industry) marginal cost schedule[2] at the point where the new marginal cost schedule intersects the industry demand schedule. Their marginal cost will equal the outside market price for refined copper.[3]

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[1]Producers have, undoubtedly, been aware of this fact, as it has been frequently mentioned by industry observers in the trade press.

[2]The upward shift in the marginal cost schedule is occasioned by the difference between the outside market price and the pre-rationing primary producers price.

[3]This assumes a largely competitive market for semifabricated goods, a not unreasable assumption given the relatively low degree of concentration in the domestic industry.

Assuming a general policy of across-the-board rationing on the part of the major producers, in the face of excess demand, rationing might turn out to be a less beneficial policy than simply letting the price of refined copper rise freely.[1] At least in the latter case, producers would be able to take advantage of the significant short-run profit gains.

The producers' dilemma thus arises from the fact that no matter which alternative policy a producer adopts in the face of a sudden unanticipated increase in demand, the economics of the industry (specifically, the low short-run elasticity of supply and the high long-run elasticity of demand) dictate that a producer may suffer negative consequences.

This assumes that producers ration their customers across-the-board and do not discriminate among types of fabricators. The specific procedure used in allocating producer copper during the two-price systems have never been explained in detail by the producers. However, the Houthakker Subcommittee report described a <u>de facto</u> allocation system in effect during the second and third two-price systems based on two general principals. First, all of the producers reportedly used some historical supply pattern from the period 1961-1963 as the basis for determining allocations: customers as of that period were to be retained, if possible. In addition, however, producers reported that they made additions to and deletions from this base list on the basis of "the best long-run interests of the firm." This second principal obviously left producers a great deal of room for altering historical supply relationships when it was considered necessary or desirable to do so.

Thus, the Subcommittee found through direct communication with semifabricators that, although a general correlation did exist between the pattern

[1] Whether or not it is ultimately less beneficial depends on the precise cost schedule facing fabricators, as well as the degree of discretionary pricing which fabricators (as opposed to semifabricators) are capable of practicing--two areas which McNicol does not specifically analyze.

of allocation and the pattern of supply during the 1961-1963 period, at times significant changes had occurred as well. Some customers received only 40% of their refined copper needs from the major producers, whereas earlier they had met 75-80% of their needs through producer copper. Other firms found their allocations sharply increased.[1]

McNicol's Solution to the Producers' Dilemma

David McNicol has proposed a solution to the producers' dilemma based on the fact that (1) some refined copper markets, such as wire mills, have a much higher propensity for LRS than other markets, such as brass mills, and (2) indirect price evidence indicating that production have at times rationed markets selectively on the basis of their propensity for LRS.[2]

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[1] Evidence concerning allocation procedures during the first two-price system is equally spotty. In the 1964 Federal Court decision requiring Kennecott Copper Corporation to divest itself of Okonite, a wire and cable firm which it had acquired in 1958, the Court found no evidence supporting the Government's contention that Kennecott had favored its own subsidiaries at the expense of its independent customers during the first two-price system and again in a high demand period in 1959.

[2] Briefly, McNicol argues that, given existing conditions in the U.S. wire mill and brass mill industries, the differential between the price of wire mill products and refined copper and the price ot brass mill products and refined copper should remain constant if fabricators are not rationed. On the other hand, if either wire mills or brass mills are rationed, the differential between the prices of their products and that of refined copper should widen, since the marginal price of copper inputs will be the price on the outside market. This argument assumes that: (1) The unconcentrated nature of the wire and brass mill market results in the price of fabricated goods equalling marginal cost; (2) Marginal cost is equal to the price of metal inputs plus marginal processing costs; (3) Marginal processing costs remain constant until capacity is reached; and (4) Capacity is generally greater than output in the two industries.

McNicol's argument requires that producers' markets be segmented; in other words, that it be impossible for unrationed fabricators to resell part of their supplies to rationed fabricators at a price approaching the outside market price. RST and AAC reportedly inserted "no resale" clauses on their sales contracts during the second two-price system; no apparent legal restrictions exist to prevent foreign producers from following this policy. U.S. producers might face antitrust prosecution if they did the same, but it is likely that producers were able to discourage resales by firms in unrationed markets, given their control over the supply of primary copper.

Brass mills and wire mills have, together, accounted for roughly 83% of refined copper demand in the past. If producers were to ration brass mills while continuing to supply most, if not all, of the needs of wire mills, producers could continue to produce at the same level of output, while avoiding both LRS and the need to operate in the short run at a loss or near loss. In other words, selective rationing would allow producers to significantly improve their short- and long-run profit position compared with the profit potential of the three alternative policies mentioned above.

Domestic U.S. brass mills were, indeed, rationed and wire mills not rationed during the first two-price system (1955-1956) and during the first half of the second two-price system (1964-mid-1965).

Unfortunately, the same evidence forces McNicol to conclude that domestic wire mills were rationed along with brass mills through the second half of the second two-price system (mid-1965 to 1966) and throughout the third two-price system (1966-1970). Besides the existence of across-the-board rationing after 1965, the revised LRS explanation cannot explain why producers continued to ration supplies after 1966, by which time they should presumably have been able to overcome short-run capacity limitations and increase output to meet the stepped-up demand.

McNicol's Second Explanation for Producer Rationing

Faced with this problem, McNicol develops a second alternative explanation for producer rationing designed to explain both the rationing of wire mills after 1965 and continued rationing beyond the period required to expand long-run capacity. This second solution, termed the "quantity discrimination" (QD) motive for rationing, is based on the observation that all of the U.S. producers and some of the foreign producers are partially integrated, possessing their own captive semifabricating subsidiaries, for the most part, in the form of wire mills.

McNicol argues that during periods of rising or high demand, semi-integrated producers would have found it possible to increase their profits at the semifabrication stage by cutting back on the total quantity of refined copper they would supply to both their own subsidiaries and to independent fabricators. The price of fabricated goods would be bid up, either because fewer fabricated goods would be brought on the market or because the cost of purchasing marginal quantities of outside market refined copper would force an increase in the marginal cost of producing fabricated goods.

In essence, the semi-integrated producer would be acting as a monopolist to regulate the availability of supplies and thereby the market prices at which fabricated goods were sold. While the producers' costs of refining copper inputs to fabrication would remain the same, the increased selling price of his subsidiary's fabricated output would provide him with an increased profit margin.[1]

It should be noted, of course, that this profit gain would be obtained at the possible expense of LRS among wire mill customers, who might be stimulated to switch to alternative materials because of the increased price of wire mill products.

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[1]The actual profit gain which a semi-integrated producer could realize would depend on the demand elasticity for fabricated goods and his own marginal cost schedule. Also relevant would be the marginal cost schedule of the producer's semifabriactor subsidiaries, which might, or might not, purchcase additional copper on the outside market.

The Problem of the Pattern of Participation

While the revised LRS motive and the QD motive in combination offer at least a theoretically logical explanation as to why U.S. producers rationed during the three two-price systems, the use of neither motive can fully explain the irregular pattern of participation by the major foreign producers during these periods.

AAC, INCO, and UMdHK rationed during the second two-price system between 1964 and 1966, but not during the first and third. The non-integrated nature of these firms means that they would not have rationed for the QD motive. However, if they did ration during the second two-price system for the LRS motive, why not during the first and third? McNicol suggests that because producers do not have identical costs and do not sell in precisely the same markets, rationing might have been profitable at times for some of the major producers while not profitable for others. In other words, these three producers might have been faced with less of a threat of long-run substitution in their European markets or might have been better able to expand production levels in the short run without a corresponding loss of short-run profits. But this line of reasoning is primarily conjectural, with little firm evidence offered to support it.[1]

RST and Noranda, on the other hand, are both partially-integrated firms which would have had both the LRS and QD motives for participating. While both participated in the first and second two-price systems, RST failed to participate in the third two-price system after 1966.

[1]McNicol refers to Fisher-Cootner-Baily's estimates of a much lower European long-run demand elasticity for copper compared with long-run demand elasticity in the United States. As McNicol points out, however, the weakness of this line of argument lies in the absence of barriers dividng the European market from the domestic U.S. market.

McNicol explains this by suggesting that the "Zambianization" of the RST and AAC firms from early 1967 onward might have had an effect on the willingness of the firms to participate, since the government of Zambia was probably concerned with maximizing short-term revenues. However, RST went off the producers' price in April, 1966; and the Zambian Government did not acquire the legal power to regulate the price of Zambian copper until 1968. McNicol cites no other evidence to support the implication that the producers were attempting to placate the Zambian Government in 1966 by shifting back to the producers' price.

Weaknesses of Available Explanations for the Two-Price System

In summary, there appears to be no complete, simple, logical explanation or set of explanations for the rationing behavior of the principal U.S. and foreign producers during the periods of the two-price system. The producers themselves, if they are aware of such an explanation, have declined to discuss it publicly. All of the available explanations are either logically inconsistent and/or are unable to explain certain "anomalous" behavior on the part of the producers.

The underlying weaknesses of both the revised LRS explanation and the QD explanation for rationing lies in the difficulty of obtaining or developing quantitative data to support these theories. In terms of the LRS motive, as McNicol himself points out, it is almost impossible to accurately estimate, for any one point in time, the price at which copper end-users will begin switching to alternative materials (i.e., the long-run elasticity of demand for copper).

To assume that producers themselves based their pricing behavior on any more perfect knowledge of potential behavior on the part of copper end-users may be misleading. In addition, the revised LRS explanation ignores a multitude of non-price factors, such as institutional rigidities, expectations of technological change, and the like, which may be reasonably expected to have exerted an important influence on LRS decisions.

In terms of the QD motive, it is similarly impossible to accurately estimate at just what combination of copper prices, long-run demand elasticity in fabricator markets, and producer marginal cost schedules producers would have faced a situation where they could gain more profit from practicing quantity discrimination than they would lose from LRS as the price of copper rose or remained relatively high.

This lack of quantitative data leaves a number of questions unanswered. For example, since rationing for the QD motive has a stimulative effect on LRS (by forcing up copper prices or maintaining them at a high level), accepting the QD motive for rationing requires accepting the idea that after 1965 producers felt that they would gain greater profits by rationing wire mills as well as brass mills than they would lose through LRS for wire mill products. But, if this was the case, why did producers not ration wire mills prior to 1965? Did their perception of long-run demand elasticity change? Were they proceeding on a trial-and-error basis? Questions such as these cannot be satisfactorily answered given present information.[1]

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[1]McNicol hypothesizes that domestic producers may have initially begun rationing wire mills in the autumn of 1965 in response to a foreign producers' price increase which U.S. producers were not allowed to match because of U.S. Government pressure to maintain price guidelines then in effect. Although the needs of domestic wire mills were assumedly being met, the price differential between U.S. and foreign refined copper led to a price differential between U.S. and foreign wire mill products. Higher wire mill product prices abroad would have stimulated a significant growth in wire mill product exports from the United States. This, in turn, would have strained the capabilities of U.S. producers to continue to meet all of the demand of the U.S. wire mills for refined copper. Rationing would have solved this problem by bidding up the price of U.S. wire mill products. The problem lies in explaining domestic rationing of wire mills after January, 1966, when U.S. controls were placed on wire mill product exports.

CHAPTER 7

FINANCIAL CHARACTERISTICS OF THE U.S. COPPER INDUSTRY AND THE PRINCIPAL COMPANIES

A. INTRODUCTION AND SUMMARY

In this chapter we present data on and discuss the operations of the principal companies which account for most of the primary copper production in the United States. We have in certain cases assembled data covering the decade 1964 through 1974, and in other cases have chosen the year 1974 for comparisons. Full data for 1975 were not yet available during the course of our work, although they became available for most of the companies just before going to press. We incorporate 1975 information as appropriate (e.g., in regard to EPA matters) and to the extent it was feasible to do so. In any event, the use of 1974 as the base and/or last year for much of the analysis is consistent with the calculations and perspective employed elsewhere throughout this study.

The remainder of this chapter is organized into three major sections. First, Section B contains an overview of the financial performance of the principal firms in the industry, based on comparisons of company financial and operating data. This is followed, in Section C, by a discussion of patterns of ownership structure, inter-firm relationships and extent of vertical integration. Next, Section D presents a review of the capital needs of the major firms in the industry and sources of capital. An analysis of foreign sales and earnings of the major producers is addressed next in Section E. Finally, Section F contains a detailed examination of trends in debt and debt-equity ratios, the term structure of debt, and the amount and means of pollution control financing.

A detailed description of the activities of each of the major producing companies is provided in Appendix A to this chapter which has been prepared for further reference.

The basic points emerging from this chapter can be summarized as follows:

1. Eleven principal companies account for most of the primary copper production in the United States. The largest producers are vertically integrated from the mining stage through fabrication of copper and brass mill products. The principal producers are publicly-owned companies whose shares are traded principally on the New York Stock Exchange. The aggregate book value of their corporate assets was approximately $17 billion, and the market value of their common stocks totalled about $8 billion at year-end of 1975.

2. Overall profitability for the copper producers, in terms of operating margin on sales, has declined from about 23% in 1967 to 19% in 1974. Over the same period, profit margins for large industrial companies and manufacturers in general was rather stable. In terms of after-tax return on stockholders' equity, copper producers have shown a rate of return equal to the FTC average for all manufacturing. However, the copper industry has been characterized by much greater volatility in its rate of return.

3. The copper industry is capital intensive with typically more than one dollar of assets behind each dollar of annual sales. Inventory turnover, however, is relatively high. By-product recovery operations,

especially for precious metals, and co-products such as molybdenum, have been at times relatively significant to several companies; however, they play a minor role in long term investment decisions regarding industry growth and new copper mining capacity and at best an imperceptible role in short-run price-output decisions.

4. Several of the major copper producers are also normally involved in the production of lead and zinc, and others are engaged in primary aluminum production and/or fabrication. A few producers participate jointly in foreign copper mining companies, notably in Africa, Canada, and South America; these companies derive 20-25% of total sales, and a higher percentage of their after tax earnings from foreign operations.

5. Given access to ore bodies, the major barrier to entry into the industry is the size of capital requirements, where the long-term investment is highly risky in the face of a great deal of uncertainty surrounding copper prices.

The minimum efficient scale of operations today would involve about 100,000 annual short tons of capacity. Investment requirements amount to approximately $1,600/ton for the mining and milling stage, and $3,400/ton for smelting and refining capacity (in 1974 dollars), so that provision for integrated or full coverage of new capacity through refined metal production would require a commitment of about $500 million.

The expected economic lifetime of investments is typically very long. Such investment is rendered highly risky because of crucial dependence of the success of such investment on the price of copper, which has been highly volatile.

Because ore bodies frequently involve lead, zinc, silver, and/or other metals of potential interest in addition to copper, and because of the riskiness of massive investments, the interests of the companies in nonferrous metals projects are frequently intertwined. Joint ventures, which constitute a means of diversification and pooling of risks, have consequently become quite common in the industry.

6. Several major oil companies, which have considerable cash flow for investment, and which have been diversifying their own holdings of mineral resources, have, not surprisingly, recently taken an interest in developing copper properties or have made investments in some of the principal producing companies.

7. The financial performance of the companies suggests that firms in the industry are typically long-term profit maximizers, with an operative target rate of return on investments. Their pricing behavior as discussed elsewhere, is always with an eye toward constant long-term competition from aluminum. Their own interests in aluminum, while this represents a small percentage of the aluminum industry, constitutes for them a natural long-term diversification strategy.

8. Capital expenditures by most companies increased sharply in recent years. A significant portion of the total industry capital expenditures (i.e., about 25%) has been for pollution abatement, mostly associated with SO_2 control at smelters. About 60% of the total, however, represents investment in mining and milling capacity. Aggregate capital expenditures have averaged about 12% of gross plant in recent years; this is about three times the level of depreciation charges.

9. With capital expenditures increasing faster than internal cash generation (from earnings, depreciation, and defined taxes), the cash-flow position of the companies has deteriorated. Consequently, there has occurred in recent years a sharp increase in external financing.

10. Long-term debt and stockholders' equity have both been increasing for the copper producing companies over the last five years. However, while overall debt has approximately doubled during this period, equity has increased by less than 35%. As a result, debt-equity ratios for most companies have increased significantly. Indeed, some companies are believed to have temporarily reached prudent limits to debt in their capital strucutre, and, as of 1975, awaited higher earnings and stock prices to restore balance and financing flexibility.

B. FINANCIAL PERFORMANCE

1. General

Table 1 presents a financial overview of the U.S. primary nonferrous metals industries for the most recent five-year period, based on Federal Trade Commission data complied for Enterprise Standard Industry Classification number 33. The picture has been one of modest growth in sales, lower turn on invested capital, eroding profit margins, and higher debt. Of course, this composite is the net effect of aluminum, copper, lead, and zinc combined. Aluminum and lead-zinc subindustries have to be analyzed separately but in general the composite accurately reflects the pressures of the last five years of inflation, higher costs of capital, increased capital requirements for environmental controls, and the worst recession in many years.

2. Copper Companies

a. Summary Comparisons

Tables 2 and 3 present selected financial statistics for the principal U.S. copper producers. These tables compare parameters which are believed to be particularly important from the standpoint of the impact analysis. More detailed summary financial data for each company are presented in the Appendix.

b. Profitability

Table 4 presents a 10-year record of return on stockholders' equity by company. Table 5 compares the company data to the FTC average for all manufacturing companies. Because the FTC data and the company data are not necessarily on the same accounting basis (e.g., the latter are likely to be inflated by inventory profits to a lesser degree) and cover a period when wage and price control anomalies existed, it cannot be asserted that differences in the average rates of return observed are statistically significant. However, the indications are that the volatility of returns

TABLE 1

FINANCIAL STATISTICS--PRIMARY NONFERROUS METALS CORPORATIONS

	1969	1970	1971	1972	1973	1974
	(in billions of dollars)					
Sales	21.45	21.00	18.61	18.82	24.77	28.98
Net Bef. Fed. Inc. Taxes	2.24	1.87	0.88	1.05	2.11	2.67
Net Income	1.42	1.29	0.62	0.69	1.34	2.04
% Net Income to Sales	6.6	6.1	3.3	3.7	6.9	7.0
Rate of Profit on Stockholders' Equity %						
Before Fed. Inc. Taxes	20.7	10.3	4.8	9.0	21.6	12.7
After Fed. Inc. Taxes	13.0	7.6	3.8	5.6	15.3	8.6
Cash Dividends	0.57	0.61	0.51	0.37	0.54	0.48
% Dividend to Net Inc.	40	47	82	54	40	24
Balance Sheet Data						
Cash and Govt. Secs.	1.08	0.99	0.91	0.92	1.15	1.27
Receivables	2.94	2.83	2.32	2.88	3.27	3.14
Inventories	4.29	4.59	4.10	4.27	3.75	4.84
Total Current Assets	9.02	9.04	7.85	8.66	8.59	9.57
Bank Loans	0.64	0.73	0.53	0.64	0.38	0.59
Total Current Liab.	3.86	4.13	3.28	3.69	3.77	4.62
Current Ratio	2.3-1	2.2-1	2.4-1	2.4-1	2.4-1	2.1-1
Cash Ratio	0.3-1	0.2-1	0.3-1	0.3-1	0.3-1	0.3-1
Long-term Debt	5.48	6.14	5.91	5.99	5.54	5.79

Source: Federal Trade Commission and Standard and Poor's Corporation.

TABLE 2

SELECTED FINANCIAL STATISTICS FOR PRINCIPAL U.S. COPPER PRODUCERS -- 1974 BASE

COMPANY (in order of copper production '74)	Sales per $ Assets	TOTAL SALES ($ M)	$MM Value of Primary Copper Production @ 75¢/lb	Value of Primary Copper as % Co Sales	Common Stock Million Shares	1974 $ Earnings per share Common	Year-end Inventory Turnover (times)	U.S. Copper Production-1974 lbs per share	Gold Production in Troy Ounces per Share Common	Silver Production Ounces per Share	Aluminum Production lbs. per share	Characteristic Growth Rate -Last 5 Years[a]: Sales	Characteristic Growth Rate -Last 5 Years[a]: Earn./Share	Δ EPS per Δ 5¢/lb Price of US Copper*
KENNECOTT	0.77	1,664	$603 MM	36%	33.2	5.08	11.0	24.2	.011	0.10	--	13.0%	3 5%	$1.21
PHELPS DODGE	0.69	1,026	421	41	20.6	5.47	5.1	27.3	nil	0.14	13.6[b]	9.5%	8.0	1.36
ANACONDA	0.86	1,673	285	17	22.0	4.83	7.0	17.3	nil	.162	27.1	2.5%	-5%	0.87
NEWMONT MINING	0.49	548	225	41	24.6	4.55	4.0	12.2	.008	.008	--	15.5%	6.5%	0.61
PENNZOIL (Duval)	0.6[c]	942	197	21	32.1	3.67	7 5[c]	8.2	nil	0.04	--	32%	29%	0.41
CYPRUS MINES	1.0	424	150	35	10.5	5.06	6.0	19.1[d]	nil	nil	--	26%	12.5%[e]	0,96
AMAX	0.66	1,164	149[i]	13[j]	23.9	5.61	8.2	8 3[i]	.042	1.10[f]	8.5[g]	13%[h]	10%	0.41
ASARCO	1.0	1,344	124	9	26.7	4.71	6.0	6.2	nil	2.05[f]	--	11%	6.5%	0.31
COPPER RANGE	0.91	169	101	60	2.34	7.66	5 6	57.3	nil	0.21	--	13.5%	0%	2.87
INSPIRATION CONS.	0.63	97	84	87	2.42	3.92	7 0	46.3	nil	.06	--	12.5%	10.5%	2.31
CITIES SERVICE	1.0	2,806	61	2	26.9	7.58	10.0	3.0	nil	nil	--		12.6%	0.15

NOTES:

[*] The figures are presented on a pre-tax basis, *ceteris paribus*. Excludes foreign price change effects, which would be important in some cases.

[a] As computed by Value Line Investment Survey, February 27, 1976, for the Metals & Mining companies; and as computed by ADL for Cities Service and Pennzoil. Growth in Earnings/Share 1964-1974 for the Fortune 500 largest industrial companies averaged 9.5%/year.

[b] Share of Conalco production.

[c] Excludes United Gas Pipe Line Co., which was spun off.

[d] Includes minority shares of Pima's production.

[e] Before effects of expropriation by Peru of Marcona subsidiary assets.

[f] Mostly refined under toll agreements. Asarco equity in mine production amounts to 0.3 oz per share.

[g] 50% share of Alumax production.

[h] Amax now reports sales on a restated basis to include Alumax, Inc. (1974 sales of $464 million) on an equity basis.

[i] Refined copper for own account, approximately 25% of which is derived from U.S. mines, 75% from scrap and/or foreign material.

[j] Actually 17% of 1974 sales, due to sale at higher prices.

SOURCE: Arthur D. Little, Inc. estimates.

The information presented above has been obtained from company annual reports and SEC filings, statistical services, financial manuals, and other sources believed to be reliable, but its accuracy and completeness are not guaranteed.

While reasonable care has been taken in data compilation and presentation, we cannot guarantee absolute comparability from one company to the next, due to differences in the nature of earnings, and differences in accounting. However, to the best of our knowledge, the above data present an accurate and meaningful basis for selective comparisons.

TABLE 3

SUMMARY OF SALIENT FINANCIAL ASPECTS OF U S COMPANIES

Company	1974 Production Sales Value Primary Copper @ 75¢/lb $MM	1971-1974 Average Operating Margin on Total Company Sales	Total Average Capital Spending 1972-1974 $MM	Level of Operating Profit @ 75¢/lb. Copper, Co. Average Margin Only on Primary $MM	Normal Employment Levels[c] Mining, Smelting and Refining	Long Term Debt 12-31-75 % Total Capitalization	Common Stock at 12/31/75	
							Book Value $/Share	Market Value % Book
Amax	$149	15.1%	$ 227	22.5	1,500	27%	42.7	111
Anaconda	285	10.2	145	29.1	5,500	28[d]	54.8	31
Asarco	159[f]	6.7	101	10.7[f]	3,400	28	32 2	41
Cities Service	61	17.5[a]	370	10.7	2,000	32	60 5	64
Copper Range	101	13 4	6	13 5	2,800	23	44.9	41
Cyprus Mines	150	31.7	43	47.6	2,000	23[e]	29 4	74
Inspiration Consolidated	113[b]	24 4	29	27 6	2,200	26	35.1	59
Kennecott	603	19.0	187	114.6	11,000	21[d]	42.2	73
Newmont	225	29.9	48	67.3	4,400	27[e]	26.4	87
Pennzoil (Duval)	197	15.9	267	31 3	2,600	55[e]	15.5	125
Phelps Dodge	421	20 4	182	85.9	7,500	37	43.4	84

NOTES: [a]Figure used in Standard and Poor's Copper Composite Average.

[b]Figure used is 1973 deliveries basis, 1974 figure not representative due to production difficulties.

[c]The employment level in U.S primary copper production totals 45,000 for the above companies

[d]Total capitalization includes capitalized lease obligations

[e]Total capitalization includes minority interests.

[f]Based on total Asarco mine production. U S. only was 78% of this. Average earnings from primary metals sales were $44 million pre-tax. If prorated based on sales, copper would have accounted for $12.8 million.

SOURCE. Arthur D. Little, Inc. estimates.

The information presented above has been obtained from company annual reports and SEC filings, statistical services, financial manuals, and other sources believed to be reliable, but its accuracy and completeness are not guaranteed

While reasonable care has been taken in data compilation and presentation, we cannot guarantee absolute comparability from one company to the next, due to differences in the nature of earnings, and differences in accounting However, to the best of our knowledge, the above data present an accurate and meaningful basis for selective comparisons

TABLE 4

OVERALL RATE OF RETURN: PERCENTAGE NET INCOME TO NET WORTH

Company	1965 (%)	1966 (%)	1967 (%)	1968 (%)	1969 (%)	1970 (%)	1971 (%)	1972 (%)	1973 (%)	1974 (%)
AMAX	18.9	16.9	13.0	13.1	12.5	13.7	8.9	10.1	12.5	15.8
(Tax Rate)	(25)	(21)	(19)	(22)	(28)	(23)	(20)	(27)	(30)	(27)
Anaconda	7.2	11.2	8.8	8.0	8.5	5.7	-30	13.6	8.3	19.5
(Tax Rate)	(50)	(49)	(57)	(54)	(54)	(11)	(credit)	(4)	(24)	(34)
Asarco	14.6	17.7	13.3	12.5	15.5	13.1	6.8	7.2	14.7	14.6
(Tax Rate)	(NA)	(30)	(23)	(15)	(21)	(22)	(11)	(17)	(17)	(21)
Copper Range	12.4	11.4	0.8	11.5	15.9	8.9	- 3.4	-2.5	10.0	15.0
(Tax Rate)	(24)	(22)	(45)	(21)	(19)	(29)	(Credit)	(Credit)	(37)	(28)
Cyprus Mines	10.9	12.6	13.1	13.7	13.6	14.4	13.4	12.8	15.4	17.2
(Tax Rate)	(30)	(27)	(17)	(23)	(31)	(26)	(35)	(20)	(31)	(36)
Inspiration Consolidated	13.3	12.1	6.0	11.6	24.1	27.1	12.5	15.8	16.7	10.4
(Tax Rate)	(22)	(25)	(10)	(14)	(43)	(33)	(28)	(27)	(4)	(14)
Kennecott	12.3	13.6	7.9	10.9	14.9	15.8	7.3	7.3	12.2	11.7
(Tax Rate)	(50)	(52)	(36)	(26)	(28)	(30)	(15)	(16)	(26)	(29)
Newmont	*	*	*	*	17.4	18.1	12.3	9.8	18.3	17.8
(Tax Rate)					(34)	(32)	(19)	(22)	(27)	(27)
Phelps Dodge	14.6	16.4	9.9	11.9	15.2	16.4	10.4	11.0	13.4	12.6
(Tax Rate)	(38)	(41)	(34)	(33)	(32)	(37)	(35)	(35)	(38)	(25)
Averages:										
Pre-Tax Returns	19.7%	20.9%	13.0%	17.2%	22.5%	20.3%	5.5%	12.0%	18.2%	18.9%
After Tax Returns	13.0%	14.0%	9.1%	11.7%	15.3%	14.8%	4.2%	9.5%	13.5%	13.8%
Tax Rate	34 %	33 %	30 %	32 %	32 %	27 %	23 %	21 %	26 %	27 %

*Newmont became an operating company with the merger of Magma Copper in 1969.

TABLE 5

RATES OF RETURN ON STOCKHOLDERS' EQUITY

	FTC All Manufacturing		Simple Average of Major Copper Companies		MEMO - Inflation Rate (Based on GNP deflator, Index 1958 = 100)
	Pre-Tax (%)	After Tax (%)	Pre-Tax (%)	After Tax (%)	(%)
1965	21.9	13.0	19.7	13.0	1.8
1966	22.5	13.5	20.9	14.0	2.7
1967	19.3	11.7	13.0	9.1	3.5
1968	20.8	12.1	17.2	11.7	3.3
1969	20.1	11.5	22.5	15.3	4.9
1970	15.7	9.3	20.3	14.8	5.5
1971	16.5	9.7	5.5	4.2	4.4
1972	18.4	10.6	12.0	9.5	3.6
1973	21.8	13.1[a]	18.2	13.5	5.5
1974	23.4	14.9[a]	18.9	13.8	10.4
Averages	20.0	11.9	16.8	11.9	N.A.
Standard Deviation (%)	2.6(13%)	1.8(15%)	5.2(31%)	3.4(29%)	N.A.

Sources: Division of Financial Statistics, Federal Trade Commission, Quarterly Financial Report for Manufacturing, Mining, and Trade Corporations, 1975 eds.; and Arthur D. Little, Inc.

[a] Fortune 500 ALL-INDUSTRY MEDIAN was 12.4% in 1973 and 13.6% in 1974.

has been greater over the period for the copper companies--i.e., their business would appear to be risker than the FTC average.

Table 6 indicates furthermore that profitability in the copper industry, in terms of operating margins on sales, has declined over the last ten years whereas that for industrials generally has been maintained.

c. Special Characteristics

Table 2 indicates that:

- The industry is capital intensive, with typically more than $ of assets behind each $ of annual sales.
- By-product gold and silver production can be quite important to the earnings of Asarco, Amax and Copper Range (silver); Kennecott and Newmont (gold). By the same token, industry joint-cost allocation and custom smelter contract practices can obscure the economies at various levels.
- A 5¢/lb. change in the price of copper has a major impact on Copper Range, Inspiration, and Pennzoil earnings per share.
- Aluminum production is now also a major factor in Anaconda's and Phelps Dodge's earnings outlook.

TABLE 6

TRENDS IN OPERATING PROFIT MARGIN

	Percent of Sales	
Year	Large Industrial Companies[1]	Major Copper Companies[2]
1964	15.9%	22.7%
1965	16.2	26.5
1966	16.4	29.3
1967	15.5	23.9
1968	15.8	22.9
1969	15.4	27.8
1970	14.5	23.4
1971	14.6	15.5
1972	15.0	16.6
1973	15.8	19.1
1974	15.4	18.7

[1]Standard and Poor's composite data, 425 industrials.

[2]Standard and Poor's composite data, based on Anaconda, Copper Range, Inspiration Consolidated, Kennecott Copper, Newmont Mining, and Phelps Dodge.

C. OWNERSHIP PATTERNS

1. Ownership

The principal producers of copper are publicly-owned companies whose shares are traded on the New York Stock Exchange (and some on the regional exchanges). The aggregate book value of their total corporate assets waw approximately $17 billion, and the market value of their common stocks totaled approximately half this (i.e., $8 billion) at year-end 1975.

We have not made a detailed study to determine the major shareholders of these companies. However, in view of several major recent proposed changes in ownership which have been widely publicized, we shall review briefly the pattern which has emerged and offer such comments as seem appropriate.

a. Asarco, Kennecott, Newmont and Phelps Dodge

Shares are widely held, as are Cities Service and Pennzoil.

b. Amax - Copper Range

For a number of years Amax held a 20% equity position in Copper Range. In late 1974, an agreement in principle was reached between the companies to merge Copper Range into Amax. In 1975, the Department of Justice sued to block the merger on antitrust grounds. Also in 1975, Amax sold a block of its stock to Standard Oil of California, which now holds approximately 20% interest in Amax. An additional 12% is held by Selection Trust Ltd.

(Selection Trust Ltd., a diversified mining and financing company primarily concerned with minerals development, is affiliated with Charter Consolidated, Ltd., in London, which in turn is prominently identified with such companies as Rio Tinto Zinc Corporation, Ltd., and Anglo-American Group companies).

Amax has stated that if consummated, the proposed acquisition should enable Amax to develop a portion of the Michigan copper deposits it has under lease near the Copper Range holdings. The proven ore reserves in Michigan that would be mineable upon the acquisition would total 121 million tons with an average grade, fully diluted, of 1.20% copper. Of this total, 18 million tons are now under lease by Amax.

An even greater tonnage of possible reserves is estimated to lie deeper than the current maximum mining depth of 2,200 feet.

c. Cyprus Mines - Pima

A major shareholder block in the case of Cyprus Mines is the family of H. Mudd, who, together with associates, represent about 31.5% of the voting power.

Cyprus consolidates the operations of Pima Mining Company--the 7th largest U.S. copper producer--in its financial statements. Cyprus owns 50.04% of Pima's stock. The balance is split between Union Oil and Utah International.

d. Pennzoil - Duval

Duval is now a wholly-owned subsidiary of Pennzoil Company. Pennzoil got into the copper business via its 1968 merger with United Gas Corporation, of which Duval was a subsidiary. Duval is the fifth largest producer.

e. Inspiration Consolidated - Anaconda - Crane et al.

In early 1975, Crane Company, through a subsidiary, acquired 5.5% of Inspiration's stock, and subsequently made a bid to obtain control of Inspiration. Anaconda had for some time held 27.6% of Inspiration's common stock, and was its largest stockholder. Anaconda did not exercise control over Inspiration, but, agreeing with the management of Inspiration, voted to permit the sale of a substantial block to the Anglo-American Group of

South Africa (Hudson Bay Mining, Anglo-American Corporation, et al.) thus precluding Crane's attempt to take control. Anaconda now owns 20.4%, and the Anglo American Group 30% of Inspiration's stock.

Later in 1975, Crane made a tender offer for 23% of Anaconda's shares. Anaconda's management was opposed to the offer. Shortly thereafter, Tenneco proposed a merger of Anaconda through an exchange of securities, and Anaconda's Board approved. But, in early 1976, Atlantic Richfield (ARCO) made a cash offer for 27% of Anaconda, with an agreement with Crane Company, giving ARCO a right of first refusal on Crane's holdings (then actually about 19%) for a stipulated period. ARCO and Anaconda subsequently agreed to merge Anaconda with ARCO and the required approvals for the merger are pending.

f. Principal Joint Holdings

The following tabulation indicates the principal joint holdings of the major U.S. companies in copper production as of 1975.

Producer and Location	1974 Copper Production (tons)	Participations
Southern Peru Copper Corp. (Peru)	133,000	Asarco - 51% Cerro Corporation - 22.3% Phelps Dodge - 16% Newmont - 10.3%
ROAN Consolidated Mines (Zambia)	304,000	Amax - 20% Zambian Government - 51%
Granduc (British Columbia, Canada)	31,900	Leased 50% each by Asarco and Newmont, with Asarco operating
O'okiep Copper Company (South Africa)	35,600	Amax - 17.0% Newmont - 57.5%
Mount Isa Mines (Australia)	175,800	Asarco - 49%
Tsumeb Corporation, Ltd. (South West Africa)	24,700	Amax - 29.6% Newmont - 29.2%
Subtotal above (outside U.S.A.)	705,000	
Anamax Mining (Arizona)	45,500	Amax - 50% Anaconda - 50%

TABLE 7

PRINCIPAL U.S. COPPER SMELTING AND REFINING WORKS--1974

Company	Smelter Capacity			Refining Capacities		
	M Tons	% Total	Rank	M Tons	% Total	Rank
Anaconda	210	11	(4)	295[a]	11	(4)
Asarco	380	19	(3)	630[b]	23	(2)
Inspiration Consolidated	150	8	(6)	72	3	(8)
Kennecott	508	26	(1)	639	23	(1)
Newmont (Magma)	200	10	(5)	200	7	(6)
Phelps Dodge	402[c]	21	(2)	544	20	(3)
Copper Range[1]	85	4	(7)	90	3	(7)
AMAX[2]	-	-	(9)	250[d]	9	(5)
Cities Service	15	1	(8)	-	-	(9)
	1950	100%		2720	100%	

[1] Lake and Fire-Refined.

[2] Oriented to Custom, Foreign Blister, Scrap.

[a] New Jersey facility shut down in 1975, when Montana facility expanded capacity by 38%.

[b] Baltimore refinery closed in December 1975. New Jersey facility to close in 1976. New refinery in Amarillo, Texas came on stream in mid-1975 with rated year-end capacity of approximately 215,000 tons/year (50% of planned total for Amarillo).

[c] New smelter at Hidalgo, N.M., scheduled for operation circa 1976, will add capacity estimated at 100 M tons/year or more, assuming continued operation of the three existing smelters.

[d] Smelter-refinery complex as estimated by ADL.

g. Participation of Oil Companies

The recent ARCO interest in Anaconda marks the fifth[1,2] major oil company venture into U.S. primary copper production, via acquisition of operating interests. The others were, as indicated above, Union Oil, Cities Service, (1963), Pennzoil (1968), and Standard Oil of California (1975). The latter was indirectly, through Amax, and appeared to be focused on Amax's substantial interests in coal. (It is the fourth largest producer).

We believe it is not yet appropriate to attempt generalization from the foregoing. There are many other examples of oil companies diversifying their interests in natural resources-based businesses, just as there are many examples of nonferrous metals companies diversifyning into coal, oil, and gas. We would expect that in at least several important cases, the provisions of the U.S. tax laws were an incentive.

2. Considerations Re: Smelting and Refining

Table 7 presents the smelting and/or refining capacity for the principal companies. This represents nearly all of the U.S. capacity, except for secondary refined capacity as represented by Cerro Corporation, and other independent fabricators. Note that Asarco, Amax and Phelps Dodge have refining capacity well in excess of their mine and/or smelter capacity.

An important aspect of the primary copper (and also lead and zinc) industries is that traditionally the cost of smelting and refining has been small compared to the price of copper, and furthermore, these operations

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[1] As we went to press, Continental Oil Company was reportedly planning a large new copper mining development, with annual production on the order of 100,000 tons per year. Conoco would thus be the sixth major oil company producer, although its entry is as a new producing firm, increasing the number of competitors.

[2] Exxon also recently announced its interest in a large ore body in Wisconsin, containing significant amounts of copper and other mineral values. Exxon is studying the opportunity to exploit this property.

have been at a fixed and relatively low margin which is not very sensitive to the price of the finished product. This, in turn, means that the smelting and refining plants have been operated mainly as <u>service operations</u> in the conversion of concentrate into usable metal and alloys. In smelter contracts, changes in price of the primary metal are typically reflected back to the mine and hence affect directly the value of the concentrate.

We illustrate the mechanism based on data from the copper industry but a similar mechanism occurs in the lead and zinc industries. In the '60's, the traditional rule-of-thumb in determining concentrate value in the copper industry was to assume 4¢/lb. for smelting charges and 5¢ for refining charges so that the value of copper contained in the concentrate is very approximately 9¢/lb. below the cathode or wirebar market price. (The 1974 smelter and refinery margin was closer to 13¢/lb). Most of the U.S. smelters are old and therefore the smelter/refinery margin comprises mainly direct costs with only a small percentage being the fixed costs and profit. Any increase in smelting or refining costs generally have not been "absorbed" by the smelter or refinery, but have largely been passed backward

In the case of producers integrated from mining through smelting and refining, a cathode or wirebar is the first product that is actually sold. The internal transfer price of the concentrates is usually calculated on the basis of the primary metal price, thus, any fluctuations in the primary metal price are again reflected back to the mine and have a major influence on the mine profitability.[1] Any change in wirebar price affects the concentrate value directly in custom smelting contracts, and the smelter and refinery margins remain unchanged.

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[1] Internal Revenue Code regulations governing the calculation of the depletion allowance from mining operations are involved here: There is a provision for cost/profit allocation when there is no established field or market price for captive concentrates shipped from an area to a company's smelter. In practice, there is considerable flow of concentrates (e.g., between one company's mines and another company's smelter),and hence the field or market price may be easily established.

3. The "Struggle Between Integrated and Independent Fabricators"

Although this study extends only through the refined copper stage of production, we cannot overlook the fact that the large primary producers are vertically integrated into fabricated products (wire and cable, tubing, sheet, other brass mill products), and there is an interplay in the market place between supply and price of new refined copper and the role of copper scrap in the fabricating industries.

Refined copper is fabricated into higher value, intermediate, and finished products by wire mills and brass mills, the former accounting for about 46% of U.S. consumption, and the latter about 40%. The balance of consumption is accounted for by foundries, ingot-makers, and powdered metal usage. Overall, 40% or more of the brass mills' copper requirements are typically supplied by scrap materials.

The manufacturing divisions, subsidiaries, and affiliates of the major primary copper producers are believed to account for roughly half of total fabricating. Of the three producers, Anaconda appears to consume the highest percentage of its own copper, Phelps Dodge the next highest and Kennecott the least. However, we do not have sufficient data to make generalizations. Also the vagaries of the market from year-to-year, and the fact that the company buy and sell to and from each other, complicates the pictures. From a financial standpoint, the conventional distinction made between the integrated producers and the independent fabricators[1] such as Cerro Corporation, General Cable, Reading Industries, Triangle,

[1] General Cable was spun off from Asarco in 1967, in connection with a consent decree arising from an antitrust action. Cerro has a gross fabrication capacity for tubing, wire and cable, and brass mills products of 350,000 tons/year (nearly 15% of the total). Other large independent capacity is represented by that owned and utilized captively by General Electric Company and the Western Electric subsidiary of American Telephone and Telegraph Company.

is best expressed by the following comments from Standard and Poor's Corporation in its 1975 nonferrous metals survey:

"For--integrated companies, this final production stage has traditionally served as an outlet for the primary copper produced. Thus, such companies have typically endeavored to maintain low prices on fabricated products, relying on the sale of primary metal for the bulk of their profits."

The largest expense for most independent fabricators is the cost of copper; thus profitability depends substantially on the fabricators' mark-up or spread. As a result, again quoting Standard and Poor's, "there is often a struggle occurring in the market--The integrated producers seek to keep product prices on fabrications low enough to boost demand and provide an expanding market for more profitable primary and refined output, while the independent fabricators strive to raise product prices and margins." Both groups generally prospered in the demand crunch--high price environment of 1974; but the independents suffered less in the recession--low price environment of 1975, benefitting from the lower raw material costs. The integrated producers, with high fixed costs, suffered reduced operating rates as well as reduced prices, and reported substantial sales and earnings decline.

The subject of integrated versus independent producers is, we believe, quite a bit more involved than this, as might be inferred from various legal actions which have occurred[1] or have been underway now for sometime, and which appear to relate at least in part to the operations of the U.S.

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[1] See U.S. vs. Kennecott Copper, in which Kennecott was required to divest Okonite Company, a very large independent wire and cable producer acquired in 1958.

two-price system and the foregoing discussions (see Chapter 6).

More specifically, as has been stated in the "Notes to the Financial Statements" of the major producers, in June, 1970, Triangle Industries, Inc., a copper fabricator, instituted an action in the U.S. Disctrict Court for the Eastern District of Pennsylvania against Asarco, Anaconda, Cerro Corporation, Kennecott, and Phelps Dodge, alleging various violations of the Federal antitrust laws and seeking treble damages and divestiture by these producers of their copper fabricating facilities, and other relief. Reading Industries, Inc. (another copper fabricating company), filed a similar suit in October of 1970. These actions were subsequently transferred to the U.S. District Court for the Southern District of New York, and have been in pre-trial discovery stage. Counterclaims were filed by some of the defendents. Cerro filled briefs and motions for dismissal, claiming it was not a U.S. producer. Asarco and Triangle subsequently agreed to have Asarco supply Triangle with copper under long term contract, and Triangle withdrew its complaint against Asarco.

Since 1972, the Antitrust Division of the U.S. Department of Justice has been conducting a grand jury investigation of the copper industry in the United States generally. The primary producers were served with subpoenas requiring production of documents and information relating to copper prices since 1951; and exploration, development, smelting and refining activities since 1955. In 1974, the jurisdiction of this investigation was transferred to the U.S. District Court for the Southern District of New York.

The outcome of these actions should clarify the status of vertical integration in the copper industry. However, because of the nature and extent of our study, further treatment of these issues was beyond our scope, and would at best be speculative. Our analyses then necessarily have been based on the industry "as is," and as we and others outside may observe it.

D. CAPITAL NEEDS AND CAPITAL SOURCES

1. Capital Needs vs. Internal Sources

In its 1975 Survey of capital requirements at nonfinancial corporations, Business Week concluded that U.S. corporations in general were in the throes of a capital crunch which showed no signs of abating. (Those conclusions were based on data supplied by another Mc-Graw-Hill group, the IMS subsidiary of Standard & Poor's Corporation). New outlays for the plant and equipment grew nearly twice as fast as common equity over the period 1969-1974, and internal cash generation fell far short of requirements (including dividends to share holders). On average, 78% of the growth needs of large U.S. companies during the 1969-1974 period were satisfied through internal cash flow generation, with increased short term and long term debt plus sale of new equity making up the difference.

The following tabulation (Table 8) compares the data for the major copper-producing companies. Table 9 shows actual average capital expenditures, the typically higher 1974 levels, and the expenditure rate in comparison to depreciation charges. Table 10 summarizes the estimated capital expenditures made on primary copper production only; and the amount of this for pollution control. Copper Range and Cyprus Mines covered most of their requirements from internally-generated funds. In fact, Copper Range's and Cyprus' debt was only slightly higher at the end of 1974 than five years earlier, and debt-to-equity ratio remained about the same.

TABLE 8

INDICATORS OF THE NEED FOR CAPITAL FUNDS

Company	5-Yr Growth in Plant Equipment %	5-Yr Cash Flow as % of Total Growth Needs
Amax	102%	53%
Asarco	97	78
Anaconda	43	61
Cities Service	30	72
Copper Range	38*	94*
Cyprus Mines	(a)	96
Inspiration Consolidated	192*	64*
Kennecott	47	83
Newmont Mining	(b)	76
Phelps Dodge	92	62
Pennzoil Co.	15	57 (c)

NOTES: [a]Not available for purposes of comparison. The 442% indicated reflects IMS/Cyprus method of reporting, accounting, and restating for consolidation of subsidiaries over the period in question.

[b]Not meaningful for purposes of comparison, due to large investment holdings.

[c]Capital Expenditures net of retirement and disposals in some years.

*SOURCE: Arthur D. Little, Inc. All other figures are as presented by Business Week's Capital Survey, September 22, 1975.

TABLE 9

THE PATTERN OF CAPITAL EXPENDITURES AND DEPRECIATION CHARGES

Company	Reported Capital Expenditures -- Gross $MM		1970-74 Average Capital Expenditures as Percent Gross Plant	Depreciation Rate 1974-% Gross Plant
	Average 1972-74	1974		
Amax	227	338	17.8%	3.3%
Anaconda	144	194	7.4	2.8
Asarco	101	138	13.7	4.6
Copper Range	6	7.5	4.8	4.4
Cities Service	370	447	10.8	3.9
Cyprus Mines	43	67	11.6	5.9
Inspiration	29	18.8	13.7	5.7
Kennecott	187	218	9.7	4.3
Newmont	48	56	12.1	4.2
Pennzoil	267	279	11.0	5.4
Phelps Dodge	182	275	11.9	2.4
		Average	11.3%	4.3%
		Standard Deviation	3.4	1.3

SOURCE: Arthur D. Little, Inc., based on Standard & Poor's Corporation, Value Line, and Company reports.

TABLE 10

ESTIMATED CAPITAL EXPENDITURES FOR THE DOMESTIC PRIMARY COPPER INDUSTRY

	1972	1973	1974	1975
	------ Millions	of Dollars-----		
Mining and Milling[a]	233[c]	420	465	430
Smelting Capacity	18	45	70	74
Refining Capacity[b]	6	34	56	44
Pollution Control				
Smelters	105[d]	150	180	142
Other	3	5	8	18
TOTALS[a,e]	365	654	779	708

NOTES: [a]Includes capitalized mine development expenses and interest during construction.
[b]1973-1975 refinery expenditures dominated by Asarco's new Amarillo refinery.
[c]Reasonable agreement with 1972 Census.
[d]Cf. MA-200(73)-2, Expenditures for Pollution Abatement, U.S. Department of Commerce Report, 1973.
[e]Cf. Census Reports for Ore Mining and for Copper Smelting and Refining (SIC 33).

SOURCE: Arthur D. Little, Inc. estimates.

Among the other companies, debt-to-equity ratios typically increased. However, it is difficult to generalize; and the analysis must proceed on a specific, case-by-case basis, since the accounting for foreign government interventions in company operations (noticeably in Chile, Peru, and Zambia), and the effect of acquisitions and spin-offs on consolidated financial statements must be evaluated.

2. Debt

Section F (presented subsequently) develops detail on the principal copper producers in regard to the trend in debt-equity ratios, the term structure of debt, and the increasing significance of pollution control debt. Total long-term debt at year-end 1974 exceeded $2 billion, and debt-equity ratios were approaching 30/70. (Cf. Tables 3 and 17).

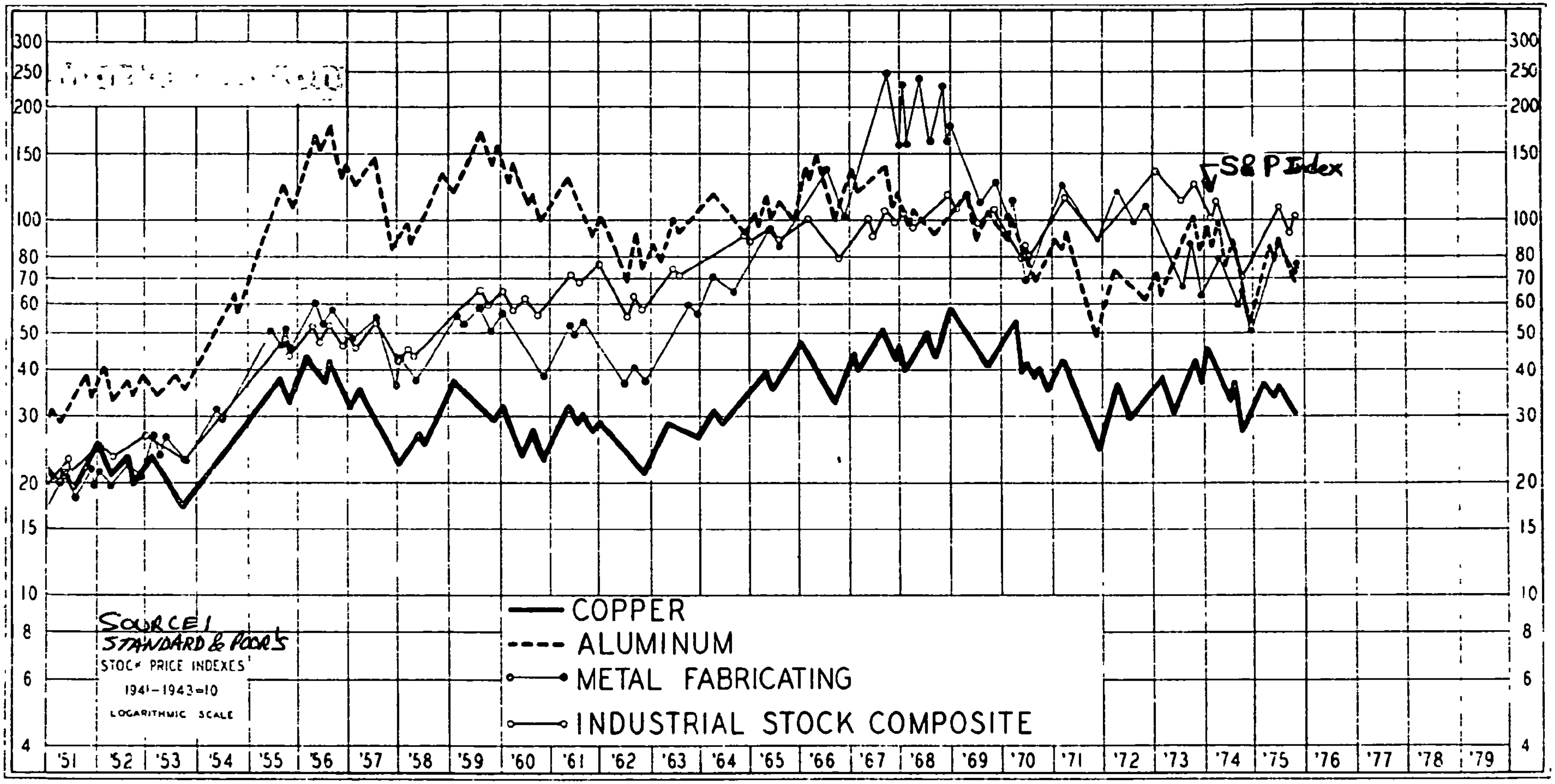
The overall average for the 550 companies studied by Business Week showed a capital structure with 60% equity and 40% debt (long term and short term), as of the end of March 31, 1975.

3. Equity Capital

- Stock Prices

Figure 1 indicates the pattern of stock price changes for the major copper producers versus other metals stock groups and the Standard and Poor's Industrial Stock Composite. The extreme volatility over the recent period has important implications in regard to incremental cost of capital, suggesting that investors would normally demand a substantial risk premium on new equity offerings. A more precise formulation of the cost of capital problem will be discussed, including the work of Pogue with the Capital Asset Pricing Model, in a separate section. (Cf. the Technical Appendix).

FIGURE 1 BEHAVIOR OF COMMON STOCK PRICES



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- P/E Ratios

For a zero or nearly zero-growth company, one model of the cost of equity capital is the reciprocal of the price-to-earnings ratios. In general, P/E ratios of industrial issues have declined over the last 10 years (1965-1975), from an average of about 17, to about 10 recently.

Copper issues sold at about 10 times earnings in 1965 (or 60% of the Industrial's P/E), and at about 6.2 times 1974 earnings (65% of the Industrial's P/E); for 1975 the comparison was not easy to establish because of several complicating developments with respect to the copper companies, including consolidations, acquisitions, and losses on operations for some companies.

In current dollar terms, these P/E relationships suggest a cost of new equity capital in the range of 15-19%, consistent with data and estimates of the cost of capital made by Pogue, and our own estimates as explained formally in the Technical Appendix to this report.[1]

[1] See Arthur D. Little, Inc. (ADL), Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry, Technical Appendix to Economic Impact of Environmental Regulations on the U.S. Copper Industry (1976), Supporting Paper 3: "Analysis of the Cost of Capital for the Primary Producers."

E. DOMESTIC AND FOREIGN SALES AND EARNINGS OF NONFERROUS METALS COMPANIES

1. General

The foreign versus domestic sales and earnings from nonferrous metals operations are estimated in Table 11. This information is based on or computed from 1974 data presented in company annual reports and reports to the SEC. (While reasonable care was taken in compiling this data and presenting it in a consistent fashion, we do not guarantee its absolute accuracy or comparability because of variations in accounting from company to company).

Very few companies reported foreign earnings in a clear manner, and even where statements are made they were often somewhat ambiguous.

Of the nine major primary copper producers listed, there is considerable variation in the percentage of earnings accounted for by foreign operations:

- Copper Range has a very small percentage of foreign sales revenues and earnings, Inspiration did not report any at all.
- Anaconda did not indicate net foreign sales, but reported $115 million in 1974 sales from Anaconda Canada Ltd. The net equity of nonconsolidated foreign affiliates abroad contributed 13.5% of its total after-tax earnings.
- Kennecott indicated that 16% of their sales was derived from customers abroad, producing 16% of earnings after tax.
- Phelps Dodge had foreign sales as percent of total sales revenue equal to 2% or less and foreign earnings after tax equal to 4% or less of total earnings.
- Amax's, Asarco's and Newmont's foreign sales are 20-25% of total sales, and their foreign after-tax earnings as percent of total after tax earnings ranges from about 30% for Newmont and Amax to over 60% in the case of Asarco.

TABLE 11

1974 DOMESTIC SALES AND EARNINGS FROM NONFERROUS METAL OPERATIONS AND FOREIGN SALES AND EARNINGS--AS COMPARED TO TOTAL EARNINGS

Company	Sales from Domestic Nonferrous Metals Plants $ (millions)	Earnings From Domestic NFM Operations $ (millions)	Foreign Sales as Percent of Total Sales Revenue	Foreign Earnings (After Tax) $ (millions)	Foreign Earnings (After Tax) As Percent of Total
Asarco	$1,260.1	$ 89.7	23.2%	$ 93.4	67%
Amax	607.0	95.0[b]	18.0	62.07[a,c]	30.6[a,c]
Anaconda	1,567.3[d]	173.0[e]	11.0 Est.	14.4[g]	13.5[h]
Cyprus Mines	279.0[i]	82.7[j]	28.0	52.7[a]	37[a] 42[j]
Copper Range	166.6	28.3	10.0	N.A.[f]	N.A.
Inspiration Consolidated	97.1[k]	9.91[k]	nil	nil	nil
Kennecott	999.56[l]	248.8[l]	16.0	27.0[m]	16[m]
Newmont	301.2	70.7	25.0	37.8	30
Phelps Dodge	1,026.1	138.3	< 1.0	1.524[n]	1.4

NOTES: [a]Indicates before taxes.

[b]Includes $19 million equity in Alumax.

[c]Twenty percent of its earnings from operations before income taxes, exploration and unallocated corporate expenses were derived from its operations outside of the United States, primarily in Australia, Western Europe, Japan, Zambia, and Canada. In addition, approximately 9% of its income before taxes and extraordinary items was derived from dividends from foreign investments, primarily in Africa.

$$\frac{(0.2 \times 219) + (0.09 \times 203)}{203} = 30.6\%$$

Applicable foreign earnings from operations, excluding exploration and unallocated corporate expenses were $43.5 million in 1974; $6.45 million of foreign exchange gains were included in 1974 earnings. Trading income, consisting primarily of profits on copper and silver transactions, was $12.5 million in 1974 (based on sales of $32 million, and BTE of $20 million) and is included in earnings from operations.

[d]Sales 93.7% of net sales--i.e., excludes sales between divisions, uranium oxide sales, etc.

[e]Total operating earnings showns.

[f]N.A.: Not Available

[g]Anaconda's equity in net income of affiliated companies in Mexico and Brazil accounted for $14.1 million in 1974. These foreign affiliated companies' contributions, after all applicable taxes, amounted to $10.8 million or 10.1%. Anaconda also received $5.45 million of interest from Chilean investments, which after tax of 34% (effective 1974 rate) was $3.6 million.

[h]Based on net after taxes before extraordinary income, $\frac{14.4}{106.8} \times 100 = 13.5\%$. There was an extraordinary item which contributed $140.37 million to net income which involved settlement on the 1971 expropriation loss with the Government of Chile. If this item is considered, then 62.6% of total 1974 net income--i.e., $247.1 million, including the extraordinary item, was related to foreign activities.

[i]Includes manufacturing and nonferrous metals. Manufacturing includes copper and aluminum wire and cable, and some steel conduit and specialty steels.

[j]After tax basis estimated excluding minority interests. See separate material on Cyprus in statistical appendix.

[k]Includes interest income.

[l]Total metal and metal product sales were $1,160.1 million, out of total sales revenues of $1,664.2 million. Of these metal and metal products sales, $999.56 million were of nonferrous metals and products. Reports do not state amount attributable to United States. Earnings show total before tax earnings from metal and metal products operations, including items that are not nonferrous.

[m]Income derived from foreign sources before extraordinary credit represented about 16% of 1974 consolidated income before extraordinary credit. In addition to this $27 million, the company had an extraordinary credit (net of tax effect) of $42.3 million related to compensation from Chile for a 1971 expropriation of property. If the credit and net foreign sources ($69.3 million) are considered as percent of net income after tax <u>and</u> the extraordinary item, the percent from foreign sources was about one-third of 1974 total net income.

[n]Reported $1.524 million dividends included in reported earnings from foreign manufacturing interests abroad.

2. The Hazards of Foreign Investments

Extraordinary losses, as discussed in the financial reports of the major nonferrous metals mining companies, illustrate the risk of foreign holdings today. Indeed, the last several years would suggest the related write-offs are "ordinary" and not "extraordinary" losses in the course of business--as the panorama of nationalizations in Chile, Peru, Mexico, and Africa unfolds. In most cases, Overseas Private Investment Corporation insurance was available to cover much of the loss. But this is phasing out.

While foreign sales are considered subject to greater uncertainties-depending on the location of foreign subsidiaries and/or affiliates, expropriation, currency fluctuations, export and import restrictions, exchange restrictions, and other factors--the percentage of income before taxes on income from foreign sales revenues has generally been greater than that realized on consolidated total sales and operating revenues and hence on domestic operations. When the companies share of dividends and/or equity in foreign affiliates' earnings is added to earnings from direct foreign operations, the fraction of foreign after tax earnings to total after tax earnings rises significantly. A higher return, of course, is consistent with the notion of higher risk.

F. LONG TERM DEBT AND TREND IN DEBT-TO-EQUITY RATIOS

1. Term Structure of Debt for the Primary Nonferrous Metals Companies

a. Introduction

The debt structure of the primary copper producers was studied along with that of the primary lead and zinc companies, using data published in the annual reports of the subject companies.

The long-term obligations of each company and its consolidated subsidiaries are reviewed below in tables breaking debt down by maturity and rate of interest. Wherever interest rates were not specified, the amounts were placed in an interest category labeled "Other," by year of maturity. Pollution control-related debt was identified. Capitalized leases are included, as are sinking fund payments.

It should be noted that while reasonable care was taken in compiling this data and presenting it in as consistent a fashion as possible, we cannot guarantee absolute comparability from one company to the next, due to differences in the nature of their debt, differences in their accounting for certain balance sheet items, etc. To the best of our knowledge, the data herein present a meaningful basis for study and comparison.

b. Total Debt of the Primary Copper, Lead and Zinc Companies

Table 12--Total Debt of Primary Copper, Lead and Zinc Producers, shows the debt and the debt repayment schedule as of December 31, 1974, for each of the companies and their consolidated subsidiaries.

Table 13--Debt of Primary Copper, Lead and Zinc Producers by Period of Maturity and Interest Rate (Percent), shows the total debt by period within certain interest ranges. The "Other" category was used for debt for which rate of interest was unidentified.

TABLE 12

TOTAL DEBT OF PRIMARY COPPER, LEAD AND ZINC PRODUCERS[1]
(millions of dollars)

Company	Repayment Schedule 1975	1976	1977	1978	1979	1980 & Beyond	Sum=Total Long-Term Debt 12/31/74	Long-Term Debt 6/30/75[7]
Asarco	18.2	6.7	4.7	8.4	9.2	237.4	266.4[4]	285.3
Anaconda	16.8	59.4	8.4	19.6	16.7	301.6	405.7[3]	476.4
Cyprus Mines	1.5	6.7	11.5	10.9	10.7	70.5	110.3[5]	115.0
Copper Range	1.4	1.4	2.7	2.7	2.7	23.2	32.7	32.7
Inspiration	5.9	5.7	5.7	6.2	5.3	23.4	46.3	43.3
Kennecott	8.8	7.2	6.4	4.2	2.4	206.2	226.4	443.6
Phelps Dodge	2.4	2.5	27.5	52.5	13.0	301.6	397.1[6]	525.4
Newmont	13.0	17.4	20.8	24.8	27.2	119.2	209.4	256.0[8]
AMAX		30.4	13.8	63.7	43.3	249.7	400.9	545.2
Gulf Resources	2.3	2.2	2.1	6.8	5.8	72.2	89.1	72.4
St. Joe	8.4	5.9	4.1	2.7	1.0	22.0	35.7	35.6
Engelhard	2.9	7.1	4.7	3.4	5.5	93.2	113.9	113.6
Total Long-Term Debt		152.6	112.4	205.9	142.8	1670.2	2333.9[2]	2944.5
Plus 1975 Installment							81.6	
							2415.5	

[1] Source: 1974 Annual Reports, SEC Form 10-K reports, and Arthur D. Little, Inc.

[2] Does not include current installment (i.e., 1975).

[3] Capitalized leases account for $131.9 million of LTD.

[4] Includes notes and debentures issued in January 1975 for $150 million

[5] Includes notes issued in January 1975 for $100 million.

[6] Includes $70 million of indebtedness to finance air quality control facilities, incurred in January 1975.

[7] Source: Company 1975 reports and ADL.

[8] Business Week on first quarter since Treasurer would not comment.

Information used to prepare this table was taken from sources believed to be reliable, but its accuracy and completeness are not guaranteed.

TABLE 13

TOTAL DEBT OF PRIMARY COPPER, LEAD AND ZINC PRODUCERS[1]
BY PERIOD OF MATURITY AND INTEREST RATE (PERCENT)

(millions of dollars)

Matures	4 - 5-7/8	6 - 7-7/8	8 - 9-7/8	10 and Over	Other[2]	Total
1975-1979	$100.2	$ 384.8	$127.8	$ 82.5	$37.0	$ 732.3
1980-1984	117.4	320.2	260.8	19.4	23.6	741.4
1985-1989	86.4	167.5	172.5		3.5	429.9
1990-1999	49.6	227.2	155.3		4.2	436.3
2000 and Beyond		55.7	16.0			71.7
Unknown					3.9	3.9
	$353.6	$1155.4	$732.4	$101.9	$72.2	$2415.5[3]

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[1]Source: ADL estimates based on company 1974 annual reports and SEC 10-Ks.

[2]Other = Interest rate not indicated and, in some cases, final repayment date not given.

[3]Includes debt through January 1975, as given in annual reports.

Information used to prepare this table was taken from sources believed to be reliable, but its accuracy and completeness are not guaranteed.

Table 14--Debt Allocated for Pollution Control Purposes, Including Certain Capitalized Lease Obligations, shows the debt allocated to pollution control by the subject companies. About 13.7% of the total debt ($2,315 million) was specifically earmarked for pollution control ($317.9 million). This amount could be considerably higher, but variability in how companies report may mask the total debt issues committed to pollution control.

c. Review of Pollution Control Debt Issues

- Inspiration Consolidated Copper Company carried long-term debt of $33.2 million at December 31, 1974, used to finance construction of pollution control facilities. Funds were obtained for this loan from the sale by an Industrial Development Authority of tax-free Pollution Control Revenue Bonds. The company has guaranteed the Authority's payment of principal and interest on these bonds. Interest is at 75% of the prime rate charged by The Chase Manhattan Bank. As discussed in the separate section on Inspiration and elsewhere (cf. "Environmental, Health and Safety Matters"), repayment was scheduled in 36 quarterly installments of $900,000 and a final payment of $800,000 on February 15, 1984.
- St. Joe Minerals Corporation and its consolidated subsidiaries had a liability of $18.361 million as of December 31, 1974, with respect to pollution control revenue bonds and entered into agreements with the State Environmental Improvement Authority (Missouri) and Beaver County (Pennsylvania) Industrial Development Authority to make payments to trustees under installment sales agreements sufficient (together with other available funds) to pay all amounts due on the bonds. The bonds are subject to optional redemption

commencing in 1982 and mandatory redemption in 1988. The proceeds from the sale of the bonds are to provide funds for the construction of pollution control facilities at St. Joe Minerals' lead and zinc smelters. The debt at December 31, 1974, represents the amount of proceeds from the sale of bonds applied to construction payments; the balance of the proceeds is held and invested by the trustees pending disbursements and, if not applied toward construction payments, is available to service the bonds or to repay them in part.

- Newmont Mining's subsidiary, Magma Copper Company, had $30 million of air pollution control bonds, payable at 3.67% $\pm$ 50% of the difference between prime rate and 5% payable 1975 to 1982, outstanding as of December 31, 1974.
- Asarco sold $10 million of Gila County, Arizona, pollution control bonds in 1974, and indicated that it needs to finance additional pollution control revenue bonds. As of December 31, 1974, there was $8.4 million of this long-term debt issue, with interest at 75% of prime, due in quarterly installments to August 31, 1982. The company's prospectus dated May 7, 1975, stated that it was negotiating additional revenue bond financing for qualified pollution control facilities. (By mid-1976 the amount so financed was $50 million.)
- Phelps Dodge had $135.782 million in (tax-exempt) air quality control obligations (due after one year) as of December 31, 1974. In January, 1975, the Corporation also incurred $70 million of indebtedness to finance the air quality control facilities at its

TABLE 14

DEBT ALLOCATED BY PRIMARY COPPER, LEAD AND ZINC PRODUCERS FOR POLLUTION CONTROL PURPOSES, INCLUDING CERTAIN LEASE OBLIGATIONS

(millions of dollars)

Period	Debt
1975 - 1979	$ 67.8
1980 - 1984	117.9
1985 - 1989	21.0
1990 - 1999	55.5
2000 and Beyond	55.7
	$317.9*

*The pollution control obligations of the copper, lead and zinc companies was equal to about 13.7% of total debt at year-end 1974.

Information used to prepare this table was taken from sources believed to be reliable but its accuracy and completeness are not guaranteed.

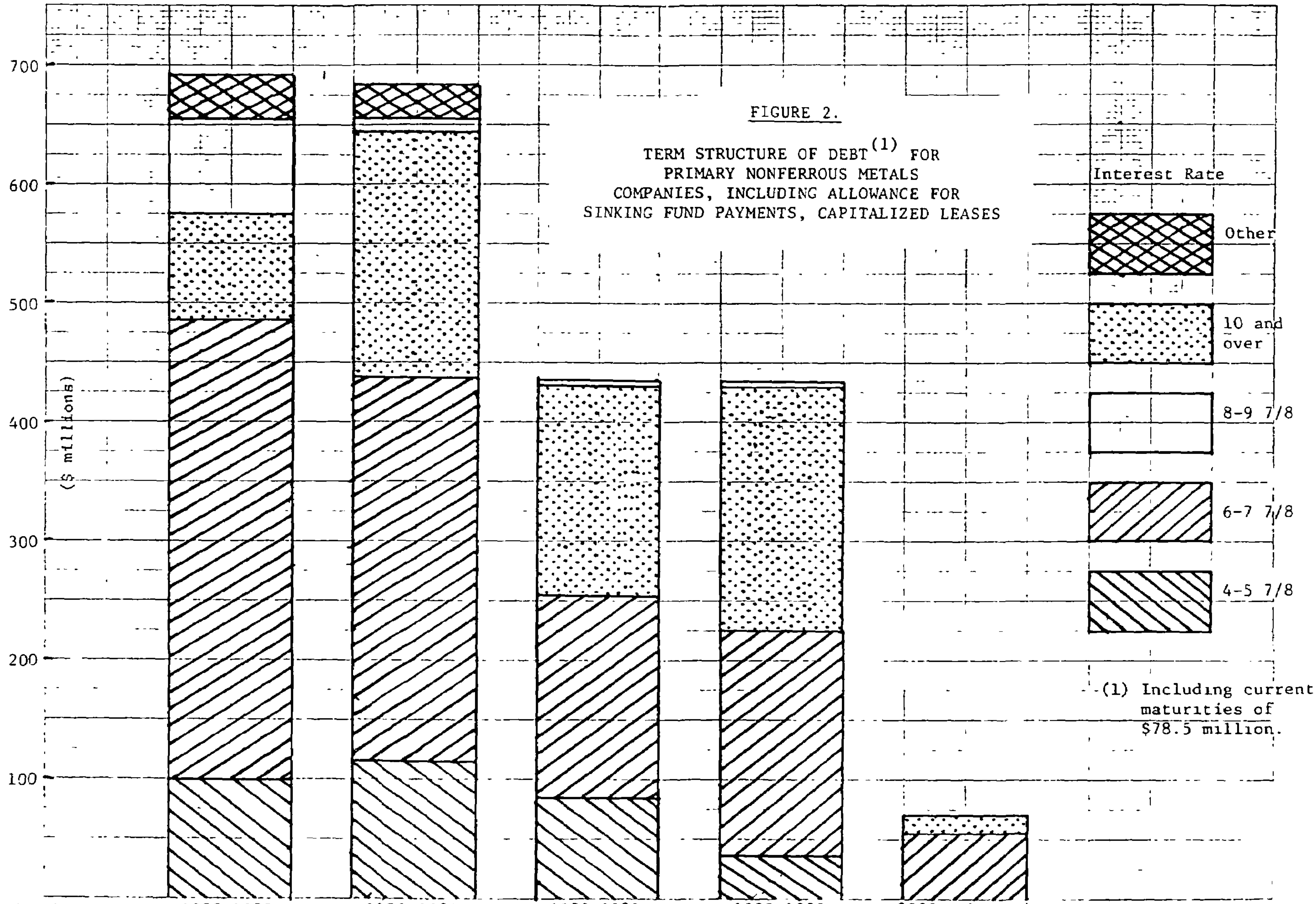

FIGURE 2.

TERM STRUCTURE OF DEBT(1) FOR PRIMARY NONFERROUS METALS COMPANIES, INCLUDING ALLOWANCE FOR SINKING FUND PAYMENTS, CAPITALIZED LEASES

Debt Matures In	1975-1979	1980-1984	1985-1989	1990-1999	2000 & beyond	
Total ($ millions)	$692	681	430	436	72	$2,315
[illegible] ($ millions)	68	118	21	56	56	289

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TABLE 15

Long-Term Debt of Twelve Copper, Lead, Zinc Producers[1]

(millions of dollars)

	1970	1971	1972	1973	1974
AMAX, Inc.	261.5	392.0	457.4	440.7	400.9
Asarco	23.7	38.1	51.0	91.7	266.4[2]
Anaconda	366.5	391.5	388.9	379.3	405.9
Copper Range	24.3	36.3	35.0	33.6	32.7
Cyprus Mines	40.4	34.9	22.4	17.1	110.3[3]
Engelhard	80.4	77.2	117.7	115.5	113.9
Gulf Resources	42.0	48.6	53.1	73.6	89.1
Inspiration Consolidated	1.26	1.14	19.1	49.8	46.3
Kennecott	177.9	314.6	269.0	220.8	226.4
Newmont Mining	108.4	201.6	224.0	218.1	209.4
Phelps Dodge	86.1	166.0	181.3	281.9	397.1[4]
St. Joe Minerals	11.7	10.7	34.7	50.3	35.7
Total	1224.2	1712.6	1853.6	1972.4	2334.1[2,3,4] 2014.1 year end

[1]Source: Annual reports, SEC 10-K's, S&P reports, and ADL. Includes capitalized leases, convertible subordinated debentures, and sinking fund debentures. Does not include current installment.

[2]Includes $150 million notes and sinking fund debentures issued in early 1975.

[3]Includes $100 million of notes issued in January 1975.

[4]Includes $70 million of indebtedness to finance air quality control facilities incurred in January 1975.

Information used to prepare this table was taken from sources believed to be reliable, but its accuracy and completeness are not guaranteed.

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TABLE 16

Shareholders' Equity of Twelve Copper, Lead, Zinc Producers

(millions of dollars)

	1970	1971	1972	1973	1974
AMAX, Inc.	609.7	625.2	693.0	840.4	942.2
Asarco	672.8	673.3	682.6	774.0	862.5
Anaconda	1,202.3	837.4[a]	966.7	1,042.0	1,267.3
Copper Range	108.1	101.7	94.8	105.3	119.8
Cyprus Mines	217.6	235.6	256.6	281.6	313.8
Engelhard	235.7	252.8	279.3	313.9	403.5
Gulf Resources	53.3	28.4[b]	31.9	41.7	76.1
Inspiration Consolidated	66.6	70.5	77.9	87.9	91.2
Kennecott	1,160.5	1,188.5	1,203.8	1,307.1	1,442.0
Newmont Mining	446.9	473.4	490.4	564.4	637.4
Phelps Dodge	662.0	710.2	749.3	815.2	892.3
St. Joe Minerals	180.3	191.0	205.1	229.5	298.9
Total	5,655.1	5,389.0[a,b]	5,731.4	6,403.0	7,347.0

Source: Annual reports, SEC 10-Ks, and ADL.

[a]Discontinuity reflects write-offs taken in connection with the expropriation of its Chilean properties. The accounting for the 1971 expropriation and write-offs had the effect of creating a massive deficit for the year, establishing a large tax loss carryforward and increasing the debt-to-equity ratio.

[b]Discontinuity reflects write-offs associated with the Great Salt Lake Project.

Information used to prepare this table was taken from sources believed to be reliable, but its accuracy and completeness are not guaranteed.

TABLE 17

Debt Ratios (Debt/Debt Plus Equity Capital) of Twelve Copper, Lead, Zinc Producers on December 31 of Year Shown[1]

(percent)

	1970	1971	1972	1973	1974
AMAX, Inc.	30.0	38.5	39.8	34.4	29.8
Asarco	3.4	5.4	7.0	10.6	11.9[2]
Anaconda	23.4	31.9	28.7	26.7	24.3
Copper Range	18.4	26.3	27.0	24.2	21.4
Cyprus Mines	15.7	12.9	8.0	5.7	3.2[3]
Engelhard	25.4	23.4	29.6	26.9	22.0
Gulf Resources	44.1	63.1	62.5	63.8	53.9
Inspiration Consolidated	1.9	1.6	19.7	37.2	33.7
Kennecott	13.3	20.9	18.3	14.5	13.6
Newmont Mining	19.5	29.9	31.4	27.9	24.7
Phelps Dodge	11.5	18.9	19.5	25.7	26.8[4]
St. Joe Minerals	6.1	5.3	14.5	18.0	10.7

[1]Source: Annual reports, SEC 10-Ks, and ADL. Debt refers to noncurrent long-term debt; i.e., debt does not include current installment, and unless otherwise indicated, ratio is as of December 31, 1974.

[2]This increased sharply to 20.8% because of a $150 million debt issued in January.

[3]This increased to 26% in January, 1975, as a result of a $100 million note issue.

[4]This increased to 30.8% in January when Phelps Dodge issued $70 million of Pollution Control Revenue Bonds.

Information used to prepare this table was taken from sources believed to be reliable, but its accuracy and completeness are not guaranteed.

Table 18

NONFERROUS METALS COMPANIES COMPARISONS

Long-Term Debt, Shareholders' Equity, and Indicators of Ability to Attract Additional Capital

	Long-Term Debt 6/30/75 $ Mill.	Long-Term Debt as % of Invstd. Capital 6/30/75	Share-holders' Equity 6/30/75	Stock Price as % of Book Value, Mid-1975	Av. Int. Covge. Ratio Pre-tax 3/31/75	Av. Int. Covge. Ratio Pre-tax 1965-74	S&P Bond Rating
Aluminum Co. of America	1,179.9	42.7	1,585.2	1.0	5.4	5.4	A
Amax, Inc.	545.2	36.1	965.5	1.3	9.6	9.1	A
Anaconda	476.4	27.8	1,234.4	0.3	4.8	20.5	A
Asarco	285.3	24.8	863.9	0.4	11.3	48.9	A
Copper Range	32.7	27.7	117.9	-	10.7[c]	-	-
Cyprus Mines	115.0	26.2	324.0	0.8	26.0	28.5	A
Engelhard	113.6	20.0	454.3	1.5	7.6	5.4	BBB[e]
Gulf Resources	72.4	39.9	109.0	1.8	2.7	-	-
Inspiration Consolidated	43.4	26.3	90.1	0.7	1.1[c]	-	-
Kaiser Aluminum	684.7	46.1	799.3	0.8	4.4	3.2	-
Kennecott Copper	443.5	23.6	1,436.4	0.7	10.4	75.4	A
Martin Marietta	279.4	32.2	589.3	0.7	6.8	8.3	BBB
Newmont Mining	256.0	28.7	637.4	0.8	8.0	-	-
Phelps Dodge	525.4[a]	37.0	893.9	0.8	5.3	18.7	A+
Reynolds Metals	816.4[b]	50.2	809.3[b]	0.5	3.3	2.9	B[e]
St. Joe Minerals	35.6	9.7	332.1	1.9	33.9[d]	40.9	-
12 Cu, Pb, Zn Cos.	2,944.5		7,458.9				
4 Al Cos.	2,960.4		3,783.1				
Total	5,904.9		11,242.0				

NOTES:
[a]Includes $125M of offered notes in 1975.
[b]Reflects restructure of the company's investment in a primary aluminum smelter and rolling mill in Hamburg.
[c]December 1974 data.
[d]Based on company's fiscal year end.
[e]Subordinate debt rating.

SOURCE:

new Hidalgo smelter. The indebtedness bears interest at a rate of 7.25% per annum. Principal payments are due in 1979 (15%), 1980 (15%), 1981 (30%), and 1982 (40%).

- Kennecott (See Appendix A).
- Anaconda financed the first stage of the installation of an acid plant and related equipment at the copper smelter at Anaconda, Montana, which was completed in 1973 at a cost of approximately $21.1 million, by a leasing arrangement under which the County of Deer Lodge, Montana, issued $17 million in bonds and a third party invested the balance. The second stage, which involves installation of an electric furnace and related control equipment, is nearing completion. Use of an electric furnace is expected to substantially eliminate air pollution. Construction funds for this stage are being made available, up to an expected total of approximately $31.5 million, from working capital and bank loans. Anaconda also installed a major pollution control system in the course of construction of its aluminum smelter at Sebree, Kentucky. Funds totaling $10.6 million were made available for this project through a lease financing with several large institutional investors.

Figure 2--Term Structure of Debt for Primary Nonferrous Metals Companies, is a bar chart showing the amount of debt by interest rate and the maturity periods for the companies listed in this section.

2. Trends in Debt Ratio for Leading Nonferrous Metals Companies

a. Introduction

The debt ratios computed for 12 primary copper, lead and zinc companies, expressed as percent, were computed as follows:

$D' \equiv$ Debt ratio (percent) = $(\frac{D}{D+E}) \times 100$, where

D = total long-term debt, excluding current installments

E = total shareholder's equity[1]

b. Long-Term Debt

Long-term debt for most of the companies whose financial results were reviewed peaked in 1971 to 1973. By the end of 1974 the long-term debt of nine of the 12 companies hit a three-year low (see Table 15). but by mid-1975, several of these companies had large increases in their long-term debt (Amax, Anaconda, Asarco, Cyprus Mines, Kennecott, Newmont, and Phelps Dodge). Six of these companies each had long-term debt of $250 million or more outstanding on June 30, 1975. The seventh, Cyprus Mines, which in January, 1975, increased its debt by $100 million, had $115 million (see Figure 3). Engelhard Minerals had $113.6 million, and the remaining four companies' debt ranged from $33 million to $72 million.

The long-term debt of these 12 companies increased from $1,224 million at the end of 1970 to $2,014 million by December 31, 1974, and then sharply rose to $2,944.5 million by June 30, 1975. In January, 1975, three large debt offerings were made. Asarco issued $150 million in notes and debentures, Phelps Dodge added $70 million to its long-term debt, and Cyprus Mines issued $100 million of notes; of these new additions, the $70 million was for Pollution Control Revenue Bonds. These three January issues brought long-term debt to $2,334 million by January, 1975.

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[1] Note that, if $D' \equiv \frac{D}{D+E}$, then Debt:Equity = $\frac{D}{E} = \frac{D'}{(1-D')}$

c. Shareholders' Equity

Shareholders' equity (Table 16) rose from $5,655 million to $7,347 million from December 31, 1970 through December 31, 1974 (30%), and by June 30, 1975, was $7,458.9, up 1.6% from the December amount.

3. Debt Ratios

The debt ratios of the companies studied appear in Table 17. The percentage of long-term debt to debt plus shareholders' equity stayed fairly constant for some companies between 1970-1974. The larger, integrated companies showed more stable ratios than the others. As we have shown in the footnotes to Table 17, Asarco's, Cyprus Mines', and Phelps Dodge's ratios for all increased sharply in January, 1975. Figure 1 through 4 show the ratio of long-term debt to long-term debt plus total shareholders' equity. During the period ending June, 1975, the percentages for Amax, Anaconda, Asarco, Copper Range, Cyprus Mines, Kennecott Copper, and Phelps Dodge rose; Engelhard, Gulf Resources, and Inspiration Consolidated fell and Newmont's and St. Joe Minerals' remained fairly constant.

4. Indicators of the Ability to Attract Additional Capital

Table 18 presents long-term debt, long-term debt as percent of invested capital, and shareholders' equity for the companies as of June 30, 1975. Also shown are some indicators of ability to attract additional capital. Only four of the 16 companies had a capital structure that was leveraged about equal to, or greater than, the overall average for the 550 companies reported in the Business Week[1] study mentioned earlier.

Several nonferrous metals companies showed a decline in their pretax interest coverage ratios from the average interest coverage ratio

[1] Business Week, op. cit.

pretax, 1965-1974. By March 31, 1975, Kennecott, Asarco, Anaconda, and Phelps Dodge each declined by about 80% of their previous coverage as expressed by the ten-year average. Business Week reported that the interest-coverage ratio for the overall average of 550 companies had slipped to 9.9, and that in the ten years past it was 18.5. Five of the companies had ratios of ten or more.

G. DESCRIPTION OF THE BUSINESS OF THE MAJOR COPPER PRODUCERS (DETAILS IN APPENDIX A)

Appendix A was prepared in conjunction with this section to highlight the nature of each company's business and describe some of the pertinent features of its operations. Additional information, in the form of statistical data for the last five (or ten) years, is also presented. The eleven companies described herein account for typically 95% or more of U.S. mine output and refinery production.

In general, with respect to primary copper production, Phelps Dodge and Kennecott are thought to be the lowest cost producers; Copper Range and Anaconda, the highest cost producers.

These four companies plus Inspiration Consolidated have a heavy dependence on domestic production of copper in their operations, and in terms of sales and earnings. On the other hand, Amax, Asarco, Cities Serivce, Cyprus Mines, Newmont and Pennzoil are more diversified by lines of business and/or derive significant earnings from investment holdings in other companies, including foreign mining ventures.

Except for Cities Service and Pennzoil, the major influences on earnings, from the companies' viewpoints, are nonferrous metals facilities operating rates and metal prices. These fluctuate much more than annual consumption or demand. Metal prices reflect the nature of the commodity markets, and the profitability of all producers is most sensitive to changes in refined metal prices.

APPENDIX A

DESCRIPTION OF THE BUSINESS OF THE MAJOR U.S. COPPER PRODUCERS

1. Copper Range Company

Copper Range Company, a Michigan corporation, and its subsidiaries, have since its organization in 1899 been engaged in the business of mining and refining primary copper in northern Michigan and, since 1931, in fabricating and distributing copper and brass products. The company is the seventh largest producer of domestic primary refined copper in the United States. Sales in 1974 were $97.6 million. Refined copper typically has accounted for about 61%, fabricated copper products 37%, and other revenues 2% of sales over the last five years. The company had approximately 3,600 employees in 1974, but subsequently reduced its work force substantially due to the recession in 1975.

The company's mine, mill and smelter for producing refined copper are located in White Pine, Michigan. Its principal fabricating plant is located in Leetsdale, Pennsylvania, with two smaller plants in Eminence, Kentucky, and Anderson, Indiana. The mine and mill have a capacity of 25,000 tons of ore per day. The company is a relatively high-cost producer. The smelter has a capacity of 180 million pounds of copper per year.

During the past two years, Copper Range has begun development of a portion of the White Pine mine known as the Southwest Orebody, in which ore grades are believed to be higher than those in the area currently being mined. Achievement of these goals is expected to result in some 70% of production coming from that area in future years, and in an increase of approximately 10,000 tons annually int the amount of copper derived from the White Pine operation because of the higher grade of ore in the Southwest Orebody.

In addition to continued development of the Southwest Orebody, Copper Range plans to expand its mining operations in future years by mining, both in the area currently being mined and in other areas, to depths greater than the 2,200-foot level to which mining is now carried out.

The copper produced at White Pine is Lake Copper whose principal distinctive characteristic is a natural silver content. It is fire-refined and cast at White Pine into standard commercial shapes for sale. Copper Range has fabricating facilities with an annual capacity of 51.5 million pounds of copper-brass products.

Sales of copper and prices received for the three years ended December 31, 1974 were shown in the following table.

COPPER RANGE COMPANY

	1970	1971	1972	1973	1974
Finished Copper Production--tons	67,798	58,634	70,427	78,506	66,896
Average Grade of Ore Milled--% Copper	1.077	1.000	1.011	1.002	1.006
Sales of Copper--tons	64,255	61,395	68,218	82,103	65,947
Average Price Received per Pound of Copper (Net of Freight)(1)	$ .5908	$ .5114	$ .5050	$ .6106	$ .8183
Cost per Pound of Refined Copper Sold (2)	$ .4458	$ .5107	$ .5075	$ .5247	$ .7000
Sales of Silver--Ounces(3)	771,123	590,058	699,160	662,837	537,387
Average Price Received per Ounce of Silver Sold(3)	$1.7698	$1.5660	$1.5927	$2.3408	$4.6937

(1) Includes any premium for silver content.

(2) Does not include interest expense and certain unallocated corporate costs not considered material. Includes amounts for overhead and other indirect costs for the periods indicated as follows: 1970--$.0515; 1971--$.0616; 1972--$.0495; 1973--$.0437; 1974--$.0791.

(3) Average price received is net of tolling and outside processing charges. Since this silver is recovered as a by-product, only negligible costs are allocated to it.

During 1974, approximately 21% of Copper Range's total sales of refined copper were to Revere Copper & Brass Incorporated and approximately 16.5% to Anaconda Brass Company ("Anaconda"). During the past ten years these purchasers have accounted for from 21% to 27% and from 4% to 16.5%, respectively, of Copper Range's total sales of refined copper. During 1974, 8.7% of Copper Range's total sales of refined copper were to the Company's Hussey Metals Division ("Hussey") for use in Hussey's own fabrication activities. During the past ten years, between 8.7% and 22.5% of Copper Range's total sales of refined copper were to Hussey.

Copper Range's copper is sold primarily on a current basis, with orders generally being accepted only during the month next preceeding the month of shipment. A contrast with Anaconda American Brass Company called for the shipment of 2 million and 2.5 million pounds of copper during each month in 1975, at prices which vary with New York Commodity Exchange prices. This contract was subject to cancellation or renegotiation by Anaconda if Copper Range changes its general pricing policy. A second contract called for the monthly shipment to a foreign customer of between 175,000 and 225,000 pounds of copper through April, 1975, at prices based upon copper prices on the London Metal Exchange (an eight-month extension of this agreement was the subject of negotiations).

The silver deposited out during the process of refining the copper produced at White Pine is sold in the form of concentrate to a refiner of silver at prices based upon the then current market price for silver, less a charge to cover the cost of refining the silver concentrate.

a. Copper Fabrication--Hussey Metals Division

Hussey fabricates a variety of copper and copper-based alloy products including copper bar and strip sold primarily to the electrical industry, standard copper sheet for the construction and metal-working industries and industrial copper strip, plate and sheet sold principally to the electrical, industrial equipment, graphic arts and casket manufacturing industries. It also distributes metal products made by others, including copper, brass and bronze rods and aluminum sheet and strip.

Hussey purchases refined copper in meltable forms (which must be cast before being fabricated) and in rolling shapes from copper producers and from merchants. During the past five years from 1970 through 1974 Hussey purchased from White Pine Copper Comoany approximately 86%, 60%, 62%, 59%, and 26%, respectively, of its total copper requirements (excluding copper toll-refined for others). The decline in the percentage of Hussey's requirements purchased from White Pine during 1974 was due, in part, to Hussey's withdrawal from buying following awards to Hussey of national stockpile copper from February to May.

During the past five years Hussey's sales to Square D company, a producer of electrical equipment, have constituted from 6.8% to 11.2% of Hussey's sales of its fabricated products; during the past three years Hussey's sales to General Electric Company have constituted from 5.5% to 11.9% of sales of its fabricated products. A portion of Hussey's production represents material toll-refined for others. During the period from 1970 through 1974 toll-refined materials represented approximately 3.1%, 10%, 11.0%, 19.6% and 19.4%, respectively, of Hussey's sales of its fabricated products.

In May 1974, Copper Range adopted a new pricing policy for domestic sales of primary refined copper, which policy is based on New York Commodity Exchange prices. Copper Range believed that this departure from the pricing system used by most other domestic producers offers long-term advantages to it. For a period of approximately four months after the adoption by Copper Range of its new pricing policy, that policy resulted in Copper Range's obtaining significantly higher prices for its copper than would have been obtained under the system previously used; however, during the latter part of 1974, the operation of Copper Range's pricing system resulted in its obtaining prices for its copper significantly below those which it would have obtained under the method used by most other domestic producers.

During February, 1976, the Company adopted a new policy for the pricing of its refined copper under which prices will be determined and published from time to time based on the Company's evaluation of the market. This policy replaced the prior system under which Company prices were determined soley on the basis of New York Commodity Exchange prices.

The natural silver content of the copper derived from the White Pine mine constitutes a competitive advantage to Copper Range in several markets. In addition, because of its silver content, such copper is sold at prices which include a premium of 1/8 cent or 1/4 cent per pound, depending upon the market on which it is sold. However, the same silver content effectively precludes the use of such copper in wire mills, the largest single market for refined copper, because its heat-resistant qualities require the application of higher temperatures in order to permit such copper to be drawn.

COPPER RANGE COMPANY AND SUBSIDIARIES

HISTORICAL TABLE 1955-1975

								Net Working Capital		Book Value			
YEAR	Net Income	Number of Common Shares	*Income* Per Share—Adjusted (1)	*Funds* Generated From Operations	Capital Expenditures	Cash Dividends Paid	Dividends Per Share—Adjusted (1)	Total	Per Share-Adjusted (1)	Total	Per Share—Adjusted (1)	Non Current Long-Term Debt	Refined Copper Production (Pounds)
1975	**$(13,692,218)**	**2,343,795**	**$(5 84)**	**$(10,927,930)**	**$10,462,933**	**$ 878,949**	**$ 38**	**$42,965,100**	**$18 33**	**$105,184,232**	**$44 88**	**$31,269,551**	**141,551,410**
1974	17 947 037	2 343 795	7 66	33 427 160	7 519 845	3 515 729	1 50	70 439 438	30 05	119 755 399	51 09	32 666 703	133 795,919
1973	10 568 656	2 343 795	4 51	25 828 218	5 487 854	—	—	48 919 059	20 87	105 324 091	44 94	33 567 779	157 011 226
1972	(6 934 706)	2 343 795	(2 96)	6 041,517	4 116 122	—	—	30,280 555	12 92	94 755 435	40 43	35 019 677	140,853,407
1971	(5 595 703)	2 343 795	(2 39)	4 895 632	11 929 109	585 870	25	30,267 187	12 92	101 690 141	43 39	36 321,457	117 268 854
1970	9 586 119	2 343 435	4 09	19 412 680	13 953 454	1 116 426	48	25 680 246	10 97	108 140 577	46 18	24 300 000	135 596 115
1969	15 866 075	2 228 065	6 80	24 797 459	12 137 694	1,060 283	45	25 062 978	10 74	99 528 978	42 64	27 600 000	156,709 694
1968	9 706 016	2 117 804	4 16	17 554 001	14,416 405	1,028 295	44	18 018,645	7 73	84 641 250	36 32	33,400 000	147 604 119
1967	614 665	2 054 668	26	7 971 347	18 074 371	1 025 393	44	18 664 070	8 03	75 962 056	32 64	35 412 500	101 568 460
1966	8 467 627	2 046 775	3 65	14 503 682	24 611 993	994 231	43	18,111 475	7 80	76 178 193	32 82	22 400 000	131 069 202
1965	8 532 708	1 982 169	3 69	13 932 806	5 076,296	236 446	10	29 778 017	12 87	69 351,438	29 96	23 600 000	138 064 322
1964	3 302 035	1 886 625	1 45	8 784 885	3 227 790	—	—	21 525 868	9 48	60 372 823	26 58	24 800 000	118 107,726
1963	3 545 717	1 877 773	1 57	7 229 864	8 721 331	—	—	21 245 272	9 40	57,611 308	25 48	29 642 263	121,998,453
1962	3 299 904	1 877 573	1 46	7 350 579	4 446 070	—	—	25,138 775	11 12	54,906 985	24 28	33 095 731	117 484,025
1961	2 657 639	1 877 473	1 18	6 089 557	3 139 191	—	—	26 470 520	11 71	51 605 514	22 83	36,495 731	112 881 034
1960	(1 291 022)	1 877 473	(57)	2 329 722	2 932 954	938 761	42	26 151,143	11 57	48,947 875	21 65	39 080 731	79,583,493
1959	2 405 095	1 877 473	1 06	6 501 502	1 732 632	938 761	42	31 499 707	13 93	51 177 658	22 64	42 480 731	74 776,464
1958	2 585 309	1 877 473	1 14	6 848 971	883 624	938 749	42	32 852 309	14 53	49 711 324	21 99	46 861,333	86 431,989
1957	2 164 979	1 877 473	96	6 442,864	1,968 492	1 876 546	83	29,081 421	12 86	48 064 764	21 26	51 448 048	74 938 684
1956	9 155 972	1 875 420	4 05	13 137 932	, 885 351	1,787 984	79	29 110 347	12 89	47 723 992	21 13	51 596 274	80 426 212
1955	9 040 059	1 778 534	4 02	13 221,191	3,673 328	621 419	28	26 486 265	11 79	40 361 203	17 96	57 850 876	68,137,483

(1) Adjusted to reflect 5% stock dividend 12/15/58
3% stock dividend 12/9/65
3% stock dividend 12/9/66
3% stock dividend 12/6/68
5% stock dividend 12/5/69
5% stock dividend 12/4/70

Copper Range views of the market place is that, with three major fabricators of copper products in the United States, seven medium-size fabricators (including Copper Range) and approximately 70 smaller fabricators, competition in this area is principally on the basis of price and time of delivery; and that Copper Range's facilities are better suited to the specialized order market for fabricated copper products, which involve somewhat higher production costs and prices, than to the market for larger, standard orders. Copper Range believes that Hussey's network of warehouses provides it with a competitive advantage of terms of delivery at industrial centers.

2. Inspiration Consolidated Copper Company

Inspiration is a domestic mining company and accounts for about 4% of U.S. refined output. A continusous cast and rolled copper rod-making facility converts about 65% of Inspiration's copper production into a fabricated form sold to wire and cable manufacturers.[1]

As discussed elsewhere, Anaconda has held a significant stock interest in Inspiration, and supported sale of a larger block to the Anglo American Group in 1975, the result being that these two groups collectively hold the majority of Inspiration's stock.

The bulk of Inspiration's mine production comes from relatively low-cost open-pit operations in Arizona. Revenues were $98 million in 1974, and included $83 million in deliveries of copper and $15 million in

[1] Inspiration lists two major customers, Western Electric and Anaconda Wire and Cable Co., each of whom accounted for more than 24% of total 1972 revenues.

smelting and refining tolls and fabricated product sales.

Total mine production in 1974 was 122 million pounds of copper, of which some 75% was obtained from open-pit mining. The Inspiration area mines including heap and dump leaching operations, contributed about 81%, Christmas Mine 11%, and the Ox Hide Mine's open-pit and heap-leaching operations, 8%.

Approximately 8% of Inspiration's output is in the form of electrowon cathode, another 14% from waste dump leaching, and another 18% from precipitation of cement copper from low grade solutions. These operations require substantial amounts of sulfuric acid and will be able to utilize that from the new acid plant which came on stream in 1974, in conjunction with the new smelter (discussed below).

The average price received for the 112 million pounds of refined copper delivered in 1974 was 74.5 cents per pound. This was 50% higher than that received in 1972. Costs before depreciation, depletion, and taxes were about 44 cents a pound in 1972. The company began depreciating its new smelter pollution control facilities in 1974, which increased its average cost by 3 cents/lb. in that year and 4 cents/lb. on the somewhat lower production for 1975; it shows a pre-tax loss in 1975 on deliveries at 63.3 cents/lb., and lower fabricated product sales.

Reserves at the Inspiration area are estimated to contain nearly 2 billion pounds of recoverable copper; they have been expanded periodically by inclusion of lower-grade ores as the company becomes able to treat such ores economically.

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TEN-YEAR REVIEW 1965-1974
(Amounts expressed in thousands, except price and per share figures)

Year	1974**	1973**	1972**	1971
Highlights	Price controls end April 30, price rises to 85¢ by June 5 40-day strike in 3rd quarter, market weakens with downturn in U S and foreign economies Price drops to 72¢ by year end	Rapidly increasing demand world-wide U S prices move back to 60¢ ceiling in first quarter U S government allows increase to 68¢ in December Pollution control facilities ready for start-up at year end	Copper supply ample, demand modest until year-end upturn Smelter pollution control facilities and acid plant under construction	Strike closes operations for two months Copper price falls to 50 25¢ in November
Deliveries of copper				
Pounds	111,568	129,732	145,519	108,679
Price per pound***	74 50¢	59 18	50 80	51 98
Proceeds	$83,123	76,774	73,922	56,492
Other operating revenue	14,190	12,605	11,239	9,253
Interest and other income	1,134	820	388	441
	98,447	90,199	85,549	66,186
Costs, other than those shown separately below	62,330	58,878	54,564	41,429
Taxes, other than income taxes	6,768	5,793	5,399	4,543
Exploration and metallurgical research	3,697	2,770	2,241	1,679
Selling and general administrative expense	1,521	1,492	1,227	1,165
Interest expense	3,083	–	–	–
Depreciation	9,836	5,800	5,096	5,036
Depletion	167	221	250	254
	87,402	74,954	68,777	54,106
Income before income taxes	11,045	15,245	16,772	12,080
Income taxes	1,576	644	4,592	3,352
Net income	$ 9,469	14,601	12,180	8,728
Net income per share	$ 3 92	6 05	5 06	3 63
Average number of shares outstanding	2,416	2,414	2,407	2,407
Dividends	$ 6,283	4,829	4,815	4,814
Dividends per share	$ 2 60	2 00	2 00	2 00
Capital expenditures	$18,751	40,781	27,746	9,809
Stockholders' equity at year end	$91,208	87,948*	77,882*	70,496*
Stockholders' equity per share	$ 37 74	36 42*	32 35*	29 29*

*Restated to reflect adjustment related to settlement of excavator-collapse litigation
**See Management's Discussion and Analysis of Earnings on page 8
***1972 and subsequent deliveries are shown at cathode price whereas 1971 and prior deliveries are on a wirebar basis

At the Christmas mine, underground mining was plagued by water inflow and unstable rock conditions and operations were suspended in 1966; the open-pit operations have been expanded. The underground operations are being maintained on a standby basis.

Inspiration's smelter, with a capacity of about 300 million pounds of copper per year, has typically treated a substantial amount of toll and custom material from other copper producers' mines, notably those of Cities Service and Anaconda. This has apparently stood the company in good stead in regard to financing its new smelter, designed to meet Arizona emission control standards.

In 1972, Inspiration's plan for meeting Arizona smelter emission control standards by 1974 called for a new installation costing about $45 million. Some $13.2 million was to be advanced by a toll customer to be repaid over the term of a ten-year contract for treating the customer's concentrates. The balance was being borrowed on bank revolving credit, to be replaced by long-term debt financing. This smelter complex, involving a new technology, was a substantial undertaking, relative to the size of the company: total net plant and equipment was $66 million at the beginning of 1973 with net working capital of $24 million.

The new smelter came onstream in 1974, at a higher cost than originally estimated, but having the benefit of favorable external financing. Further details are presented in the section on Environmental Matters.

3. Newmont Mining

Newmont, a diversified mining investment and operating company, is the parent of Magma Copper Company. Newmont also owns, importantly, Carlin

Gold Mining Company, and 91% of Foote Mineral Company, and interests in petroleum and cement companies. Internationally, it has diverse mineral interests, notably in Canadian and African mining companies. Total revenues in 1975 were $516.5 million, and net income $52.9 million, compared to $547.7 million and $113.6 million respectively in 1974. Total assets are approximately $1.1 billion, of which its investments in companies owned 50% or less represent nearly $200 million at cost or equity.

Magma Copper Company is the single largest source of Newmont's income: $189.6 million in sales and $20 million in net income for 1975, compared to $251 million and $57 million respectively in 1974. Magma is the fourth largest U.S. copper producer and presently among the more profitable of the major companies (with estimated average total costs of between 50¢ and 60¢/lb). Its principal copper properties, smelter, and refinery are located at San Manuel, Arizona. Another mine-mill complex is at Superior, Arizona. Magma normally employs about 4,400 persons in copper mining, smelting, and refining operations.

In Canada, the Granduc copper mine in northern British Columbia is jointly leased with Asarco. The wholly-owned Similkameen project near Princeton, B.C., began producing copper concentrates in mid-1972. Newmont has sold its share of concentrates production at both Canadian properties for several years to Japanese interests.

O'okiep Copper Company, 57.5% owned, operates several South African copper mines (Amax has a 17% interest). Dawn Mining Company, 51% owned, is a medium-size supplier of natural uranium concentrates, from the Midnite Mine. Resurrection Mining Company, a small wholly-owned subsidiary,

Newmont Mining Corporation and Subsidiaries

Ten Year Summary

	1975	1974	1973
Gross Income:			
Sales and other operating revenue	$516,524,000	$547,738,000	$427,780,000
Dividends, interest and other income	14,367,000	16,043,000	11,894,000
Equity in income of affiliated companies	12,210,000	40,304,000	38,949,000
Net gain on security transactions (on an identified cost basis)	13,547,000	740,000	3,400,000
	556,648,000	604,825,000	482,023,000
Costs and Expenses.			
Operating costs and expenses	414,995,000	366,473,000	276,774,000
Depreciation and depletion	32,342,000	26,098,000	20,056,000
Granduc write-off	—	12,278,000	—
Exploration and research	11,237,000	15,007,000	15,910,000
Interest expense	20,237,000	17,619,000	18,825,000
Income taxes (current and deferred)	22,197,000	45,227,000	40,072,000
Minority interest	2,752,000	8,517,000	7,010,000
	503,760,000	491,219,000	378,647,000
Income before extraordinary items	52,888,000	113,606,000	103,376,000
Extraordinary items	—	—	—
Net Income	52,888,000	113,606,000	103,376,000
Preferred stock dividends	2,578,000	2,833,000	3,181,000
Net Income applicable to common stock	$ 50,310,000	$110,773,000	$100,195,000
Cash Dividends Paid on Common Stock	$ 39,356,000	$ 37,858,000	$ 27,289,000
Average Shares of Common Stock Outstanding	24,580,000	24,332,000	24,135,000
Per Share of Common Stock Based on the average number of shares outstanding and after preferred stock dividend requirements			
Income before extraordinary items	$2 05	$4 55	$4 15
Extraordinary items	—	—	—
Net income	$2 05	$4 55	$4 15
After full conversion of convertible preferred stock (amount before extraordinary item in 1972 is $1 84)	$2.00	$4 33	$3 92
Cash dividends	$1 60	$1 55	$1 13
Stock dividends	—	—	—
Expenditures for Property, Plant and Mine Development	$ 53,231,000	$ 55,769,000	$ 47,636,000
Stockholders' Equity	$648,331,000	$637,370,000	$564,361,000

has a joint venture with Asarco, which is producing lead and zinc concentrates from a mine near Leadville, Colorado; production began early in 1971. Newmont is also engaged in petroleum and natural gas exploration and production in the U.S. and Canada.

Newmont now has most of its consolidated assets attributable to companies in North America. These companies accounted for 97% and 77% of consolidated net income in 1975 and 1974, respectively.

With respect to financing, Newmont took steps to restructure its corporate debt in 1972. A loan of $50 million from a leading insurance company was closed in November 1972, in the form of 12-year notes, with repayment beginning in December 1978. Simultaneously, the $130 million revolving credit, placed in 1972 with a group of New York banks, was restructured. Magma obtained financing for its air pollution control program in the form of a $30 million pollution control revenue bond issue, as discussed in another section.

Newmont's consolidated long-term debt was 27% of total capitalization at December 31, 1975, down from a figure near 30% at year-end of 1972.

4. <u>Pennzoil Company (Duval)</u>

Pennzoil engages in oil and gas exploration and production, in processing, refining and marketing of oil and gas and refined petroleum products and in mining and processing copper, molybdenum, potash and sulfur. It markets refined products under the name PENNZOIL(R) and various other trade names. Total revenues were $942 million in 1974 and $1,082 million in 1975. A five-year financial summary is presented in the Appendix.

a. Mining

Duval Corporation (Duval), a wholly owned subsidiary of Pennzoil, is engaged in the mining and processing of ores and minerals, principally copper, molybdenum, potash and sulfur. It is the fifth largest copper producer. Mining revenues were approximately $280 million in both 1974 and 1975; mining operations income was approximately $47 million in 1975, compared to $70 million in 1974, when it represented about one-third of Pennzoil operating income.

During the past eight years (since the acquisition of Duval by Pennzoil through merger with the United Gas Corporation), Duval has spent more than $419 million for the acquisition and development of new properties and the installation of new facilities, including more than $49 million in 1975. The new facilities require Duval to market substantially increased amounts of its products and to participate in markets, both domestic and foreign, in which it did not previously participate to a significant extent.

Metals sales constitute the bulk of Duval's revenues and typically the major part of gross operating income.

Duval owns and operates three open-pit copper-molybdenum mines in Arizona and two open-pit copper mines in Nevada, and four concentrating mills located near its mines. Silver is recovered as a by-product from all the ore bodies, and gold is recovered as a by-product from the Nevada ore bodies. Duval's largest mine, the Sierrita Property located near Tucson, Arizona, is owned by Duval Sierrita Corporation (Duval Sierrita), a wholly owned subsidiary of Duval. Operations at the Sierrita Property began in 1971.

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Statistics

PENNZOIL COMPANY AND SUBSIDIARIES

		1975	1974	1973	1972	1971
Gross Revenues—In Thousands (A)						
Oil and Gas Production (B)	$	313,168	243,890	135,463	103,073	94,821
Refining and Marketing		518,097	441,796	282,765	196,603	146,931
Mining		284,308	281,425	201 723	166,356	130,504
Gross Operating Income—In Thousands (A) (C)						
Oil and Gas Production (B)	$	164 947	121,904	45,833	38,417	33 999
Refining and Marketing		24,310	27,202	31 617	23 358	20 272
Mining		36,890	70,240	33,989	15 987	15 896
Net Crude Oil and Plant Products Produced (Bbls) (B)		21,143,908	19 821 548	16,983 435	15,548 091	14,937 768
Daily Average		57,929	54,305	46,530	42,481	40,925
Net Natural Gas Produced (Mcf) (B)		270,315,000	273,360,000	246,435,000	221,396,000	214,800,000
Daily Average		741,000	748,000	675,000	605,000	588 000
Crude Oil and Liquids Processed (Bbls)		18,529 083	17 388,496	13,283,971	12,114,159	11 640 078
Daily Average		50,765	47,640	36,394	33 099	31,891
Refined Products Produced (Bbls)						
Lubricating Oils, Waxes and Other		10,993,976	10 492,515	6 356,766	5,307 107	5 135 694
Gasoline and Naphtha		6,885 384	6,361,269	6 257,666	5,981,568	5,884,236
Mined Products Sales—In Thousands						
Sulphur—Long Tons		1 787	1,993	1 762	1 400	1 026
Potash—Short Tons		1,043	1,527	1 357	1,109	1 270
Copper—Pounds		313,217	244,889	251,032	282 229	193,216
Molybdenum—Pounds		16,371	20,924	21 965	16 596	10 405
Silver—Ounces		1 805	1,287	1,570	1,621	1 348
Gold—Ounces		19	10	8	13	16
Number of Employees		9,433	9,487	8 872	7,726	7 689
Payroll and Payments for Account of Employees —In Millions	$	146 1	122 8	102 9	84 2	77 2

(A) Without adjustment for certain intercompany transactions
(B) Includes POGO's entire interest but does not include any amounts attributable to PLATO
(C) Income before interest charges, Federal income tax and outside shareholders' interest

Duval's copper concentrates and precipitates are currently sold as such or are toll smelted and refined by others for redelivery to and marketing by Duval. Duval has recently completed the physical construction of and is now in the process of starting up the operation of a CLEAR-process hydrometallurgical plant near the Sierrita Property for the electrolytic production of copper crystals (equivalent to a high-grade blister copper) from concentrates produced at the Esperanza and Sierrita Properties and precipitates produced at the Esperanza and Mineral Park Properties. The patented CLEAR process is designed to create no solid, liquid or gaseous pollution. The plant is intended to produce 40,000 tons of copper crystals per year. Design changes and inflation have resulted in higher costs for the plant and later completion than originally estimated. It is currently estimated that the plant will cost a total of $43 million, including capitalized interest and start-up and test costs. The copper crystals will be marketed as such to refiners and others or will be toll-refined by others for marketing by Duval.

Most of Duval's molybdenum concentrates are currently treated by Duval for marketing as molybdenum sulfide or for roasting in Duval's roasters. The roasted product, molybdenum trioxide, is packaged and marketed by Duval as technical molybdic oxide. The balance of the molybdenum concentrates is converted into ferro-molybdenum, one of a broad line of products offered to the steel and foundry industries. In the last several years, Duval has accounted for about 18% of domestic molybdenum production (Amax accounts for about 60%, Kennecott and Molycorp most of the balance).

b. Duval Sierrita--GSA Contract

In November, 1967, the U.S. General Services Administration (GSA) and Duval Sierrita Corporation entered into a domestic copper production expansion contract pursuant to the provisions of the Defense Production Act of 1950 for the development of the low-grade copper-molybdenum Sierrita ore body adjacent to Duval's Esperanza Property. Construction of facilities were substantially completed in March, 1970. Approximately $181 million was required to develop the original project (not including the cost of the expansion project referred to below) of which $83 million was obtained from the GSA in the form of advances against future deliveries of copper produced from the property; $48.75 million from commercial bank loans guaranteed in part by the GSA; $10 million from Pennzoil; and the remainder from Duval in equity or loans. Duval provides management and technical guidance to Duval Sierrita at cost.

The contract with the GSA provided that repayment of advances would be made by delivery of about 218.4 million pounds of copper to the GSA prior to June 30, 1975. The advances were credited at the rate of 38¢ for each pound of refined copper delivered. While the contract provided that certain minimum deliveries must be made at stated intervals Duval Sierrita was entitled to sell in the open market its molybdenum and by-product silver production and such amount of its copper production as may be necessary to cover all cash operating expenses and maintain working capital.

In May, 1970, these contracts were amended to provide for an increase in the mine and mill capacity at the Sierrita Property. Duval Sierrita agreed to spend not less than $8 million on additional facilities and guaranteed the GSA an average rate of ore throughput on an annual basis of not less than 72,000 tons per day. In turn, the GSA and the commercial banks agreed to permit Duval Sierrita to sell on the open market for its own account 90% of production attributable to any ore throughput exceeding 72,000 tons per day. The remaining 10% of such production (net of sales required to meet cash operating expenses attributable thereto) was to be delivered to the GSA at a fixed price of 38¢ per pound.

The facilities for integrated copper-molybdenum milling operations were completed in the latter part of 1970 and normal production commenced subsequently.

Generally, prices and costs for copper in the U.S. subsequently rose substantially in the inflationary period of 1971-1974. In 1975, Duval Sierrita arranged a substantial acceleration of deliveries to the GSA, after obtaining a new $55 million bank credit, and by December 1975, the total amount of copper required to be delivered to the GSA had been made available for delivery to the GSA at refineries. Duval Sierrita's cash flow in excess of that needed to cover cash operating expenses and capital additions and replacements and to maintain working capital is now dedicated to accelerate the repayment of the bank loans, and Duval Sierrita's operations will not contribute to Duval's cash flow until the bank loans have been repaid.

Duval estimates the proven ore reserves of the Sierrita Property to be 523 million tons with an average copper content of 0.33% and an average molybdenum content of 0.032%.

c. Marketing

Duval produced 132,148, 132,594 and 137,956 tons of copper in 1973, 1974, and 1975, respectively. This production accounted for approximately 8% of domestic mine copper production in 1973 and 1974 and approximately 10% of such production in 1975. In 1975 Duval sold 156,604 tons of acopper by the acceleration of deliveries (65,000 tons) to discharge Duval Sierrita's obligations under the GSA contract. Substantially all copper sales during this period were made in the United States.

Asarco currently smelts and refines substantially all Duval's copper concentrates and precipitates. Under existing arrangements Asarco purchases a portion of the copper production (in the form of copper concentrates and precipitates) and smelts and refines the balance on a toll basis for redelivery to and marketing by Duval. Duval's current sales are made to a number of wire and brass mills.

Through 1975, Duval's sales of refined copper on the open market were priced on the basis of the Metals Week wirebar average for U.S. producers, delivered. Effective January 1, 1976, Duval declared its own pricing basis.

5. Phelps Dodge Corporation

Phelps Dodge (PD) is the second largest domestic copper producer. Sales and operating revenues in 1974 exceeded $1 billion, of which approximately 35% was attributable to deliveries from PD's own mine production. Net income after taxes was $112.5 million. Both sales and net income were down substantially in 1975, due to decline in nonferrous metals demand and prices. The company has approximately 14,000 total employees, some 50% of whom are associated with primary copper production.

Phelps Dodge (PD) is an integrated producer of copper from mines located in the United States. It sells part of such copper as refinery shapes or as rods, and fabricates the remainder of such copper (as well as copper purchased from others) for sale as wire, cable, and tubular products. PD also does smelting and refining of copper and rolling of copper rod on toll for others. Approximately one half of its refinery production in 1974 and 1975 was material under contract for other companies.

PD participates in the uranium market through Western Nuclear, full ownership of which was acquired in 1971, and is expanding this subsidiary's uranium mining and milling production capacity.

PD investments include importantly, a 40% equity in Conalco, Inc., a large domestic aluminum producer and fabricator; a 16% interest in Southern Peru Copper; plus various interests in 25 companies in 19 countries abroad manufacturing wire and cable and related products.

Phelps Dodge fills most of its copper requirements from its own openpit copper mines at Morenci, Ajo, Metcalf, Arizona; and Tyrone, New Mexico.

PD produced a record 319.6 thousand tons mine output of copper in 1973; production was lower in 1974 due to strikes and in 1975, due to reduced demand. Additional capacity has recently been brought in at the Metcalf mine, at a cost of $194 million to replace the Bisbee operations and to raise overall capacity to 330,000 tons per year. The Tyrone mine was expanded in 1972-1973 to 100,000 tons annual production capacity.

In general, Phelps Dodge is thought to be one of the lowest cost copper producers. The company has reported that production costs per

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phelps dodge

Ten-year Summary of Operations (1966-1975)

(Dollar amounts are in millions except per share figures and copper price)

	1975	1974(a)	1973	1972	1971(a)	1970	1969	1968(a)	1967(a)	1966
Phelps Dodge-mined Metals:										
Copper—thousand tons	**249.7**	281 3	319.6	305 4	281 2	313.5	284.2	213 2	156 7	271 7
Silver—thousand ounces	**1,806**	2,212	2,564	2,385	2,425	2,647	2,425	1,780	1,203	2,126
Gold—thousand ounces	**41**	52	68	70	70	82	84	71	48	87
Copper sales—thousand tons	**276.6**	231 7	324.7	327 7	288.8	270 9	283 5	212.4	157.2	272 3
Copper price—cents per pound(b)	**64.2**	77 3	59 5	51.2	52 0	58 2	47.9	42 3	38.6	36 6
Revenues and Expenses:										
Operating revenues	**$ 780.8**	1,026 1	962 0	765 8	703 6	716 2	628 9	531.7	509.8	554 0
Non-operating revenues	**27.4**	14 3	21 2	14 7	15 3	17.9	21 1	16 7	17.5	15.5
Costs and expenses exclusive of items shown below	**636.5**	789 0	705 3	554 1	524 1	495 7	464 3	412.5	415 3	395.9
Exploration and research	**23.0**	18 0	14 9	11 9	11 2	8 2	5 5	4.3	3.6	3.1
Selling and general administrative expenses	**31.9**	34 1	32.6	31.0	27 8	27.7	24.3	19.1	19.4	18.3
Depreciation, depletion and amortization	**35.1**	36 6	35 9	34 2	29 1	21 9	19 5	15 0	11 9	13 5
Interest expense	**37.4**	24 4	15.8	14 1	8 7	6 6	4 6	2 5	0 6	—
Income taxes	**(13.2)**	36 7	66 7	44 8	39 9	65.1	43 3	31 3	25 6	56.5
Equity earnings (losses) less income tax	**(11.1)**	10 9	(3 0)	(8 2)	(4 3)	(0 9)	1 0	0 9	—	—
Extraordinary items less income tax	**—**	9 2	—	—	2 0	4 8	—	—	—	—
Net Income	**$ 46.4**	121 7	109 0	82 2	75.8	112.8	89 5	64 6	50.9	82.2
Dividends	**$ 45.2**	45 2	44 6	43 1	42 9	42.3	39 3	35 3	34 4	43 1(c)
Capital Outlays:										
Capital expenditures	**$ 203.2**	274 7	178 0	94 2	75 5	89 2	84.7	73 9	55 0	30 9
Pre-operating mine development	**19.6**	14 4	10 3	11 4	8 1	4 6	9 4	8 3	3 2	0 4
Investments	**2.8**	7.3	5.9	1 6	6.6	0 3	7 7	5.7	5.1	--
Per Share										
Net income(d)	**$ 2.26**	5 92	5 31	4 01	3 72	5 60	4 43	3.20	2.52	4 05
Dividends	**2.20**	2 20	2 175	2 10	2 10	2 10	1 95	1 75	1.70	2 125(c)
Stock prices (NYSE)—high	**40.25**	49 88	50 25	44 50	48 00	56 50	52.50	55 75	40 00	41.50
—low	**29.00**	25 50	38 75	34.38	28 00	34 00	39 13	29 75	31.25	27.13
Average number of shares outstanding (in thousands)	**20,563**	20,567	20,526	20,514	20,379	20,153	20,179	20,178	20,222	20,285
At December 31										
Net current assets	**$ 146.5**	92 7	217 0	213 7	208 5	141.8	137 3	126.6	173 6	215.2
Total assets	**1,652.1**	1,492.9	1,268 9	1,043 1	988 7	878 5	792 3	652 8	610.1	581.7
Long-term debt	**522.5**	327 1	281 9	181 3	166 0	86 1	77 2	28 5	2 7	—
Shareholders' equity	**893.3**	892.3	815 2	749 3	710 2	662 0	593 9	543 8	509 5	500 1
Per share	**43.44**	43 38	39 67	36 53	34 62	32.90	29.43	26.95	25.25	24 65

(a) Primary metal production curtailed by strikes
(b) Metals Week average domestic delivered price—wirebars
(c) Includes extra of 42½¢ per share
(d) Based on average number of shares outstanding for year

phelps dodge

Supplemental Schedules (Continued)

SCHEDULE C—PROPERTY, PLANT AND EQUIPMENT	December 31, 1975	1974
Buildings, machinery and equipment, at cost	$1,359,110,000	$1,187,102,000
Mining properties	141,671,000	231,098,000
Pre-operating mine development	97,679,000	78,616,000
Land and water rights, at cost or less	30,522,000	28,665,000
	1,628,982,000	1,525,481,000
Less accumulated depreciation, depletion, amortization	446,610,000	529,382,000
Net asset value	$1,182,372,000	$ 996,099,000

The reduction in "Mining properties" and related "accumulated depletion" above reflects the closing of the fully depleted mines at Bisbee, Arizona

SCHEDULE D—LONG-TERM DEBT (due after one year)	December 31, 1975	1974
6% Notes due 1977-1984	$ 8,000,000	$ 9,000,000
7½% Eurodollar Notes due 1977	25,000,000	25,000,000
7⅜% Notes due 1978(a)	50,000,000	50,000,000
8½% Notes due 1985	125,000,000	—
8 10% Sinking Fund Debentures due 1982-1996(b)	100,000,000	100,000,000
Air Quality Control Obligations		
4⅜% Bond due 1980 (Ajo)	28,000,000	28,000,000
7% Loan due 1977-1987 (Douglas)	8,574,000	9,082,000
5 60% to 6¼% Series A and B Notes due 1983-2004 (Morenci) (c)	98,700,000	98,700,000
7¼% Installment Sale Obligations due 1979-1982 (Hidalgo)	70,000,000	—
Other	9,235,000	7,300,000
	$ 522,509,000	$ 327,082,000

(a) Subject to optional redemption at par beginning in 1977

(b) Subject to optional redemption at par beginning in 1991 Annual sinking fund payments of $6,650,000 are required from 1982 through 1995.

(c) Maturities falling due in 1993 and 2003 involve required sinking fund payments beginning in 1987 and 1994, respectively Maturities falling due in 1994 and 2004 involve required sinking fund payments beginning in 1990 and 1995, respectively

Annual maturities 1976-1980 of long-term debt outstanding December 31, 1975 1976—$3,367,000, 1977—$28,407,000, 1978—$54,532,000, 1979—$13,814,000, 1980—$40,891,000 pound of copper are lowest at Morenci, which mines the largest quantity of ore.

All the ore at Phelps Dodge's mines is now sulfide ore. As of early 1973, Phelps Dodge estimated the copper ore reserves at its properties at approximately 1.580 billion tons of ore, containing 9.4 million tons (18.8 billion pounds) of recoverable copper. The Morenci property, the largest of PD's mines, also holds about 60% of PD's reserves. Additional properties are undergoing exploration and development.

a. Copper Smelting

Phelps Dodge's copper smelters are located at Morenci, Ajo, and Douglas, Arizona; and (the new Hidalgo smelter) in New Mexico. Production of the Morenci mine and most of that from Tyrone is treated at the Morenci smelter, which has the capacity to treat nearly 1 million tons annually of copper-bearing materials such as concentrates, ore and scrap. Production of the Ajo mine, and a portion of the Tyrone production, is treated at the Ajo smelter, which has the capacity to treat approximately 300,000 tons of new metal-bearing material annually. Production from a portion of Tyrone, as well as custom material and scrap, is treated at the Douglas smelter, which has the current capcity to treat approximately 860,000 tons of new metal-bearing material annually. The smelters produce anode copper--copper which is then shipped to Phelps Dodge refineries for refining. Metcalf concentrates will be smelted at Morenci. The latter plant is a custom operation, processing copper for other producers and treating scrap. The new Hidalgo smelter, completed at a cost of about $226 million, is expected to begin treating concentrates from Tyrone in the second quarter of 1976. The smelter is the first in the U.S. to use the flash process developed in Finland.

Refinery capacity is located at El Paso (electrolytic and fire-refined) and Laurel Hill, New York (80,000 tons electrolytic and 20,000 tons fire-refined). Wire mills are located in New York (4), New Jersey, (2), Indiana (2), Kentucky and Arkansas. Tube mills are in California and New Jersey. A brass foundry is operated in Alabama and interests are held in 13 foreign fabricating operations.

In 1975 capital expenditures and pre-operating developments at mines, concentrators, and smelters totaled about $200 million, compared with about $260 million in 1974. Of the 1975 expenditures, $39.0 million was spent at Morenci ($56.3 million in 1974), $13.0 million at Metcalf ($64.0 in 1974), $3.4 million at Ajo ($5.9 million in 1974), $2.4 million at Tyrone ($2.6 million in 1974), $6.1 million at the Douglas smelter ($13.7 million in 1974), and $93 million at the Hidalgo smelter.

This accounts for the bulk of all Phelps Dodge expenditures, the balance of the order of $20 million per year or so going into the manufacturing (fabricating) plants and affiliates.

In 1975, a total of $15.3 million was expended for air quality control facilities at the Morenci, Ajo, and Douglas smelters ($45.2 million in 1974), and $21.5 million for the related tailings leach programs at Morenci ($21.6 million in 1974).

Additional information on Phelps Dodge's pollution control programs is presented in the separate "Environmental" section.

Capital investment in the Hidalgo smelter project was $226.6 million by the end of 1975, of which $92.9 million was spent during the year.

Total investment, including the new town of Playas and the 36-mile industrial railroad linking the smelter with the Southern Pacific system, is expected to amount to about $240 million.

Phelps Dodge has agreed with Cyprus Mines Corporation to treat at Hidalgo, beginning in 1978, concentrates from Cyprus' expanded Bagdad, Arizona, mine. Additional facilities to make this possible, including a second sulfuric acid plant, are being designed and construction is expected to begin in the second quarter of 1976. Under this agreement, Cyprus will lend PD $35 million toward to cost, estimated at $40 million, of the additional facilities.

Phelps Dodge had $166 million in long-term debt outstanding at December 31, 1971. Reports to the Securities and Exchange Commission showed that, as of September 30, 1973, long-term debt had increased to $288 million primarily as a result of the issuance of nearly $100 million in Pollution Control obligations. Additional long-term debt and pollution control financing were obtained subsequently; by year-end of 1975, long term debt was 31% of total capitalization, the highest among the traditional copper companies (i.e., excluding the oil companies from the comparison).

6. Cities Service Company

Cities Service is engaged in finding, producing, manufacturing and distributing oil, gas, and chemical products. The company's annual revenues are in the $3 billion category. Employment totals 17,000-18,000.

Its North American Chemicals and Metals group produced the following tonnages for sale in the last three years:

CITIES SERVICE

	1975	1974	1973
	(thousand tons)		
Sulfuric Acid	865	850	910
Copper	47	31	40
Iron Products	284	124	217
Zinc Concentrates	9	6	206
Other Industrial Chemicals	156	161	206

Total sales from North American Chemicals and Metals operations are now in the range of $140-150 million per year, but representing only about 5% of the company total, and a somewhat higher percentage contribution to profits. Detailed financial statistics are presented in the Appendix.

a. Copper

The Company conducts extensive operations in the "Copper Basin" region of Copperhill, Tennessee. Cities Service commenced its activity there with the purchase of Tennessee Copper Company in 1963. The ore is mined from five underground mines, and contains 35% iron, 24% sulfur, 1% copper and 1% zinc. Operations are integnated for production of industrial chemicals and iron products. The values of iron and sulfur recovered at Copperhill are considerably greater than the copper values per se. In 1970, a very large expansion and modernization program was begun, including a new copper smelter, iron ox ide pellet plant and an additional sulfuric acid plant. Construction of yet another acid plant was completed in 1975, and completion of two water treatmetn plants to remove both chemicals and suspended solids from process water is scheduled for 1976.

Cities Service thinks of itself as one of the top ten copper producers in the United States. (It is either 10th or 11th, depending upon how one views the Cyprus Mines group). In addition to operations at Copperhill, a much more extensive copper mining operation is conducted in Arizona as will be discussed below.

After many years of production, the in-place reserves of the Copper Cities and Diamond H openpit mines at Miami, Arizona, were exhausted early in 1975, but leaching operations will continue at declining rates for several years.

The mine and mill facilities of the Pinto Valley openpit mine near Miami, Arizona, were completed in 1974 ahead of schedule and at capital costs slightly below estimates. This represented the largest construction project in the Company's history. The first division began production in June of 1974 and the second division in October of 1974. The design capacity of 40,000 tons of ore per day was reached early in 1974. This production rate will recover in excess of 60,000 tons of copper annually.

Copper produced in concentrate form will be controlled by the throughput of new smelter operations of another company (believed to be Inspiration Consolidated).

Start-up of the Miami East underground mine was expected to begin in the early part of 1976, but was postponed due to escalated costs and depressed market conditions. It is believed the production could amount to 2,000 tons of high grade ore per day in 1978.

A solvent extraction-electrowinning plant to produce cathode copper at the Miami leaching operation is under construction and should be completed by mid-1976. This will eliminate the toll smelting-refining on the major part of copper recovered by leaching.

An active mineral exploration program is being conducted in the Rocky Mountain area, in Alaska, and in Canada. The objective is to find deposits of copper and copper-associated minerals.

Sales of fabricated copper products in the form of sheet, strip, and insulated wire were at record levels in 1974. (Volumes have declined in the early months of 1975, reflecting the trend of economic conditions). At the Chester, New York, plant which manufactures insulated wire and cable for the electric and electronic industries, in 1974, a 50% expansion was completed.

b. Financing

The Company has used various sources of funds to supply its capital needs. Earnings and other funds from operations were the major source providing approximately 60 percent of the funds expended on its diverse operations recently. Additional funds were obtained from the sale of $150 million 9-3/4 percent sinking fund debentures and the receipt of $37 million in interest-free advances from natural gas pipeline companies to be repaid from future natural gas production. The Company also raised $48 million by guaranteeing environmental control and industrial development revenue bonds issued by municipal agencies at favorable interest rates for construction of facilities leased to the Company. (The obligations under these leases are recorded as long-term debt in conformity with accepted accounting practices).

CITIES SERVICE COMPANY

LINE OF BUSINESS — SALES AND CONTRIBUTIONS TO CONSOLIDATED PROFITS

	1975		1974		1973		1972		1971	
SALES	$ Millions	%	$ Millions	%	$ Millions	%	$ Millions	%	$ Millions	%
North American petroleum	2,407 8	75	2,102 5	75	1,382 3	68	1,177 1	63	1,167 5	64
Natural gas transmission	226 1	7	203 4	7	174 1	9	170 2	9	157 4	9
North American petrochemicals	273 2	9	272 6	10	215 2	11	200 2	11	173 5	10
North American chemicals & metals	143 4	4	136 6	5	151 5	7	223 6	12	217.6	12
International	137 1	4	74 8	2	59 3	3	45 8	3	42.7	2
Other (a)	13 1	1	16 4	1	52 2	2	45 2	2	51 2	3
	3,200 7	100	2,806 3	100	2,034 6	100	1,862 1	100	1,809 9	100
CONTRIBUTION TO PROFIT										
North American petroleum	279 9	97	312 2	90	162 2	69	109 7	67	101 6	62
Natural gas transmission	58 8	20	33 3	10	35 0	15	37 2	23	31.8	20
North American petrochemicals	10 0	3	19 6	6	20.3	8	18 6	11	6 2	4
North American chemicals & metals	(24 0)	(8)	(21 6)	(6)	6 1	3	10 3	6	17 8	11
International	(42 2)	(15)	(19 3)	(6)	(3 3)	(1)	(1 9)	(1)	—	—
Other (a)	7 5	3	20 0	6	15 2	6	(10 5)	(6)	5 6	3
	290 0	100	344 2	100	235 5	100	163.4	100	163 0	100
Interest expense	(52 9)		(51 3)		(44 7)		(42.7)		(41 0)	
Federal and foreign income taxes	(99 4)		(89 1)		(55 2)		(21.6)		(17 5)	
Income before extraordinary credits	137 7		203 8		135 6		99 1		104 5	

(a) Includes sundry operations and general corporate income and expenses

Source: 1975 Annual Report

CITIES SERVICE COMPANY (Continued)

Summary of Consolidated Financial Data

Stated in millions of dollars except per share data

CAPITAL EXPENDITURES	1975	1974	1973
North American petroleum			
Production	151 0	182.4	178 5
Natural gas liquids	10 5	6 9	4 1
Refined products	38 4	49 7	33 2
Alternate fuels	92 5	46 4	4 9
	292 4	285 4	220 7
Natural gas transmission	19 2	16 6	13 6
North American petrochemicals	21 3	19.0	12 5
North American chemicals & metals	50 0	90 5	75 1
International	47 8	28 0	19 6
Other operations	5 2	5 4	54 9
Total plant additions	435 9	444 9	396 4
Investments	3 5	2 0	5 8
Total	439 4	446 9	402 2

PROPERTY, PLANT AND EQUIPMENT			
North American petroleum			
Production	1,354 2	1,253.1	1,124 6
Natural gas liquids	229 5	220.7	215 2
Refined products	697 7	696 5	691 2
Alternate fuels	120 9	52 6	5 5
	2,402.3	2,222 9	2,036 5
Natural gas transmission	394 6	379 5	365 4
North American petrochemicals	325 4	309 2	313 3
North American chemicals & metals	408 2	365 2	281 7
International	68 0	50 8	39 0
Other operations	85 6	84 2	255 5
Total gross investment	3,684 1	3,411 8	3,291 4
Accumulated depreciation and depletion	1,597 4	1,481 0	1,437 6
Total net investment	2,086 7	1,930 8	1,853 8

CAPITALIZATION			
Long-term debt	780 1	581 2	613 8
Stockholders' equity	1,631 8	1,673 7	1,530 1
Total capitalization	2,411 9	2,254 9	2,143 9
Ratio of long-term debt to capitalization	32 3%	25 8%	28 6%
Stockholders' equity at year end, per share*	60 46	62 25	56 95
Return on stockholders' average equity — income before extraordinary credits	8 6%	12 7%	9 2%

*Adjusted for 3% stock dividend paid in 1974

In 1975, Cities Service substantially completed negotiations for an agreement to borrow $100 million from the Province of Alberta, Canada, to help finance development of the Syncrude Canada Ltd. project. The company renegotiated an expanded $200 million line of credit from a consortium of banks. The company issued commercial paper during the year; none was outstanding at year end.

There is a production payment liability on the Pinto Valley orebody which totaled $107.9 million at December 31, 1975. This was a net reduction of $300,000 during 1975 as repayment began from a percentage of the revenues on sale of related copper production.

7. Cyprus Mines Corporation

Cyprus Mines Corporation was incorporated in 1916 in New York. It operated the Old Dick Mine near Bagdad, Arizona. Cyprus is now engaged directly and through its subsidiaries and affiliated companies in the production and marketing of a diverse group of metallic minerals including copper, lead, zinc, iron ore, silver, and molybdenum; ocean transportation of iron ore and other basic commodities; the production, processing and marketing on nonmetallic minerals, including premium grade talc, kaolin clays, and cement; and in the manufacture and marketing of wire cable, tubing and related products for the electrical industry.

Cyprus, through Prima Mining and Bagdad Copper, is a source of over 200 million pounds per year of domestically mined copper.

The company operates principally through wholly-owned divisions and corporations in which it has a majority interest and management control. (The two major exceptions are: (1) Marcona Corporation, which is engaged in iron ore mining [principally associated with Peru] and shipping, is owned 50% by Cyprus and 50% by Utah International as to voting stock and 46% each as to equity; (2) Mount Goldsworthy Mining Associates, in which the company owns and undivided one-third interest in the iron ore reserves in Western Australia and participates equally with Consolidated Gold Fields Australia and Utah Development Company in the ownership and management of Goldsworthy Mining Limited, the contract mining company).

The consolidated financial statements include all of the wholly owned and majority-owned subsidiaries of Cyprus Mines Corporation (Cyprus). The majority-owned subsidiaries are the following: Cyprus Anvil Mining Corporation (Cyprus Anvil, 63%-owned), Cyprus Pima Mining Company (Cyprus Pima) (50.01%-owned), Cyprus Hawaiian Cement Corporation (Cyprus Hawaiian) (92.98%-owned), and Cyprus Metallurgical Process Corporation (Cymet) (90%-owned).

Affiliated corporations which are owned from 25% to 50% are accounted for by the equity method (wherein Cyprus includes in its investment account for each affiliate the cost of the capital stock acquired, its equity in their retained earnings, and advances made). The products, and profits of Cyprus for the last five years are listed on the next page.

a. Nonferrous Minerals Group

The company's nonferrous minerals group includes the Pima, Bagdad, and Bruce mines in Arizona; and the Anvil mine in the Yukon Territory of Canada.

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CYPRUS MINES CORP.

1971-1975 REVENUES AND PROFITS BY LINES OF BUSINESS

(Dollars in millions)	1975		1974		1973		1972		1971	
REVENUES										
Nonferrous Minerals	$114 1	28%	$132 8	28%	$126 5	32%	$ 96 9	32%	$ 82 9	28%
Industrial Minerals	38 5	9	34 6	7	25 4	7	20 0	6	18 0	6
Iron Ore	112 9	28	137 2	29	108 3	28	89 6	30	89 3	31
Shipping	15 7	4	18 3	4	20 3	5	15 3	5	28.3	10
Manufacturing	114 6	29	148 7	31	105 3	27	77 6	26	70 5	24
Other	8 9	2	6 6	1	5 0	1	3 3	1	4.2	1
Subtotal (a)	404 7	100%	478 2	100%	390 8	100%	302 7	100%	293 2	100%
Add minority interests	74 8		86 8		69 7		48 8		42 0	
Total (b)	$479 5		$565 0		$460 5		$351 5		$335 2	
GROSS PROFIT (c) AND OTHER INCOME										
Nonferrous Minerals	$ 30 0	56%	$ 54 7	59%	$ 44 5	64%	$ 27 3	58%	$ 27 4	54%
Industrial Minerals	4 6	9	5 0	5	3 8	5	3 5	7	2 4	5
Iron Ore	2 1	4	(1 6)	(2)	6.6	9	9 8	21	9 2	18
Shipping	1 6	3	11 0	12	8 1	12	5 4	12	10 4	20
Manufacturing	13 2	25	29 1	31	12 0	17	4 9	11	4 4	8
Other	1 9	3	(4 4)	(5)	(4 7)	(7)	(4 0)	(9)	(2 5)	(5)
Subtotal (a)	53 4	100%	93 8	100%	70 3	100%	46 9	100%	51 3	100%
Add minority interests	14 6		41 6		29 7		15 7		16.9	
Total (b)	$ 68 0		$135 4		$100 0		$ 62 6		$ 68 2	

(a) "Revenues" and "Gross profit and other income" are primarily the aggregate of Cyprus' ownership percentage of the revenues or gross profit of each of the various operations or companies in which Cyprus has an interest of 20% or more

(b) "Total revenues" and "Total gross profit and other income" are the amounts shown in Cyprus' Consolidated Statement of Income, and represent the amounts defined in (a), above, plus the minority shareholders' interests in the revenues or gross profit of Cyprus' consolidated subsidiaries (owned 50% or more by Cyprus) consisting of Cyprus Anvil, Cyprus Pima, Cyprus Hawaiian Cement, and Cymet

(c) "Gross profit" represents sales less all costs of production, including depreciation and depletion but before charges for general and administrative costs, interest expense, and income taxes

b. Pima Mining Company

Pima Mining Company, which has been managed by Cyprus Mines Corporation since its initial development in the mid-1950's, is a California corporation 50.01% owned by Cyprus. It has accounted for most of Cyprus' copper production in recent years. The balance of Pima stock is owned by Union Oil and Utah International, Inc. While essentially a producer of copper in the form of copper concentrates, Pima also recovers minor amounts of molybdenity (a molybdenum sulfide) concentrates and silver. In 1974, the open pit copper mine and the concentrator near Tucson, Arizona, produced in concentrates approximately 160 million marketable pounds of copper, approximately one million ounces of silver, plus molybdenite concentrates.

Ore reserves are estimated at approximately one million tons of contained copper.

Copper concentrates are shipped to two Arizona smelters for smelting and refining under long-term contracts. (Cf. comments elsewhere re: Phelps Dodge). About half of the refined copper and the silver are returned to Pima for sale through normal channels while the balance of the copper is sold to one of the smelters and the balance of the silver to the other smelter. Molybdenite concentrates are sold in the open market.

c. Cyprus Island Division

The old Cyprus Island Division is not considered a material asset of the company or a foreseeable material contributor to the total revenues of the compnay, and has essentially been written off.

d. Bruce Mine Division

The Bruce Mine Division is not considered a material asset of the company or a foreseeable material contributor to the total revenues of the company.

e. Bagdad Copper Corporation

- New Developments

Cyprus Mines Corporation acquired Bagdad Copper Corporation in June of 1973 in an exchange of stock. Bagdad has sales revenues of about $33 million and earnings of $3.7 million in 1972. Cyprus' financial results are restated to account for Bagdad on a pooling-of-interests basis.

Bagdad had production of 18,000 tons of copper in 1974, and about 14,000 tons in 1975. A major expansion of Bagdad is underway, and Cyprus states that its proven ore reserves with nearly 1.5 million tons of contained copper will assure operation at the accelerated rate beginning in 1977, for about 20 years.

f. Financing Operations

Cyprus' principal expansion effort is the major program of the Cyprus Bagdad copper operation in Arizona, budgeted at an estimated cost of $240 million. Completion of the program is scheduled for the end of 1977. At the close of 1975, $55 million had been spent. To finance the first stages of the expansion and other smaller projects, in January 1975 Cyprus sold $100 million of ten-year notes to the public through a group of underwriters. This was the first public borrowing in the Company's history. In May, 1975, a $100 million bank credit agreement was made with a group of seven banks to assure availability of funds in 1976 and 1977 while the Cyprus Bagdad expansion is being completed. No borrowings under the agreement have yet been made. The Company is considering alternative financing which would reduce or eliminate the need for bank borrowings.

g. Foreign Investment

"Extraordinary Losses" as discussed in financial reports of Cyprus and other mining companies with significant foreign interests, illustrate the risk of such holdings today. Indeed, the last several years would suggest the related write-offs are ordinary and not extraordinary.

On July 25, 1975, the Peruvian Government expropriated the iron ore mining properties and facilities of Marcona Mining Company in Peru. Marcona Mining Company is a wholly owned subsidiary of Marcona Corporation (Marcona). Cyprus' underlying share of the book value of Marcona's investment in the Peruvian properties was approximately $12.9 million which is net of approximately $10.2 million of income taxes previously provided by Cyprus on the undistributed earnings of Marcona. Subsequent to the expropriation, Marcona sustained additional losses which are deemed to be directly associated with the takeover by the Peruvian Government. These losses relate to Marcona-owned and chartered vessels which were involved in transporting ore from the Peruvian mine. Such losses, totaling $5.8 million (Cyprus' share), have been combined with Cyprus' share of the book value of Marcona's investment in the Peruvian properties as losses resulting from the expropriations. Accordingly, Cyprus has written off such losses, totaling approximately $18.7 million as an extraordinary item during 1975.

U.S. Government officials working together with Marcona management have held discussions with the Peruvian Government in an attempt to receive just compensation for the expropriated Peruvian assets and to resolve proposed additional tax assessments which have been asserted for prior years. While it is still premature to predict the outcome of these negotiations, any recovery will be recorded as an extraordinary gain when received.

During 1974 hostilities arose on the Island of Cyprus, resulting in the Company's operations being forcibly halted. The Board of Directors on December 11, 1974, therefore directed the write-off of the Cyprus Island Division by the taking of an extraordinary loss in 1974 of the amount of $4.0 million, consisting of net assets of $10.1 million less income tax of $6.1 million.

8. American Metal Climax, Inc. (Amax)

Amax is one of the largest diversified, multinational, nonferrous metals and mineral resources companies. Principal products are molybdenum, aluminum, iron ore, coal, copper, lead, zinc and potash. It also produces nickel, plus zirconium and other specialty metals.

In addition to being one of the principal suppliers of refined copper, lead, and zinc, Amax is the leading producer of molybdenum in the United States (through its Climax Molybdenum Company), and one of the largest producers of coal. It has been investing substantial sums in recent years, particularly in the expansion of its coal, copper, and aluminum businesses in the U.S.

In July, 1972, Amax said it would enter the copper mining business in the U.S. in a two-step transaction in which it would acquire Banner Mining Company, which owned the Twin Buttes/Pima County, Arizona property then leased to and mined by Anaconda; and then enter into a partnership arrangement with Anaconda to develop and expand operations at Twin Buttes and

Financial Review

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AMAX Ten-Year Financial Summary

For the Year[1]

(dollars in millions except per share amounts)		1974	1973	1972	1971	1970	1969	1968	1967	1966	1965
Sales		**$1,163**	$ 964	$ 566	$ 480	$ 582	$ 474	$ 342	$ 273	$ 356	$ 305
Earnings from operations		**$145.5**	$115 8	$ 71 3	$ 48 9	$ 69 3	$ 48 0	$ 38 8	$ 27 4	$ 50 5	$ 46 7
Equity in earnings of Alumax Inc		**18.9**	17 3	10 5	7 2	8 9	12 0	11 0	9 3	8 0	2 1
Interest expense[2]		**(22.0)**	(26 9)	(21 0)	(25 8)	(19 7)	(10 8)	(8 5)	(6 8)	(6 1)	(4 3)
Interest and other income, net		**41.2**	16 8	15 9	26 1	22 0	12 8	10 1	9 2	8 0	12 1
Dividend income		**19.4**	14 2	8 0	11 2	14 2	32 8	28 0	21 9	23 9	22 3
Federal and foreign income taxes		**(54.6)**	(32 1)	(18 5)	(12 5)	(22 1)	(12 8)	(10 7)	(4 4)	(15 2)	(16 4)
Earnings before extraordinary items		**148.4**	105 1	66 2	55 1	72 6	82 0	68 7	56 6	69 1	62 5
Extraordinary items		**—**	—	—	(3 8)	—	—	7 6	3 5	—	—
Net earnings		**$148.4**	$105 1	$ 66 2	$ 51 3	$ 72 6	$ 82 0	$ 76 3	$ 60 1	$ 69 1	$ 62 5
Dividends declared on											
Preferred stock		**$ 9.3**	$ 10 1	$ 4 1	$ 3 4	$ 3 2	$ 1 2	$ 4	$ 9	$ 1 4	$ 1 8
Common stock		**39.0**	35 0	33 2	33 1	33 1	31 3	29 4	28 6	28 1	24 3
Total		**$ 48.3**	$ 45 1	$ 37 3	$ 36 5	$ 36 3	$ 32 5	$ 29 8	$ 29 5	$ 29 5	$ 26 1
Per share of common stock											
Primary earnings[3]		**$ 5.82**	$ 4 03	$ 2 62	$ 2 03	$ 2 93	$ 3 47	$ 3 28	$ 2 62	$ 3 06	$ 2 78
Fully diluted earnings[3]		**5.26**	3 74	2 59	2 00	2 83	3 40	3 20	2 55	2 94	2 67
Dividends declared		**1.64**	1 48	1 40	1 40	1 40	1 33	1 27	1 27	1 27	1 12
Dividends as a per cent of primary earnings		**28%**	37%	53%	69%	48%	38%	39%	48%	42%	40%
Book value		**$31.72**	$27 50	$25 75	$24 54	$23 91	$21 14	$19 97	$17 85	$16 13	$14 13
Price range	high	**$ 52⅞**	$ 51¼	$ 33⅞	$ 37⅜	$ 40	$ 37	$ 35⅝	$ 38¾	$ 43⅝	$ 36⅛
	low	**$ 30¼**	$ 29	$ 27	$ 25¼	$ 28¾	$ 29⅛	$ 28	$ 28⅛	$ 22¾	$ 26⅞
Price earnings ratio		**9-5**	13-7	13-10	18-12	14-10	11-8	11-9	15-11	14-7	13-10
Return on January 1, shareholders' equity		**17.7%**	15 2%	10 0%	7 9%	12 5%	17 3%	17 9%	15 0%	19 6%	19 8%

At Year-End[1]
(in millions)

	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965
Working capital	**$ 197**	$ 327	$ 339	$ 299	$ 217	$ 191	$ 197	$ 194	$ 172	$ 167
Investments (at book amounts) in										
Alumax Inc	**130**	206	203	218	207	201	185	145	128	98
Africa	**90**	61	85	79	83	62	52	42	40	38
Other	**52**	42	50	38	38	35	26	28	21	20
Property, plant and equipment (net)	**1,069**	771	574	485	397	332	213	182	173	147
Long-term debt	**(401)**	(441)	(457)	(391)	(260)	(201)	(190)	(157)	(126)	(108)
Deferred income taxes	**(109)**	(77)	(64)	(42)	(30)	(27)	(15)	(14)	(14)	(11)
Other	**(86)**	(49)	(37)	(22)	(3)	(10)	7	7	0	1
Shareholders' equity	**$ 942**	$ 840	$ 693	$ 664	$ 649	$ 583	$ 475	$ 427	$ 394	$ 352

(1) Previously reported amounts have been restated to include Alumax Inc on an equity basis

(2) Effective October 1, 1971, the capitalization of interest applicable to major construction projects was extended to include interest on general corporate borrowings, as well as specific project borrowings Interest capitalized totaled 1974, $17 0 million, 1973, $14 0 million, 1972, $11 6 million and 1971, $3 8 million No interest was capitalized in 1970 and interest capitalized in prior years was not material

(3) Includes extraordinary gains and charges 1971, charge of 16¢ per share, 1968, net gain of 33¢ per share, 1967, gain of 15¢ per share

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AMAX Ten-Year Financial Summary—By Lines of Business

For the Year (dollars in millions)	1974	1973	1972	1971	1970	1969	1968	1967	1966	1965
Sales										
Molybdenum and Specialty Metals	$ 240	$179	$114	$108	$145	$155	$123	$106	$123	$111
Base Metals(1)	607	534	256	205	276	275	197	141	200	161
Fuels and Chemicals	206	154	137	118	118	36	22	26	33	33
Iron Ore	78	60	45	39	25	8	—	—	—	—
RST(2)	32	37	14	10	18	—	—	—	—	—
Total sales(3)	**$1,163**	$964	$566	$480	$582	$474	$342	$273	$356	$305
Earnings from operations before income taxes, exploration and unallocated corporate expenses										
Molybdenum and Specialty Metals	$ 41	$ 46	$ 28	$ 28	$ 51	$ 55	$ 37	$ 32	$ 40	$ 39
Base Metals	76	47	16	8	11	9	14	9	20	15
Fuels and Chemicals	45	22	23	15	13	0	1	0	4	8
Iron Ore	37	32	25	23	13	4	—	—	—	—
RST	20	26	5	1	8	—	—	—	—	—
	219	173	97	75	96	68	52	41	64	62
Exploration expenses	(37)	(33)	(12)	(16)	(14)	(9)	(7)	(7)	(5)	(7)
Unallocated corporate expenses	(36)	(24)	(14)	(10)	(13)	(11)	(6)	(7)	(8)	(8)
Earnings from operations	**$ 146**	$116	$ 71	$ 49	$ 69	$ 48	$ 39	$ 27	$ 51	$ 47
Capital expenditures and investments										
Molybdenum and Specialty Metals	$ 140	$ 51	$ 39	$ 49	$ 29	$ 11	$ 17	$ 25	$ 24	$ 25
Base Metals	76	110	10	8	8	15	15	13	9	6
Fuels and Chemicals	89	64	52	36	19	83	4	5	12	7
Iron Ore	33	10	8	30	24	18	29	14	1	2
RST	—	1	8	—	84	—	—	—	—	—
Corporate	68	17	28	6	4	10	11	—	2	5
Total capital expenditures and investments	**$ 406**	$253	$145	$129	$168	$137	$ 76	$ 57	$ 48	$ 45
Depreciation and depletion	**$ 46**	$ 37	$ 32	$ 28	$ 26	$ 18	$ 18	$ 13	$ 16	$ 14

(1) Includes the sale of metals processed from concentrates and scrap materials, tolling services, sales of copper from AMAX's 50% share of the operations of the Twin Buttes Mine from January 1, 1973 and sales of copper and silver arising out of purchase and sale transactions of these metals on commodity exchanges

(2) Consists of fees, commissions and net trading revenue.

(3) Sales of molybdenum, copper and coal to total Company sales for the last five years were as follows

	1974	1973	1972	1971	1970
Molybdenum	20%	17%	18%	20%	23%
Copper*	17	17	19	16	21
Coal	12	10	16	13	10

*Exclusive of charges for toll refining of copper for others and transactions on commodity exchanges.

in Pima County, with an expected expenditure exceeding $200 million over the period 1973-1976. Banner Mining was acquired in 1973, by merger into Amax Copper Mines, Inc., a wholly-owned Amax subsidiary, in accordance with the plan of merger and partnership.

The Twin Buttes Mine is now owned and operated by Anamax Mining Company, the 50-50 partnership between Amax and Anaconda. The $275 million expansion program is expected to raise capacity from about 75,000 tons/year to 90,000 tons/year (from sulfide ores) plus 36,000 tons/year from Anaconda's hydrometallurgical process for producing cathodes from oxide ores.

Amax's subsidiary, United States Metal Refining Company, has operated (for many years) a copper smelter and refinery at Carteret, New Jersey, producing refined copper from domestic and foreign ores, concentrates, blister copper, and copper scrap. The total annual refining capacity of 275,000 short tons consists of 150,000 tons of electrolytic capacity and 125,000 tons of fire-refined capacity.

The Carteret smelter treats blister copper originating largely from foreign sources, purchased for Amax's own account and on toll for others. It processes a large volume of scarp, and also treats precious metal-bearing secondary material and precious metal from primary sources both for its own account and for others; large quantities of silver and gold are typically handled.

An environmental control program for the Carteret plant has been under review by the New Jersey Department of Environmental Protection and EPA, involving the design and construction of additional control facilities.

This program is likely to involve cumulative expenditures of $12 to $15 million, most of which has occurred.

Amax has substantial U.S. lead and zinc operations, carried out through wholly-owned subsidiaries. It has a participation in a joint venture for the operation of a lead, zinc, and copper mine and mill in New Brunswick, Canada, through Heath Steele Mines, Ltd., of Canada, also a subsidiary.

In October 1969, Amax became a coal producer through the acquisition of Ayrshire Collieries Corporation. In 1974, Amax ranked as the fourth largest coal producer in the United States, up from eleventh position at the time of its entry into the business.

The Appendix presents details on the breakdown of Amax's sales revenues and consolidated income, by lines of business, for the past ten years, as reported by the company. Base metals per se, including tolling services and trading revenues, were $607 million in 1974; they typically have accounted for somewhat over 50% of total sales, but less than 25% of operating earnings ($76 million in 1974, out of $146 million total). Copper sales have accounted for about 17% of total sales in recent years, and roughly 75% of this derived from scrap and/or foreign blister. Amax additionally derives revenues from its International Group, including fees and commissions through RST International, Inc. ($32 million) and dividends from investments principally in African copper mining companies ($18 million).

In May, 1972, Amax announced its intention to shut down its custom zinc smelter and refinery at Blackwell, Oklahoma, late in 1973 due to the inability of the plant economically to meet Oklahoma's air quality standards.

In July, 1972, (two months after this announcement), Amax purchased for $3 million dollars the electrolytic zinc refinery of American Zinc Company near St. Louis. Rehabilitation and reactivation of this plant, which was estimated to cost $20 million, will provide Amax with annual designed capacity of 84,000 tons of special high-grade zinc by 1976. The plant produced 57,600 tons of zinc in 1974. (Note that in comparison, the Blackwell plant produced 77,000 tons of slab zinc in 1972, such production representing 67% of its rated smelting capacity).

Amax and Homestake Mining Company are equal partners in the mine-mill-smelter complex associated with mining of their lead deposits with zinc content, in Southeastern Missouri. The mine participants sell a portion of their lead concentrates under long-term and spot contracts. Amax share of refined lead output was 33,600 tons in 1974; total smelter production, including toll material, was 134,300 tons.

Zinc concentrates produced by the mine and mill are sold to Amax for treatment at the zinc smelter, in Sauget, Illinois.

Ore reserves of the project at December 31, 1972, were estimated to be 60 million tons of ore with an average grade of 4.7% lead and 1.7% zinc. The principal areas to be mined are held under long-term Federal Mineral leases which call for royalty payments to the United States Government of 4% to 5% of the actual sales of concentrates and 4% to 5% of the quoted refined metal price, less smelting, refining, shipping, and selling costs. The profitability of this mine has been high due to the mining of ore with lead and zinc grades substantially above the average.

a. Amax - Copper Range

As mentioned elsewhere, Amax has held approximately 20% of Copper Range's common stock, and reached agreement in 1975 for Copper Range to merge with a wholly-owned Amax subsidiary. The merger was opposed by the Justice Department. The U.S. District Court for the District of Connecticut upheld major portions of the Government's position and enjoined any merger or consolidation of the two companies. In February, 1976, Copper Range and Amax filed Notices of Appeal to the U.S. Court of Appeals for the Second Circuit from the trial court's order.

b. Amax - Aluminum Interests

Amax Inc. holds a 50% interest in Alumax Inc., formerly Amax Aluminum Company, Inc. Since January 30, 1974, Alumax's outstanding capital stock has been owned equally by Amax Inc. and Mitsui & Co., Ltd., Tokyo. Mitsui paid $135 million cash for its 50% interest. In January, 1975, the corporate name was changed to Alumax Inc.

Alumax produces primary aluminum, semi-fabricated and fabricated aluminum products, architectural products, secondary aluminum and zinc alloys. It operates 49 domestic plants and warehouses located in 24 states, and 14 foreign plants and warehouses located in Canada, Mexico, England, Holland, Germany, France and Sweden.

Sales in 1974 were $464 million compared to $365 million in 1973 and earnings increased to $35.8 million from $16.3 million in 1973.

Subsequent to the sale of 50% of the aluminum business, Amax has followed the equity method of accounting for its 100% interest to January 30, 1974 and its 50% interest thereafter in the financial statements. Accordingly, its current financial statements have restated the results for 1973 to include the Company's equity in Alumax as a separate item and to eliminate sales of $373 million, costs and expenses of $343 million and the provision for income taxes of $12 million. (This restatement had no effect on net earnings).

During 1974, production at the Intalco primary aluminum reduction facility at Ferndale, Washington (operated jointly with Howmet Corporation, now a Pechiney Ugine Kuhlman subsidiary), was 252,400 short tons, compared with 228,000 tons in 1973. Increased prices resulted in record primary earnings. In 1974, Alumax capital expenditures were $78.7 million. $58.8 million was spent on the construction of an aluminum potline, commenced in 1973, at Howmet's Eastalco aluminum reduction plant in Frederick, Maryland. About $50 million was to be spent in 1975 to complete the project. When completed, the new potline will approximately double the capacity at Eastalco and Alumax will receive half of the expanded annual production of 176,700 tons per year. The combined facilities will be jointly owned and operated with Howmet Corporation. Alumax also plans construction in Oregon of an aluminum reduction plant with an annual capacity of 187,300 short tons. This new facility will be jointly owned by Alumax and Mitsui.

Supplies of alumina from Alcoa of Australia (WA) purchased under a long-term contract are believed to be sufficient to meet anticipated requirements for the Intalco, Eastalco and Oregon aluminum reduction plants.

Long-term rights have been granted to the company by the Government of Western Australia on bauxite deposits, and Amax has been studying development on a joint venture basis.

9. American Smelting and Refining Company (ASARCO)

Asarco's business has, for many years, been in the mining, smelting, and refining of nonferrous ores and concentrates, producing therefrom principally copper, lead, zinc, silver, and gold, and recovering related by-products from such operations. The business also includes buying and processing nonferrous scrap, and selling the alloys produced; producing and selling coal and asbestos;

and producing chemical materials and manufacturing machinery for the metalplating and finishing industry. Asarco's operations are carried on principally in the United States with additional operations in Canada, Mexico, and Peru. Asarco has substantial investments in other mining companies, principally in Australia (Mount Isa Mines holdings - 49%), Peru (Southern Peru Copper Corporation - 51.5%), Mexico (Industrial Minera Mexico - 34%), and holds a substantial interest in Revere Copper and Brass Incorporated (33.4% stock plus convertible debentures).

Sales in 1974 totalled $1,344 million, an all-time high. Earnings before taxes and extraordinary items were a record $165.8 million, including $109 million ($43 million in dividends) in equity earnings of nonconsolidated associated companies. A five-year financial summary may be found in the Appendix.

In 1974, Asarco had approximately 15,300 employees. Employment dropped to 13,500 in 1975.

Asarco accounts for between 10 and 20% of domestic sales of refined copper, lead, and zinc, and somewhat more than 1/3 of the sales of refined silver. Through its ownership of Lake Asbestos of Quebec, Ltd. in Canada, Asarco has about 6% of the domestic market for asbestos. Coal is its other principal non-metallic product, and Asarco accounts for about 1% of the domestic market, through its Midland Coal Company Division, acquired in late 1970.

In March, 1973, Asarco announced plans to phase out production at its Baltimore copper refinery after 1975. Asarco is constructing a new copper refinery, with a designed capacity of 420,000 tons of refined copper per year, in Amarillo, Texas. The estimated cost of the new facility is approximately $100,000,000. Construction began in mid-1973 and start-up operations were planned for late 1975 or early 1976. The addition of this new refinery apparently will also curtail operations at the Company's Perth Amboy copper refinery.

The associated companies--principally those in Australia, Peru and Mexico--also have major capital expansion programs under way. Capital expenditures by the three companies in 1972 aggregated $127 million and exploration expenditures exceeded $5 million.

In the U.S., Asarco plays a special role as the largest custom smelter as well as one handling considerable "dirty" concentrates and recovering special materials (especially arsenic). Asarco has incurred substantial expenditures for environmental controls associated with its smelters and refineries, as discussed more fully in the separate section on "Environmental, Safety, and Health Matters."

The Table on the next page, reproduced from Asarco's Annual Report, succinctly illustrates Asarco's participation in the nonferrous metals.

Smelters	Refineries
Hayden, Arizona (a)	Baltimore, Maryland (a)*
El Paso, Texas (a) (b)	Perth Amboy, New Jersey (a)*
Tacoma, Washington (a)	Tacoma, Washington (a)
East Helena, Montana (b)	Omaha, Nebraska (b)
Glover, Missouri (b)	Amarillo, Texas (c)* (a)**
Amarillo, Texas (c)	Corpus Christi, Texas (c)
Corpus Christi, Texas (c)	Denver, Colorado (d)

(a) copper, (b) lead, (c) zinc, (d) cadmium, high purity metals.

*Closing down, **New, expanded

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ASARCO & ASSOCIATED COMPANIES' METALS PRODUCTION

			1975	1974	1973
COPPER(to-	**Mines**	Mission	26,900	40,300	46,600
		Sacaton	21,900	9,500	–
		Silver Bell	18,300	23,500	23,800
		San Xavier	9,700	5,900	2,700
		Granduc[a]	9,300	15,900	16,800
		Quiruvilca	6,200	7,400	8,400
		Others	3,600	4,005	3,100
		Total	95,900	106,500	101,400
	Refineries	Tacoma	119,700	117,400	120,100
		Perth Amboy	117,100	127,600	154,600
		Baltimore	41,800	111,000	138,100
		Amarillo	30,600	–	–
		Total	309,200	356,000	412,200
	Associated Companies	Mount Isa[c]	175,800	167,000	129,300
		Southern Peru[b]	119,600	134,400	133,500
		Industrial Minera Mexico[d]	35,100	37,900	37,100
LEAD (tons)	**Mines**	Buchans	11,900	13,900	6,800
		Leadville	7,500	6,400	7,200
		Others	6,000	4,400	4,500
		Total	25,400	24,700	18,500
	Refineries	Omaha	118,200	125,800	136,300
		Glover	81,900	72,900	82,300
		Total	200,100	198,700	218,600
	Associated Companies	Mount Isa[c]	146,700	139,200	125,100
		Industrial Minera Mexico[e]	85,600	108,200	56,600
		Neptune[f]	1,400	3,500	3,000
ZINC(tons)	**Mines**	Tennessee	47,900	56,400	29,600
		Buchans	19,500	23,400	11,500
		Leadville	14,100	12,800	15,100
		Ground Hog	10,900	12,400	13,500
		Quiruvilca	4,400	4,700	4,900
		Park City[g]	2,700	–	–
		Total	99,500	109,700	74,600
	Zinc Fuming Plants[h]		41,800	39,600	46,700
	Zinc Oxide[i]	Columbus	14,000	20,700	19,200
		Hillsboro	7,200	15,400	13,800
		Total	21,200	36,100	33,000
	Refineries	Corpus Christi	81,900	81,100	88,600
		Amarillo	20,400	46,700	46,800
		Total	102,300	127,800	13[illegible]400
	Associated Companies	Industrial Minera Mexico[k]	132,700	135,700	136,400
		Mount Isa[c]	126,600	113,400	112,200
		Neptune[f]	11,700	15,700	20,600
SILVER(ounces)	**Mines**	Galena	3,350,000	3,486,000	4,192,000
		Quiruvilca	1,134,000	1,388,000	1,262,000
		Buchans	611,000	741,000	376,000
		Mission	292,000	511,000	571,000
		Leadville	352,000	330,000	457,000
		Others	711,000	644,000	589,000
		Total	6,450,000	7,100,000	7,447,000
	Refineries	Perth Amboy	44,576,000	37,835,000	45,255,000
		Baltimore	10,679,000	16,947,000	16,130,000
		Total	55,255,000	54,782,000	61,385,000
	Associated Companies	Industrial Minera Mexico[e]	17,303,000	20,770,000	17,225,000
		Mount Isa[c]	11,045,000	9,690,000	8,803,000
		Neptune[f]	98,000	72,000	59,000

[a] Asarco's 50% share of copper in concentrates
[b] Blister output plus copper exported in concentrates
[c] Metal content of products for fiscal year ended June 30
[d] Blister output
[e] Refined output
[f] Metal content of products
[g] Asarco's 40% share of zinc in concentrates
[h] Metal content of zinc fume recovered from lead smelter slag at El Paso and East Helena
[i] Metal content of zinc oxide
[k] Refined output plus metal content of concentrates and fume sold

SOURCE: ASARCO

a. New Foreign Developments[1]

(1) Southern Peru Copper Corporation (51.5% owned)

SPCC produced 134,000 tons of copper. In 1975, the depressed world market for copper was reflected in a drop in the average price for copper realized by Southern Peru Copper Corporation (SPCC) to 54.8¢ per pound in 1975, from 80.4¢ in 1974. Operating expenses increased as a result of the general inflation and production was plagued by strikes. Mine output of copper was also adversely affected by a decline in the average grade mined to 1.057% copper in 1975 from 1.243% in 1974.

As a consequence of these factors, SPCC reported a net loss of $9.6 million in 1975 compared with net earnings of $40.5 million in 1974. No dividends were paid in 1975 or 1974.

A contract was entered into with an agency of the Peruvian government for the toll refining of the Toquepala blister copper production. At the same time, a "commercialization" contract was made with Minero Peru Commercial (MinPeco) where by that government agency markets the total Toquepala copper production, whether in the form of cathodes or blister copper. Under the contract, MinPeco takes title to the products upon delivery on board vessel for ocean shipment, and guarantees final payment to SPCC in Peru in foreign exchange coefficients for such export sales.

SPCC is developing the Cuajone ore body and constructing ancillary facilities under a bilateral agreement with the Peruvian Government dated December 19, 1969. The 170,000-ton-per-year Cuajone copper project is expected to start up in 1976 with a production rate in excess of 50% of capacity. Approximately 7,300 workers were actively employed in construction in 1975.

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[1] Source: 1975 Annual Report

ASARCO

The following tables set forth, for the five years ended December 31, 1975, the approximate amounts of Asarco's (i) consolidated sales and earnings, before taxes on income and extraordinary items, attributable to its principal lines of business and (ii) consolidated sales of principal products and services Sales figures do not include sales by nonconsolidated associated companies

Lines of Business (dollars in thousands)	1975 Sales	1975 Earnings (Loss)	1974 Sales	1974 Earnings (Loss)*	1973 Sales	1973 Earnings (Loss)*	1972 Sales	1972 Earnings (Loss)*	1971 Sales	1971 Earnings (Loss)*
Primary metals (a)	$ 697,000	$ 27,493	$1,067,658	$ 78,927	$ 820,692	$ 60,911	$653,706	$27,754	$512,184	$ 8,677
Secondary metals	121,698	3,340	192,395	10,706	137,162	1,467	107,754	1,032	103,587	818
Other products (b)	185,940	(4,489)	83,997	824	110,585	(5,257)	52,885	(157)	40,986	800
Equity in earnings of nonconsolidated associated companies (c)	—	27,829	—	109 123	—	81,184	—	31,382	—	36 826
Non-operating (d)	—	(18,309)	—	(3 921)	—	(7,108)	—	(3,277)	—	2,[illegible]68
Unusual items (e)	—	(20,500)	—	(29,838)	—	2 237	—	—	—	—
Total	$1,004,638	$15,364	$1,344 050	$165,821	$1,068,439	$133,434	$814,345	$56 734	$656 757	$49 389

*Restated, see note 2 of notes to financial statements

Sales (dollars in thousands)	1975		1974		1973		1972		1971	
Copper	$ 167,676	17%	$ 290,316	22%	$ 324,671	31%	$263,942	32%	$211,290	32%
Silver	252,634	25	285,176	21	174,083	16	110,534	14	96,798	15
Lead	81,712	8	143 125	11	110,547	10	67,438	8	60,619	9
Zinc	85,893	9	120,866	9	75,697	7	56,232	7	57,623	9
Secondary metals	121,698	12	192,395	14	137,162	13	107,754	13	103,587	16
Other products (f)	295,025	29	312 172	23	246 279	23	208 445	26	126 840	19
Total	$1,004,638	100%	$1 344 050	100%	$1 068 439	100%	$814 345	100%	$656 757	100%

(a) Includes mining, smelting and refining of copper, silver, lead, zinc and by-products as well as toll treatment charges for smelting and refining

(b) Primarily coal, asbestos and ilmenite

(c) See note 4 of notes to financial statements

(d) Primarily dividends and interest on investments (other than those accounted for by the equity method), patent royalties and interest expense

(e) See note 11 of notes to financial statements

(f) Includes by-products coal, asbestos, ilmenite, etc and toll treatment charges

CONSOLIDATED STATEMENT OF CHANGES IN FINANCIAL POSITION
For the Years Ended December 31

ASARCO

	1975	1974	1973	1972
		(dollars in thousands)		
Cash and Marketable Securities, beginning of year	$ 20,239	$ 19,618	$ 15,097	$ 10,379
Source of Funds:				
Net earnings before extraordinary items	25,438	130,365	110,849	47,681
Add expenses not requiring outlay of funds:				
Depreciation and depletion	36,484	38,877	26,801	23,928
Deferred income taxes	(2,884)	6,009	(983)	1,138
Estimated loss on plant closings and partial mine write-off	20,500	29,838	19,700	-
Equity in earnings of nonconsolidated associated companies	(5,847)	(65,770)	(65,880)	(12,483)
Funds provided from operations	73,691	135,319	90,487	60,264
Investments, net	325	17,806	9,472	232
Current liabilities, other than reserves for plant closings	(80,842)	38,382	(3,616)	47,794
Long-term debt incurred	232,180	38,370	50,750	16,500
Funds committed to construction	19	2,544	11,873	(14,436)
	225,373	232,421	158,966	110,354
Use of Funds:				
Inventories	20,243	33,032	(15,450)	(8,527)
Property	167,495	137,666	96,679	66,732
Accounts receivable	(6,691)	(11,112)	37,773	9,456
Long-term debt reductions	6,687	13,580	10,083	3,600
Dividends	28,148	38,103	32,040	32,097
Treasury stock, net	(1,106)	(494)	(318)	2,301
Other, net (including materials & supplies)	(3,763)	21,025	(6,362)	(23)
	211,013	231,800	154,445	105,636
Cash and Marketable Securities, end of year	$ 34,599	$ 20,239	$ 19,618	$ 15,097

SPCC announced in January 1975 that it had obtained financing for the Cuajone project of $404 million through 54 lending institutions in Europe, North America and Japan. The balance of the funds were provided by equity capital of $216 million from SPCC (88.5%) and Billiton B.V. (11.5%) a Netherlands company. In November SPCC announced a new capital cost estimate for the Cuajone project of $656 million and working capital requirements of $70 million. At year-end $557 million had been invested, and discussions were under way to arrange for the required additional financing.

A Peruvian joint venture was established to operate the Cuajone project. SPCC will manage the project. Asarco is committed to invest additional equity of $10.3 million in SPCC under the terms of an agreement signed in December, 1974. The investment will be made in early 1976. In addition, Asarco has agreed to idemnify SPCC against certain losses and expenses up to a limit of certain future cash dividends received from SPCC.

The bilateral agreement provides that failure to maintain the investment program or complete the project as scheduled, in the absence of force majeure, will result in termination of the concession for the Cuajone mine. Reserves there are estimated at 468 million tons of sulfide ore averaging slightly over 1% copper.

A Peruvian mining law provides, among other things, that workers of the mining companies, through "Mining Communities," will acquire increasing participation in profits and ownership (eventually to 50%) of mining enterprises. At December 31, 1975 and 1974, such ownership participation in the Peru Branch of SPCC was approximately 9.0%. Asarco's equity investment in SPCC and the subsidiary, Northern Peru Mining Corporation amounted to $154.2 million and $5.7 million, respectively, at December 31, 1975.

(2) Industrial Minera Mexico, S.A. (34% owned)

The investment program in new mines and expansion of the existing units, and the rehabilitation and modernization of the plants continued at an accelerated rate and capital expenditures in 1975 were the highest of any year in the history of the company. The expansion of the Taxco silver-lead zinc mine was completed in December.

To help finance its expansion and modernization program, Industrial Minera Mexico negotiated $150 million of long term loans with a consortium of U.S. banks in December. The largest project in this program is the new electrolytic zinc refinery at San Luis Potosi. Detailed engineering of the plant, which will have an annual capacity of 125,000 tons of zinc is under way.*

Since the 1965 Mexicanization of the company, Asarco has handled the sales of Industrial Minera Mexico's metals in world markets. These arrangements terminated in 1975.

Asarco received $2.3 million in dividends from Industrial Minera Mexico in 1975, compared with $2.0 million in 1974.

(3) Revere Copper and Brass Incorporated

Revere reported a net loss of $31.3 million in 1975 compared with net earnings of $17.2 million in 1974. By far the largest portion of Revere's loss in 1975 resulted from a writedown of its investment in Revere Jamaica Alumina, Ltd., a wholly owned subsidiary which mines bauxite and converts it into alumina in Jamaica. (A decline in shipments of aluminum and copper and brass mill products in the United States due to the weak economy also

*As we went to press, Industrial Minera said it plans to invest $286 million during the next two years in construction, modernization and expansion.

contributed to the poor outcome.) Asarco received $469,000 in dividends from Revere in 1975 compared with $235,000 in 1974; however, Revere did not pay any dividends during the last two quarters of 1975.[1]

In January, 1976, Revere instituted suit in the Supreme Court of Jamaica challenging the constitutionality of the retroactive bauxite production levy (equal to about $33.00 per ton of alumina), introduced by the Government of Jamaica.

10. The Anaconda Company

The Anaconda Company was incorporated in the State of Montana in 1895. Anaconda is the third largest producer of primary copper, the largest producer of brass mill products in the United States, and is a significant producer of wire mill products.[2] In addition to mining and processing copper, it has a significant position in the production of aluminum and the mining and milling of uranium.

Anaconda conducts its mining, processing and manufacturing operations at over 50 locations throughout 22 states of the United States, and has 120 sales offices throughout the country. It also has investments in mining, processing and manufacturing operations in Australia, Brazil, Canada, Jamaica, Mexico, Puerto Rico and the Netherlands.

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[1] The company's 33.4% investment in Revere Copper & Brass Incorporated is accounted for by the equity method. Under a consent decree with the U.S. Department of Justice entered into in March 1967, among other things, the company and Revere were prohibited from having a director or officer who was at the same time a director, officer or employee of the other, and the company was, in effect, prohibited from voting its stock except in very limited circumstances, and from participating in the determination of the business policies or practices of Revere. In March 1972, in accordance with the terms of the decree and on application of the company, the decree was terminated and the action dismissed without prejudice.

Since the termination of the consent decree, Asarco has been studying its future course of action with respect to its investment in Revere, which action might include taking an active role in the policies of Revere and/or increasing, decreasing or eliminating its present holdings.

[2] In 1975, Anaconda acquired the WALWORTH CO., one of the leading valve manufacturers.

Anaconda employed approximately 21,934 persons at June 30, 1975, compared to 27,840 persons employed by it at June 30, 1974. (This substantial reduction in employees resulted from layoffs which were compelled by reduced demand for Anaconda's products in the recent recessionary economy, together with company-wide efforts to reduce costs and increase productivity.

a. Sales and Operating Income by Division

The following table sets forth the approximate relative contributions to consolidated sales and operating income by Anaconda's organizational profit centers for the six months ended June 30, 1974 and 1975 and the three years 1972-1974. Comparable information for prior periods is not available, primarily because of the Chilean expropriation and subsequent corporate reorganization in 1971 (see "Chilean Expropriation.")

b. Copper Production

Anaconda's domestic production of primary copper was 190,059 tons in 1974. Over the last five years, production ranged from a low of 149,600 tons in 1975 to a high of over 200,000 tons in 1970. Approximately 60% of such production comes from the Butte Mines in Montana; certain of these operations are being phased out. The Twin Buttes Mine in Arizona, on the other hand, has been the subject of new development investments, through Anamax Mining Company, a 50-50 partnership between Anaconda and Amax (see also Amax).

Approximately 49% of Anaconda's mined copper was sold to its manufacturing divisions in 1973, compared to 58% in 1974 and 72% for the six months ended June 30, 1975, and the balance was sold to others. Approximately 37%, 41% and 63% of the copper required for Anaconda's domestic manufacturing operations was purchased from Anaconda during 1973, 1974 and the six months ended June 30, 1975, respectively, and the balance was purchased from other primary copper producers, scrap dealers, customers and other sources.

Sales and Operating Income by Division (millions of dollars)

The following table sets forth the contributions to consolidated sales and operating income by Anaconda's organizational profit centers for the four years 1972-1975. Comparable information for 1971 is not available, primarily because of the Chilean expropriation and subsequent corporate reorganization in 1971.

	1975	1974	1973	1972
Sales and other operating revenue:				
Montana Mining and General Mining Divisions	$ 278.1	378 5	341.3	341.6
Uranium Division	24.0	28 6	29 5	18.2
Natural Resource Divisions	302.1	407.1	370 8	360.0
Aluminum Division	311.2	384.0	276 2	198.4
Brass Division	347.2	616.4	497.3	346.5
Wire and Cable Division	294.1	502 0	390.5	286.1
Walworth Division (Acquired October 1975)	11.6			
Forest Products Division (Sold June 1972)			9.7	24.6
Less sales between divisions	(178.4)	(236 8)	(201.4)	(204.0)
Net sales and other operating revenue	$1,087.8	1,672 7	1,343.1	1,011.6
Operating income (loss):				
Montana Mining and General Mining Divisions	$ (40.7)	41.1	49.9	27.2
Uranium Division	.5	4.5	10.1	5.8
Natural Resource Divisions	(40.2)	45.6	60.0	33.0
Aluminum Division	17.4	48.9	(2.9)	3.9
Brass Division	(1.8)	30 1	24 9	10.3
Wire and Cable Division	9.2	61 3	23 9	13.8
Walworth Division (Acquired October 1975)	.8			
Forest Products Division (Sold June 1972)				3.6
Unallocated corporate expenses	(13.2)	(11 0)	(9.1)	(8.4)
Consolidating adjustments	(.9)	(1 3)		
Operating income (loss)	$ (28.7)	173.6	96 8	56.2

Five-Year Sales by Class of Products (millions of dollars)

	1975	1974	1973	1972	1971
Copper and copper products	$ 625.1	1,163.1	960.9	701.3	662.5
Aluminum and aluminum products	335.8	403.8	299.7	220.2	177.0
Uranium oxide	24.0	28.6	29.5	18.2	20.4
Other metals, forest products, etc.	102.9	77.2	53.0	71.9	86.6
Total	$1,087.8	1,672 7	1,343.1	1,011.6	946.5

Primary Production

	1975	1974	1973	1972	1971
Copper (short tons)	149,622	197,543	208,110	242,955	227,415
Aluminum (short tons)	243,591	298,737	217,950	177,618	171,677
Uranium oxide (short tons)	1,736	2,025	2,069	2,022	1,763
Silver (thousands of ounces)	2,352	3,571	4,256	3,979	3,869

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Five-Year Summary of Operations

(Millions of dollars, except per share figures)

	1975	1974	1973	1972	1971
Sales and Other Operating Revenue	**$1,087.8**	1,672 7	1,343.1	1,011.6	946.5
Operating Costs and Expenses					
Cost of sales and expenses	**1,065.2**	1,448.4	1,200.6	911.3	882.3
Provision for depreciation and depletion	**51.3**	50.7	45.7	44.1	46.9
	1,116.5	1,499.1	1,246.3	955.4	929.2
Operating Income (loss)	**(28.7)**	173.6	96.8	56.2	17.3
Equity in net income of affiliated companies	**5.8**	16.7	15 3	10 0	4.2
Income from Chilean investments	**9.4**	5.4			
Interest and miscellaneous income	**6.1**	5.6	4.8	4.3	1.6
Interest expense	**(32.0)**	(29.7)	(23.2)	(21.7)	(25.2)
Gains (losses) on foreign exchange	**.8**	(10.4)			
Income (loss) before Taxes and Extraordinary Income	**(38.6)**	161.2	93.7	48.8	(2.1)
Provision for income taxes	**1.2**	54.5	24.6	5.4	3.9
Income (loss) before Extraordinary Income (loss)	**(39.8)**	106.7	69.1	43.4	(6 0)
Extraordinary income (loss)		140.4	17.7	88.3	(347.9)
Net Income (loss)	**$ (39.8)**	247.1	86.8	131 7	(353.9)
Per share of common stock:					
Income (loss) before extraordinary income (loss)	**$ (1.80)**	4 83	3.13	1.97	(.28)
Extraordinary income (loss)		6.36	.80	4.00	(15.89)
Net income (loss)	**$ (1.80)**	11 19	3.93	5.97	(16.17)
Dividends paid:					
Amount	**$ 16.6**	22.1	11.0	2.7	10.9
Per share of common stock	**$ .75**	1.00	.50	.125	.50

Notes.

(a) Reference should be made to the company's previous annual reports to shareholders for more complete explanations of the extraordinary income (loss) shown above The extraordinary items included: 1971—losses due to the expropriation of Chilean investments and corporate reorganization costs; 1972—gain on sale of Forest Products Division's principal assets and income tax benefits from utilization of loss carryforwards; 1973—utilization of tax loss carryforwards, and 1974—settlement of 1971 expropriation loss with the Government of Chile and utilization of tax loss carryforwards (as more fully explained on page 29 of this report)

(b) Certain changes in accounting practice were adopted during the five-year period The only changes significantly affecting reported annual earnings occurred in 1972 in the method of translating foreign currency debt, which resulted in an extraordinary charge of $5 2 million (24 cents per share), and in 1974 in the extension of the use of the Lifo method, which had the effect of reducing income before extraordinary income and net income for that year by $8 9 million (40 cents per share) and $17.2 million (78 cents per share), respectively.

c. Copper Processing (U.S.)

- Smelting

Substantially all copper concentrates from Anaconda's mines and precipitates from leaching operations are shipped to its reverberatory furnace smelter in Anaconda, Montana for smelting. The Anaconda smelter operated at approximately 100% of capacity in 1973, 94% in 1974, and at approximately 96% for the six months eneded June 30, 1975. The current capacity of the smelter is approximately 33 million pounds per month.

- Refining

All anode copper produced at the smelter in Anaconda, Montana is shipped to Anaconda's electrolytic refinery at Great Falls, Montana for refining and casting into commercially marketable forms of refined copper, and slimes are set apart for recovery of precious metals.

In October, 1974, production commenced at Anaconda's new Arbiter plant near Anaconda, Montana. The Arbiter plant represents the first commercial application of a hydrometallurgical refining process in the copper industry, instead of the traditional combination of pyrometallurgical and electrolytic refining processes. A principal advantage of the new Arbiter process is the elimination of sulfur oxide and other air pollutants produced by the conventional pyrometallurgical smelting of sulfur ores. The Arbiter process was developed by Anaconda's metallurgical research department as a part of a major research effort to reduce pollution.

Anaconda has stated that the Arbiter plant is capable of treating a wide range of concentrate types and grades with a recovery capability approximately equal to the most efficient smelters. Capital costs of a plant using the Arbiter process are estimated to be lower than those of a conventional smelter and refinery, and it is anticipated that the operating costs of the Arbiter plant will be competitive with costs incurred in the conventional method. Anaconda has invested approximately $47 million in the construction and development of the Arbiter plant as of June 30, 1975.

In July, 1975 the Arbiter plant was temporarily shut down, primarily because the smelter at Anaconda, Montana has sufficient capacity to meet the reduced demand for copper. It is expected that the Arbiter plant will be reopened in mid-1976, after required adjustments relating primarily to materials handling and mechanical problems. (It is expected that an additional investment of approximately $8 million will be required for these adjustments). The arbiter plant is expected to have a capacity of approximately 36,000 tons of cathode copper production per year.

The Arbiter process yields solid waste in the form of calcium sulfate (gypsum). Although gypsum is used in the manufacture of building materials, gypsum waste from the Arbiter process cannot be commercially disposed of at this time and therefore is being stockpiled.

Anaconda believes that its smelter, refinery and Arbiter plant provide it with sufficient capacity to produce cathode copper for the foreseeable future.

d. By-Products

Significant sales are produced in the course of Anaconda's copper processing operations, since the huge tonnages of ore handled by Anaconda mean that significant amounts of precious metals are recovered. Molybdenum, an important ingredient in making ferroalloys, is recovered in molybdenite at the Twin Buttes Mine. Silver, gold, selenium and tellurium are recovered by other refineries from the slimes left in the refining plant after the production of electrolytic copper. As a result, Anaconda's by-product production of silver makes it one of the largest producers of silver in the United States. Anaconda received approximately $30.3 million from the sale of precious metals in 1974, compared with $15.2 million in 1973.

e. Foreign Operations

Among Anaconda's foreign manufacturing interests as a wholly-owned subsidiary, Anaconda Canada Limited, which operates a large brass mill in Toronto, Ontario. Anaconda Canada Limited had sales of $115,169,000 in 1974, compared with sales of $98,472,000 in 1973.

Anaconda owns 49% of Compania Minera de Cananea, S.A., which has an open-pit mine at Cananea in the State of Sonora, Mexico. The Cananea Mine produced 44,373 metric tons of blister copper during 1974, compared with 41,999 metric tons during 1973. In 1973, an expansion program commenced which is expected to increase production to approximately 70,000 metric tons of copper per year by the end of 1976.

Cananea Mine production is concentrated and smelted at Cananea facilities, and the resulting blister copper is shipped for refining to Cobre de Mexico S.A. in Mexico City, in which Compania Minera de Cananea has a small ownership interest.

Anaconda also owns a 40% in National de Cobre, S.A., which operates casting and brass mill manufacturing facilities in Mexico City, a 49% interest in S.A. Marvin, which operates a brass mill in Brazil.

f. Aluminum Division

- Bauxite Mining and Alumina Production
- Aluminum

Anaconda produces aluminum in primary forms from alumina at its reduction plant located at Columbia Falls, Montana, which has an annual capacity of 180,000 tons of aluminum, and its reduction plant in Sebree, Kentucky, which has an annual capacity of 120,000 tons of aluminum. The Sebree facility was phased into operation in mid-1973. These plants produced a total of approximately 597 million pounds of aluminum in 1974 and 1973, respectively, and 262 million pounds for the six months ended June 30, 1975. Approximately 13% of Anaconda's aluminum production was sold to others in 1974.

Anaconda normally receives 59% of its alumina (the raw material for producing primary aluminum) from Alumina Partners of Jamaica ("Alpart"), a joint manufacturing venture in which Anaconda has a 27% interest. Alpart owns and operates bauxite mines and an alumina production plant in Jamaica, West Indes. At present rates of production, it is believed that Alpart has adequate bauxite reserves to meet its anticipated needs for a minimum period of 20 years. The Alpart plant has a designated annual capacity of 1.3 million tons of alumina. Anaconda's equity and debt commitments in Alpart, aggregating $70 million as of June 30, 1975, are almost entirely insured against expropriation and certain other risks by Overseas Private Investment Corporation, a U.S. Government agency. Of Anaconda's remaining alumina requirements, substantially all is provided by a contract under which Anaconda has agreed to purchase 20,000 metric tons of alumina per year through 1986 at competitive prices.

g. Uranium Division

Anaconda has one of the larger uranium mining and milling complexes extant in the U.S.

Uranium ore produced from the Jackpile and Paquate mines is processed into uranium oxide at Anaconda's Bluewater plant near Grants, New Mexico. The plant's current milling capacity is approximately 2,500 tons of ore per day. Production of uranium oxide during the five years ended December 31, 1974 and the six months ended June 30, 1975 was about 23 million pounds U_3O_8. Delivery commitments 1976-1980 are expected to approximately equal this amount.

h. Chilean Expropriation

Anaconda suffered from the expropriation of its Chilean properties in July, 1971. The Chilean copper mines provided, it is believed, over 40% of

Anaconda's 1970 earnings and an even greater proportion in prior years. In connection with the expropriation, which has been well publicized, Anaconda's financial statements showed large write-offs, (accounted for as an extraordinary loss) tax credits, and tax-loss carry forward efforts, offset in subsequent years by insurance and Chilean settlement adjustments and their corresponding tax effects. Because of their magnitude, one has to proceed carefully in examining Anaconda's financial results and restatements in order to properly view the company's financial picture.

Because of their importance, we reproduce below the company's comments on its Chilean notes and OPIC insurance claims.

On July 17, 1975, a panel of three independent arbitrators held the Overseas Private Investment Corporation (OPIC, a U.S. Government Agency) liable to Anaconda under two contracts insuring against the expropriation of Anaconda's investments in the Chuquicamata and El Salvador Chilean mining properties. The arbitrators' award did not specify the amount OPIC must pay Anaconda, but left this matter to be determined by further proceedings. OPIC has since moved in federal court to have the award set aside, on the basis of an alleged appearance of partiality in the arbitration panel. (In September 1975 one member of the three-man panel became associated with a law firm that in the previous winter had assisted Anaconda's trial lawyers with respect to the preparation of an affidavit about foreign law--an affidavit that ultimately was not used in presenting its case. While the arbitrator in question has stated that he had no knowledge of these circumstances until after he became associated with the firm, OPIC nevertheless argues that the impartiality of the panel has been placed in question). In the company's view, OPIC's contentions are without merit, and the company has moved to have the award confirmed.

The July 17, 1975, award was the outgrowth of the binding arbitration of Anaconda's 1972 claims against OPIC for $159 million. In connection with the ultimate recovery by Anaconda against OPIC, OPIC will have the right to succeed under the insurance contracts to a percentage of the proceeds of the 1974 settlement with the Government of Chile of approximately $253 million, of which $65 million was received in cash and $188 million in U.S. dollar promissory notes of Corporation del Cobre (Codelco), a Chilean public corporation. The notes, which after Chilean income tax yield six percent, are payable in equal semi-annual payments from February 1975 through 1985, and are guaranteed by the Central Bank of Chile. The precise nature and amount of OPIC's interest, the dollar value of which would be less than the dollar value of Anaconda's recovery from OPIC, is not now determinable, since it is included among the issues to be determined by further proceedings. Accordingly, at December 31, 1975 and 1974, Anaconda valued its Chilean investment at no less than the amount of the currently outstanding Codelco notes together with accrued interest less Chilean income taxes.

In 1974 extraordinary income included $93.6 million (before $44.9 million of related tax effects), representing the excess of the 1974 settlement with the Chilean government over the aggregate amount of insurance claims pending against OPIC.

11. Kennecott Copper Corporation

Kennecott together with its subsidiaries is an integrated producer of metals, minerals and metal products, principally copper and copper products. It is the largest domestic producer of copper and an important source of molybdenum, gold, silver, lead, zinc, titanium slag, high purity iron and iron powders. Peabody Coal Company ("Peabody"), a wholly-owned subsidiary of Kennecott, is the largest domestic producer of coal and also the largest supplier of steam coal to the electric utility industry in the United States. Kennecott is required by an order of the Federal Trade Commission to divest itself of its interest in Peabody.

Kennecott's sales of metals and metal products were $1,160 million in 1974 and primarily as a result of a depressed copper market, declined to $769 million in 1975. The average price received in 1975 was 61.2 cents/pound, compared to 76.7 cents/pound on much larger tonnage in 1974.

Tables K-1 and K-2 show a breakdown of Kennecott's sales and income by principal category. Income is before income taxes, minority interests and extraordinary items. Kennecott's pre-tax operating income from its metals mining and metals products sales (excluding dividends and interest items) was about $233 million in 1974; such operations produced only a few million dollars operating profit (before write off of a Chase Brass and Copper fabrication plant) in 1975, when Kennecott's copper mining and fabrication businesses were at essentially a break-even level (Kennecott's copper mine production was at about 70% of economic capacity).

Additional statistics and financial information may be found in the Appendix.

Kennecott's net earnings before taxes and before equity in net income of Peabody Coal Company, and before minority interests and extraordinary items, was $229 million in 1974 (and a loss of $52 million in 1975); Kennecott made provision for $17 million current and $28 million deferred U.S. income tax, and $11 million current and $1 million deferred foreign income taxes, for a total of $56 million before extraordinary items.

It is instructive and relevant for purposes of cost and rate of return analysis to note that the total tax credit in 1975 is more and the total tax expense in 1974 is less than the amount which would be provided by applying the

the U.S. income tax rate of 48% to (loss) income before tax. The reasons for the differences, expressed as a percentage of pretax (loss) income, are as follows:

	1975	1974
Computed "expected" tax (benefit) expense	(48.0%)	48.0%
Minimum tax	6.6	2.9
Percentage depletion	(13.7)	(16.9)
Investment credit	(9.5)	(2.1)
Peabody tax benefits, principally attributable to percentage depletion and investment credit	(11.8)	(8.7)
Other	(.8)	1.4
	(77.2%)	24.6%

Kennecott's subsidiaries include Chase Brass Copper Co., and Ozark Lead Company. Chase is a leading fabricator of copper and brass mill products; it buys a large portion of its copper from Kennecott, accounting for about 10% of Kennecott's copper sales. Profit margins are typically low in this part of the industry; in fact, Chase showed a loss in 1971 and 1972, and 1975.

Kennecott also holds two-thirds of Quebec Iron and Titanium Corporation. (Gulf & Western/New Jersey Zinc have minority interests).

Kennecott opearates four copper properties in the United States. Kennecott's Utah Copper Division mine in Bingham, Utah, is the second largest copper producer in the world, ranking next to Chile's Chuquicamata mine. (The El Teniente mine in Chile is the world's largest underground copper mine). Most of the blister copper from the Utah smelter is refined at the company's electrolytic refinery at Garfield, with an annual capacity of about 200,000 tons (somewhat less than Utah's production capability). Construction continued during 1975 on smelting facilities required to meet sulfur dioxide emission standards. The new facilities are expected to be operational in 1977, and (as discussed elsewhere) when completed the Magna smelter complex, together with Kennecott's other capacity, is thought to provide the company sufficient smelter capacity for at least the next several years.

The Chino mines Division comprises the Chino mine at Santa Rita, New Mexico, and a concentrator and smelter at Hurley, New Mexico, nine miles away. The Chino mine is an open-pit operation. The Ray Mines Division operates an open-pit mine at Ray, Arizona. The ore is concentrated and smelted in company facilities at Hayden, Arizona.

The Nevada Mines Division has the smallest copper production (less than 10% of the total). It was shutdown due to a smelter furnace accident in the third quarter of 1975. Then, the mining and milling operations were curtailed indefinitely in early 1976, because of market conditions.

a. New Mines Development

Development work on a potential copper ore deposit beneath the perimeter of the Utah Copper Division's Bingham Canyon open pit mine continued during 1975, and development work in this area is scheduled for completion by 1981.

Design engineering continued in connection with future operations of a small copper mine near Ladysmith, Wisconsin. The mine could be in operation by 1978 with estimated annual production of copper in concentrates of 11,000 tons.

b. Exploration

Among other prospects, development of the San Poil, Washington, prospect yielded data indicating that copper and molybdenum concentrates of satisfactory grades can be produced; studies indicate potential for substantially increasing the current 140 million tons of reserves with little or no increase in stripping ratio.

TABLE K-1

KENNECOTT REVENUE ANALYSIS
(in millions of dollars)

Kennecott Revenues	1975	1974
Copper and Copper Products	$506.9	$ 876.3
Molybdenum	20.0	30.1
Gold	40.4	45.8
Silver	14.3	10.0
Lead and Zinc Concentrates	30.7	41.2
Titanium Slag	54.5	50.1
Sorelmetal	78.3	68.8
Iron Powders	10.1	11.4
Other Products	13.4	26.2
Dividends, Interest and Miscellaneous Revenue	15.2	15.5
Sale of 925,000 shares of Kaiser Aluminum & Chemical Corporation common stock	19.4	-
Total	$803.1	$1,175.7
Peabody Coal Company Revenues		
Coal	$705.9	$ 504.1
Dividends, Interest and Miscellaneous Revenue	17.5	10.8
Total	$723.4	$ 514.9

SOURCE: Kennecott's 1975 Annual Report.

TABLE K-2

SALES AND INCOME BY LINE OF BUSINESS, 1972-1974
(in millions of dollars)

Kennecott Copper Corporation Business Category	1974 Sales	1974 Income	1973 Sales	1973 Income	1972 Sales	1972 Income
	Twelve Months Ended December 31					
Metals and metal products	$1,160.1	$ 248.7	$1,013.8	$ 236.2	$ 800.9	$ 117.7
Non-operating income[a]		7.3		5.6		9.6
Non-operating deductions		(1.4)		(1.6)		(1.6)
Coal[b]	504.1	23.5	381.3	(3.6)	344.4	10.2
Non-operating income		12.3		18.2		8.3
Non-operating deductions		(6.5)		(7.5)		(2.8)
Shutdown expenses during strikes		(12.8)		(.4)		(4.0)
Other non-operating income		7.9		6.6		2.3
Other non-operating deductions		(28.7)		(29.1)		(32.6)
TOTALS	$1,664.2	$ 250.4	$1,395.1	$ 224.5	$1,145.3	$ 107.1

NOTES: [a]In 1970 a substantial portion of non-operating income resulted from dividends and interest received from Sociedad Minera El Teniente S. A. in which the Company held a 49% equity interest. The Company's interest in El Teniente was expropriated by the Government of Chile during 1971 (see "El Teniente" infra).

[b]Sales and income exclude revenues applied against a reserved production payment.

SOURCE: Form 10-K Annual Report to SEC, 1974

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Copper Statistics

Metal Mining Division Production—1966-1975 (U. S. and Canada)

Year	Copper Ore Mined, Milled and Treated (000 Net Tons)	Material Removed to Dumps (000 Net Tons)	Copper Produced (Net Tons)	Grade of Ore Mined (Per-cent Copper)	Molybdenum Produced (000 Pounds)	Gold (Ounces)	Silver (Ounces)
1975	44,158	170,280	288,104	.716	8,833	256,049*	4,852,418*
1974	62,093	194,676	402,213	.714	10,316	280,561	3,619,922
1973	66,542	179,590	471,721	.766	14,288	342,284	4,246,543
1972	58,493	163,978	460,576	787	15,041	350,080	4,335,074
1971	59,332	157,689	456,142	796	18,460	340,636	3,711,141
1970	68,555	179,759	518,888	.773	23,123	404,141	4,338,730
1969	66,698	164,648	495,968	.749	21,471	442,339	3,863,239
1968	47,249	120,154	378,215	747	17,023	290,594	3,229,258
1967	33,829	69,923	289,016	.778	9,853	214,689	2,769,292
1966	57,921	132,606	454,044	792	15,577	387,727	4,763,348

*The method of reporting production for gold and silver was changed in 1975 from a smelter to a refinery basis in connection with the implementation of a LIFO method of accounting In the above table *refined output* of gold and silver is shown for 1975 in contrast to previous years where smelter production of gold and silver is shown Because of this change in reporting and the lag between the smelting and refining processes, 1975 *production* of gold and silver was 28,163 ounces and 1,002,912 ounces respectively

Copper Production (by Operating Division) 1975-1974

Divisions	Total Copper Produced from All Sources (Net Tons)		Ore Mined Milled and Treated (Net Tons)		Grade of Ore Mined (Percent Copper)	
	1975	1974	**1975**	1974	**1975**	1974
Chino Mines	**53,193**	60,557	**5,297,820**	7,638,638	**.855**	.861
Nevada Mines	**21,393**	37,562	**4,849,672**	7,455,476	**.721**	775
Ray Mines	**42,036**	74,764	**6,692,267**	11,721,547	**1.023**	1.043
Utah Copper	**171,482**	229,330	**27,318,000**	35,277,300	**.613**	652
Total	**288,104**	402,213	**44,157,759**	62,092,961	**.716**	766

DRAFT REPORT – The reader is cautioned concerning use, quotation or reproduction of this material without first contacting the EPA Project Officer, since the document may experience extensive revision during review.

KENNECOTT COPPER CORPORATION AND SUBSIDIARIES

Consolidated Balance Sheets

December 31, 1975 and 1974

	1975	1974
Assets:		(Note 1)
Current assets:		
Cash	$ 41,449,214	$ 36,168,834
U S. Government and other short-term securities, at cost (approximates market)	4,800,585	47,886,636
Accounts receivable	124,718,366	133,381,135
Inventories		
Ores, concentrates, metals and metal products	189,059,357	147,786,624
Materials and supplies	86,142,418	87,550,235
	446,169,940	452,773,464
Investment in Peabody Coal Company and Subsidiaries	905,033,449	835,252,344
Investments	96,232,559	97,041,680
Deferred charges, prepayments, etc	20,934,133	8,057,685
Deferred mine development at cost, less accumulated amortization	13,754,545	13,216,440
Mining land, plants, equipment and other properties, at cost, less accumulated depreciation, depletion and amortization	741,572,515	659,739,943
	$2,223,697,141	$2,066,081,556
Liabilities:		
Current liabilities		
Notes payable	$ 23,645,021	$ —
Current portion of long-term debt	23,739,792	4,315,400
Accounts payable and accrued expenses	114,767,040	111,251,776
Taxes accrued	21,773,955	100 325,249
	183,925,808	215,892,425
Long-term debt	406,387,048	206,049,585
Deferred U. S and foreign taxes	132,000,000	140,900,000
Sundry reserves and deferred credits	50,328,459	26,615,399
Minority interests in consolidated subsidiaries	40,633,485	33,340,651
Capital:		
Capital stock, $5 par value, authorized 50,000,000, outstanding 33,159,153 shares	165,795,765	165,795,765
Capital surplus	102,280,751	102,273,395
Earned surplus	1,142,345,825	1,175,214,336
	$2,223,697,141	$2,066,081,556

Outside the United STates, Kennecott is conducting exploration for porphyry and massive sulfide copper deposits notably in Canada, Indonesia, Australia and the Philippines. Exploration work at the Ok Tedi copper deposit in Papua New Guinea, necessary to determine whether the ore body justifies a major investment, was discontinued because certain terms and conditions required by the Papua New Guinea government were judged to be too severe for a high-risk project.

c. Divestiture of Peabody Coal Company

Kennecott, by order of the Federal Trade Commission, is required to divest itself of Peabody, which it acquired in 1968. In 1974, the Supreme Court declined to accept the company's petition for review of the case.

In 1975, the $300 million reserved production payment subject to which Kennecott acquired Peabody, was finally liquidated. In an effort to retain Peabody, in July Kennecott petitioned the FTC to reopen the proceedings and modify its divestiture order "in view of the realities of the state of competition in the coal industry compared to the conditions forecasted by the FTC." The Commission denied the petition by a 3-2 vote. In October Kennecott filed a motion in the U.S. Court of Appeals for the Tenth Circuit requesting reconsideration and elimination of the divestiture requirement. (The brief filed by Kennecott attempts to demonstrate that competition in the coal industry has been substantially enhanced since the original decision in the matter and that the Commission's predictions of increasing concentration in the coal industry have not materialized). The Court has not yet acted on the motion.

Kennecott has been considering several offers from prospective purchasers of Peabody (all at a price in excess of its investment).

Interestingly, two other natural resources firms with copper interests submitted bids for Peabody: Cities Service and Newmont Mining. Cities Service has withdrawn its conditional bid, and Newmont's offer is in the form of a bid on behalf of a group of various companies including Newmont. Kennecott recently indicated it was considering selling only a portion of Peabody, and spinning off the rest to Kennecott shareholders. According to its Annual Report, Kennecott's Board has not made a final determination as to the preferred means of divestiture. When such determination has been made, FTC review and approval of any such plan will be required. Kennecott's intention in connection with certain possible forms of divestiture of Peabody such as spin-off is that "a substantial portion of the $532 million capital contributed by Kennecott to Peabody will be repaid to Kennecott."

In 1975 and in prior years, deductions for tax purposes of mining costs attributable to the production of coal dedicated under the reserved production payment agreement entered into in connection with the acquisition of Peabody, in excess of deductions that Peabody could have used on a separate company basis, have been utilized by Kennecott in its consolidated federal income tax return. Deferred income taxes relating to those deductions have been provided in Kennecott's financial statements. In addition, Kennecott has utilized, in the year they arose, percentage depletion deductions and investment tax credits generated by Peabody of which Peabody would not have been able to avail itself on a separate company basis. In the event of the disposition of Peabody, deferred taxes provided by Kennecott with respect to the utilization of certain tax deductions generated by Peabody would no longer be required and would have the effect at the time of disposition of reducing Kennecott's investment in Peabody. (At December 31, 1975, the amount provided and included in deferred U.S. and foreign taxes was $71.3 million).

d. Capital Expenditures and Financing

Capital expenditures for property, plant and equipment by Kennecott (excluding Peabody) increased 39% in 1975 to $133.4 million from $95.7 million in 1974. More than half of this amount related to pollution control facilities. Sharply lower internal funds generation resulted in the need for substantial outside financing during the last year. (In a "normal" year, Kennecott could look forward to a cash flow from its copper business equal to roughly its record capital spending in 1975).

As far as its financial capability to have funds available for expansion and improvement of its basic copper business, including necessary pollution control expenditures, it is obvious that in the short-run this can be very significiantly altered by the disposition of its ownership and equity in Peabody Coal operations. The indications are that, in terms of a flow of funds, Kennecott could be much more liquid in the near future, either from receipt of cash from Peabody's sale, or from retention of Peabody, now that the reserved production payment no longer has a claim on its revenues.

By entering into a $200 million term loan agreement with banks, and incurring a $20 million liability for pollution control revenue bonds issued (at 7-3/8% interest rate) by the Town of Hurley, New Mexico, for facilities at Chino Mines, Kennecott increased its long term debt by $220 million in 1975. It ended the year with $406 million in debt, out of total capitalization of $1,857 million; it reported $262 million in net working capital, up about 10% from the previous year. Debt repayment 1976-1980 averages about $41 million per year.

e. Chilean Expropriation Effects

As in the case of Anaconda, Kennecott's financial picture is complicated (further) by its Chilean holdings and claims: Kennecott's 49% interest in

Sociedad Minera El Teniente, S. A., a Chilean corporation which owns and operates the El Teniente copper mine in Chile, was expropriated by the Chilean Constitutional Reform Bill, which became effective in July, 1971. In prior years, Kennecott received over $20 million per year in dividends from El Teniente. Kennecott's investment in Chile was carried at $143.3 million at December 31, 1971. $84.6 million of El Teniente Mining Company notes was the subject of a Contract of Guaranty with the U.S. Overseas Private Investment Corporation. In 1972, Kennecott received a $64.9 million settlement of its expropriation insurance claim, and wrote off (as extraordinary loss) its $50 million ($26 million after tax effects) equity in El Teniente stock.

In 1974, Kennecott and the Chilean Government reached an agreement pertaining to the 1971 expropriation. The aggregate compensation agreed upon, consisting of equity, dividends and interest was $81.4 million less Chilean taxes of $13.4 million. The net amount of $68.0 million consisted of $61.5 million in Chilean notes and the balance, cash.

U.S. taxes, net of foreign tax credits, amount to $25.7 million, leaving a net recovery of $42.3 million reported as an "extraordinary credit" in 1974. All principal and interest payments due in 1975 were received. Cash flow (amortization) should equal about $6.2 million per year for 10 years, plus interest at 6%.

Subordination agreements existing between Kennecott and other lenders, if enforceable, may affect retention by Kennecott of amounts previously received on other notes issued by El Teniente. At December 31, 1975, the amount subject to subordination was approximately $20 million.

APPENDIX

KENNECOTT COPPER CORPORATION and SUBSIDIARIES
PROPERTY, PLANT & EQUIPMENT
for the year ended December 31, 1974

Classification	Balance at Beginning of Period	Additions at Cost	Retirements and Other Changes	Balance at End of Period
	- - - - - - - - - - - Millions	of Dollars - - - - -	- - - - - - - -	
Nonferrous metals (excluding titanium)	$ 857.3	$ 81.2	$10.5	$ 928.
Coal	879.4	122.2 (B)	11.4	990.2
Iron and titanium	119.8	10.4	.4	129.8
Metal fabricating	72.1	3.2	2.2	73.0
Other	23.4	.8	4.6	19.6
	$1,951.9	$217.8	$29.1	$2,140.6

Notes:
(A) Sub-totals may not add to exact total due to rounding.
(B) Includes $61,897,300 of capitalized mining costs.

Source: Kennecott Form 10-K Annual Report for 1974 filed with the SEC.

APPENDIX

KENNECOTT COPPER CORPORATION and SUBSIDIARIES
ACCUMULATED DEPRECIATION, DEPLETION and AMORTIZATION of PROPERTY, PLANT and EQUIPMENT
for the year ended December 31, 1974

Description	Balance at Beginning of Period	Additions Charged to Costs and Expenses	Retirements and Other Changes	Balance at End of Period
	- - - - - - - - - -	Millions of	Dollars- - - - - - -	- - - - -
Reserves for depletion:				
Nonferrous metals (excluding titanium)	$ 16.5	$ 2.1		$ 18.6
Coal	11.1	2.4		13.5
Iron and titanium	.1			.1
Reserves for depreciation and amortization:				
Nonferrous metals (excluding titanium)	333.	35.4	9.7	358.7
Coal	187.1	40.9	7.7	228.5
Iron and titanium	54.1	5.		59.1
Metal fabricating	46.6	2.3	1.9	47.
Other	8.9	1.2	2.	8.1
	$657.2	$89.1	$21.3	$733.2

Note: Sub-totals may not add to exact total due to rounding.

Source: Kennecott Form 10-K Annual Report for 1974 filed with the SEC.

CHAPTER 8

ENVIRONMENTAL REGULATIONS

A. INTRODUCTION AND SUMMARY

In this chapter, we discuss environmental regulations affecting the copper industry. In Section B, we present a general legislative background for readers unfamiliar with the evolution of environmental legislation in the U.S. In Section C, we present a detailed discussion of how the specific environmental regulations for the copper industry have effectively constrained capacity growth in the copper industry and have caused a capacity bottleneck at the smelting level which will last at least until 1983. Finally, Section D presents estimates of pollution control costs which the industry is expected to face over the impact analysis period (1976-1985).

It should be noted that this chapter (and also this report) concentrates on the impact of Federal environmental regulations alone. While the capacity bottleneck in copper smelting is essentially the result of various specific environmental regulations, the industry also faces other regulations that affect its production costs and potentially interrupt its planning process. Examples are proposed OSHA regulations on handling of explosives in open pit mines and on the use of engineering controls for abating noise and inorganic arsenic emissions in the work-place environment. It is important to remember that the planning process can be disrupted just as effectively by uncertainty about future regulations, the lack of coordination among different regulatory agencies and the desire of each regulating agency to pursue its own objectives and mandate with little or no regard for the potential impact on the industry of the regulatory actions of other agencies or units of government.

B. LEGISLATIVE AND INSTITUTIONAL BACKGROUND[1]

The historical development and current status of the Federal, state, and local statutory base for the environmental regulation of the copper industry is a complicated area for discussion, given the complexity, ambiguity, and often overlapping nature of the relevant statutes and the designated authority for their implementation.

Although the Federal Government through the Congress and the EPA retains ultimate authority for overseeing regulation of environmental pollution,

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[1] The discussion presented here relies upon the following principal sources: Allen V. Kneese and Charles L. Schultze, Pollution, Prices, and Public Policy (Washington, D. C.: The Brookings Institution, 1975), Chapters 3-5; Council on Environmental Quality, Environmental Quality, Fourth, Fifth and Sixth Annual Additions (Washington, D. C.: Superintendent of Documents, U.S. Government Printing Office, 1973, 1974, 1975), Chapter 2; U.S. Department of Commerce, The Effects of Pollution Abatement on International Trade--III (Washington, D. C., April 1975), Chapters 2, 3, and Appendix B; Constance Holden, "Clean Air Act: Congress Deliberates on Amendments" in Science, Volume 192, May 7, 1976, pp. 533-35; "Significant Deterioration Conflicts Approach Crunch Point" in Chemical Technology, February 1976, pp. 76-77, article extracted with permission from Weekly Energy Report, L. King, editor and publisher; United States Senate, Committee on Public Works, Clean Air Amendments of 1976: Report (Washington, D. C.: U.S. Government Printing Office, 1976); United States Environmental Protection Agency, The Environmental Protection Agency: Legislation, Programs, and Organization, reprint (Washington, D. C.; The Library Systems and Branch, 1976); United States Environmental Protection Agency, Progress in the Prevention and Control of Air Pollution in 1974: Report to Congress (Washington, D. C.; E.P.A., 1974) Chapter 3-5; Environmental Protection Agency, "Standards of Performance for New Stationary Sources: Primary Copper, Zinc and Lead Smelters" in Federal Register, 41 (10), January 15, 1976, pp. 2332-2337.

a good deal of the actual enforcement as well as interpretation of the laws is undertaken at the state and local levels. The regulatory framework in which individual copper mining, smelting, and refining operations function is frequently conditioned significantly by state and local authorities' interpretation and implementation of Federal statutues. This process of interpretation and enforcement is in turn often conditioned by a host of unique functional, structural, and attitudinal characteristics of local and regional bureaucracies which may not be generally applicable on a nationwide basis.

We have outlined in this section the principal Federal statutes underlying the current national regulatory framework for control of air and water pollution and have discussed briefly some of the major relevant issues which have arisen in their interpretation and implementation.

1. Air Pollution

a. Background

Prior to 1970, the most important pieces of Federal legislation to deal with stationary source air pollution were:

- the 1955 Air Pollution Control Act;
- the Clean Air Act of 1963; and
- the Air Quality Act of 1967.

The 1955 Air Pollution Control Act authorized, for the first time, a Federal program of research, training, and demonstrations relating to air pollution control. However, primary responsibility for controlling air pollution remained with state and local governments. The 1963 Clean Air Act gave the Federal Government enforcement powers for the first time against both inter- and intra-state polluters; however, enforcement procedures against intra-state dischargers were cumbersome, involving conferences and hearings prior to court action.

The 1967 Air Quality Act embodied the concept that air cleanup required a national effort, but it specified that the states should retain primary authority and responsibility for doing so. The Act authorized the Department of Health, Education and Welfare (HEW) to oversee the establishment of state standards for ambient air quality and state implementation plans for achieving those standards. Following the development by HEW of criteria which set forth the relationships of concentrations of specific pollutants in the atmosphere to damages to "health and welfare," states were required within 90 days to file a letter of intent that within six months they would establish standards for ambient air quality. Moreover, within six more months, states had to develop implementation plans for each of the pollutants in the "airsheds" over which they had jurisdiction. However, HEW was delayed in providing the criteria for pollutants, and states were slow to act once criteria were issued. By 1970, no state had a comprehensive plan of both standards and implementation in effect for any of the pollutants identified by HEW.

b. <u>The 1970 Clean Air Act Amendments</u>

The major problems experienced with air-pollution control legislation until 1970 were related to inadequate regulatory procedures and the lack of specific standards. The Clean Air Act Amendments of 1970 sought to deal with these inadequacies. The existing law was amended to provide for Federal direction in setting standards and established implementation schedules and enforcement mechanisms.

(1) Establishment of National Ambient Air Quality Standards

The principal objective of the 1970 amendments was to establish and enforce national air quality standards for designated pollutants. The 1970 amendments provided for development and enforcement of two kinds of standards for ambient air quality--"primary" standards necessary to protect health, and "secondary" standards desirable to protect welfare, including property and aesthetics. The amendments' stated goal was achievement of primary standards throughout the nation between 1975 and 1977.

The amendments also set forth a strategy for attaining this goal. EPA was to establish air quality standards for major classes of pollutants. So far, such standards have been established for particulates, sulfur dioxides (SO_2), hydrocarbons (HC), carbon monoxide (CO), nitrogen dioxide (NO_2), and photochemical oxidants. These standards were to be set on the basis of "threshold values" for the designated pollutants representing levels of ambient concentration below which scientific evidence indicated that no damage occurs to human health. Congress directed the EPA to determine these values and then set "primary" standards based on these values minus "an adequate margin of safety." More rigorous "secondary" standards were also to be designated which would be sufficient to protect public welfare, broadly defined to include "economic values. . . personal comfort and well being. . . effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to pollution," (Section 302h).

(2) Implementation of National Ambient Air Quality Standards

According to the amendments, states were to develop state implementation plans (SIP) indicating how they intended to achieve the EPA standards by mid-1975. The Clean Air Act provided for extensions of up to 2 years beyond the 1975 goal in those regions where needed technology or other alternatives either was not available or would not be available soon enough to attain the primary standards. Each implementation plan, typically, was a compilation of state air pollution statutes and regulations and of pollution control strategies--including emission limitations, land use controls, and transportation controls. EPA was required either to approve the state implementation plans, thus making them part of Federal law, or to amend them in conformance with EPA criteria for attaining ambient air standards.

Because different geographical, climatic, and other conditions introduce necessary variations in the state plans and because each plan contains several often complex programs, EPA developed a policy of approving them on a program-by-program basis. In most SIP's, considerable emphasis has been placed upon the development of source control plans for the achievement of primary standards, to which the Act's 1975 compliance deadlines applied.

(3) Establishment of National Emission Standards for Hazardous Air Pollutants

The Congress did not rely solely upon the establishment of standards for ambient air quality to control pollution. It also gave the EPA power to set specific limits on the emission of certain kinds of "hazardous pollutants", considered to have especially serious health implications and attributable to relatively few source categories (some of the heavy metals are examples).

These hazardous pollutants are exclusive of the criteria pollutants for which national ambient air quality standards exist. The EPA was directed to prepare a list of such substances and to issue regulations limiting their emissions by both new and existing sources, which were to be enforced at the Federal level.

Standards have been set or are in the process of being set for asbestos, beryllium, mercury, vanadium, lead, and cadmium. The amendments allow for two years' (discretionary) lead time for compliance with emissions standards for hazardous air pollutants.

(4) Establishment of National Emission Standards for New Sources

The objective of minimizing emissions of pollutants from new sources was also written into the Clean Air Act Amendments of 1970. The amendments thus directed the EPA Administrator to set "new source performance standards" which limit the emission of pollutants from new or modified plants to an amount no greater than that attainable with "the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated." Initially, cost considerations were less formally considered than today under the original stringent deadline (7 months) for promulgation mandated by the Act. Subsequent promulgations have been reflected in more formal and rigorously research technical and cost considerations.

The Act specifically provides the EPA Administrator with the option of distinguishing among "classes, types, and sizes" within source categories. In many cases, process units rather than entire plants have thereby been assigned emissions limitations.

New Source Performance Standards for copper smelters were proposed by EPA in January, 1976.

(5) Assessment of Control Costs

The Act requires the EPA to conduct annual studies of the economic impact of air quality control upon the industry sector. With the exception of the development of New Source Performance Standards, economic considerations are otherwise absent from the Clean Air Act as amended in 1970.

(6) Citizen Participation

Allowance for major public participation in the law's execution, in both standard setting and enforcement, was an additional key feature of the 1970 amendments. Suits brought by various groups have already had a significant impact on the law's interpretation and implementation. Thus, the Natural Resources Defense Council has successfully challenged portions of the state implementation plans which permitted the issuing of temporary operating certificates or variances, while the Sierra Club and other organizations succeeded in requiring EPA to adopt regulations concerning significant deterioration of existing air quality.

c. Issues Arising from the 1970 Clean Air Act Amendments

(1) Validity of Ambient Air Quality Standards

The validity of the six ambient air quality standards established by EPA in 1971 continues to be supported by technical studies. A seventh potential pollutant, fine particulate sulfates (e.g., sulfuric acid) has been extensively studied by EPA.

(2) Intermittent Versus Permanent Control Systems

A major controversy evolved after passage of the 1970 amendments over the advantages of permanent control devices (scrubbers) versus the advantages and legality of intermittent control systems for controlling SO_2 emissions. Scrubbers remove sulfur from stack gases after combustion but before emission to the atmosphere. Intermittent control systems seek to disperse stack gas and dilute SO_x emissions by use of tall stacks and various operating practices, including curtailing operations or switching to low sulfur fuels during times of adverse air quality of other unusual meteorological conditions.

In 1974, the U.S. Court of Appeals for the Fifth Circuit, in Natural Resources Defense Council vs. EPA, held that intermittent control systems are acceptable only when emission reduction equipment has been used to the maximum extent achievable. All the other courts to address the subject have since followed the Fifth Circuit. In September 1973, EPA proposed that "supplementary control system" (SCS) be permitted as a temporary measure applicable only to sulfur oxide emissions from isolated nonferrous smelters and coal-fired power plants, where the sole alternatives were permanent curtailment of production, closing of the plants, or delays in attainment of the standards. However, constant emission limitation remained the preferred strategy for attaining and maintaining the standards in the long term. Tall stacks would also have been allowed under the proposal as a part of an approved supplementary control system. This aspect of the 1973 proposal was cited by the Fifth Circuit as an example of EPA's improper reliance on stack height as a means of achieving NAAQS. Since 1973, EPA has proposed regulations allowing the interim use of SCS at several smelters located in the Western U.S. in such states as Arizona, Montana, New Mexico, and Utah. These regulations require the installation of reasonably available emission control equipment and further state the SCS may be employed only if certain conditions outlined in the regulations are met, and its use is needed to achieve national standards. Thus far, this regulatory approach has been upheld in the Court.

(3) State Implementation Plants (SIP)

The 1970 amendments required the states to submit SIPs for existing stationary sources of "criteria" pollutants that would assure that national primary ambient air standards would not be exceeded in any part of a state after mid-1975 (or after 1977 when a two-year extension is granted). With a few notable exceptions (e.g., sulfur oxide emission limitiations in the State of Ohio), all states had fully enforceable emission limitations affecting stationary sources, by 1974, although in portions of 16 states an extension had been granted for one or more pollutants.

State and Federal programs faced an immense task in achieving compliance since there are estimated to be over 200,000 stationary sources subject to SIP emission standards. Of this number, however, approximately 20,000 are major emitters (i.e., facilities individually capable of emitting over 100 tons of a pollutant per year), which, as a class, produce about 85% of all air pollution emitted by stationary sources. Accordingly, EPA and state enforcement programs focused on ensuring compliance by this class of emitters in order to have the greatest impact on pollution abatement.

In May, 1972, the SIPs for the States of Arizona, Idaho, Montana, Nevada, New Mexico, and Utah were disapproved insofar as they applied to the copper smelters. Promulgation of Federal replacement regulations were delayed due to controversies over air quality data, the availability of controls and the possible use of intermittent control systems and tall stacks.

Resolutions to these problems were approached in late 1973, and EPA had finalized Federal regulations for the control of SO_x for some primary nonferrous smelters by early 1975. Regulations proposed required the application of the reasonably available retrofit control technology, and, if necessary, allowed the interim use of supplementary control systems (SCS) and tall stacks until adequate constant control techniques became available. Each smelter using SCS is further required to conduct a research and development program to hasten the development of such technology.

The SIPs in some states failed to fully meet EPA requirements, in others, states and local agencies adopted technically impractical standards for existing sources or chose to supersede technically-based EPA standards for new sources in order to control the use of land, for example.

When a non-technology-based standard is described in aesthetic terms (e.g., "no visible emissions") it is often referred to as a "cosmetic" standard. Such standards have varying degrees of practicability in any specific situation.

Three separate court cases, involving challenges on the reasonableness of regulations contained in SIPs approved by EPA, resulted in a recent Supreme Court ruling that the EPA need not consider technical feasibility and economic practicality in approving state-submitted SIP regulations. EPA can deny a SIP only if it will not result in the attainment of air quality standards. Under these conditions, EPA must consider availability of technology, economic practicality, etc., in proposing alternative SIPs.

(4) State Variances

Most state implementation plans were drafted so that all emission limitations were effective immediately. Because most sources were not in compliance with emission limitations of implementation plans, there was a transition period (still continuing for some) between the time a plan became effective and the time that ambient air standards had to be attained. The most common way of dealing with source noncompliance was for a state pollution control authority to issue a variance from the requirements, provided that the source and the state reached an acceptable compliance schedule and that the national ambient air quality standards were met by the statutory deadlines. EPA took the position that such variances would be treated as revisions of the state implementation plans, requiring only approval by EPA.

This variance procedure was challenged throughout the country and much litigation ensued. In April 1975, the Supreme Court held that the purposes and philosophy of the Clean Air Act of 1967 were not changed by the 1970 amendments. Accordingly, the chief responsibility for attainment of ambient air standards rests with the states. So long as a state's control strategy achieves and maintains ambient air standards through emissions reduction, the Court ruled that EPA cannot interfere with the state's timing or its enforcement techniques unless there are significant delays.

(5) "Significant Deterioration" Controversy

Although the original Clean Air Act of 1970 contained no mention of "significant deterioration" (the words used in the act are "protect and enhance" air quality) in a 1972 suit brought by the Sierra Club against the EPA, the District of Columbia District Court ruled that according to the provisions of the Clean Air Act, no state could permit "significant deterioration" of air quality in areas where it was already cleaner than required by ambient standards. This ruling was upheld by the Supreme Court, and on August 16, 1974, EPA proposed regulations to incorporate the District Court opinion into state implementation plans.

The EPA regulations, covering particulates and SO_2, were published after long public debate about the nature and severity of the controls. Those seeking strong controls had argued that the court ruling required state implementation plans that would fully protect clean air areas from pollution by new industrial facilities. Those favoring less control argued that there must be some provision for growth and industrialization even in clean air areas and that a strict interpretation of "significant deterioration" by EPA would in effect amount to land use controls prohibiting new industrial development.

The proposed final regulations separate areas into three classifications--Class I, where air quality would be protected at existing levels; Class II, where moderate changes would be permitted; and Class III, where major industrialization and growth would be allowed to a point at which air pollution reaches national standards. All areas were to be established as Class II areas at first, with authority given state governors to change any to Class I or III. In this way, the Federal Government would not be forced to determine industrial siting policies for regions based on air quality alone but would allow wide discretion to the states. The regulations were adopted in final form by EPA on November 27, 1974.

The regulations have been challenged from both sides. Industrial groups have sought to have the regulations set aside as an arbitrary and capricious exercise of authority. At the same time, the Sierra Club (the successful plaintiff in the original district court suit that forced promulgation of the regulations) and other environmental groups brought legal challenges on two grounds--that the regulations allowing growth and siting of facilities in Class III areas violate the court order and that the Act does not allow limiting the regulation to particulates and SO_x emissions, but requires that all criteria pollutants be included.

2. Water Pollution

a. Background

Until 1972, the Federal approach to water pollution was embodied in two pieces of legislation:

- the Refuse Act of 1899; and
- the 1948 Federal Water Pollution Control Act (including amendments passed in 1956, 1965, 1966, and 1970).

The Federal Water Pollution Control Act (FWPCA) was essentially the Federal Government's first venture into what was previously almost exclusively a state and local matter. It asserted that the primary responsibility for pollution control remained with the states and gave the Federal Government authority principally for investigations, research, and surveys.

Amendments to the Act in 1956 and thereafter increased the scope of Federal activity in two key ways: first, authorization was made for Federal financial support of municipal water treatment plants; second, a complex procedure was established for Federal regulation of waste discharge through enforcement actions against individual polluters. Interstate polluters were the initial targets of these actions, but eventually authorization was broadened to include both inter- and intrastate pollution.

The FWPCA originally focused on the maintenance of ambient water quality standards; allowable discharges were related to the estimated assimilative capacity of a receiving stream or lake. Enforcement was slow and cumbersome, involving conferences and long waiting periods. As a result, the Act's provisions were the basis of only three civil court actions brought against polluters before 1972.

The Refuse Act of 1899 was an obscure law passed as part of an appropriation act for construction and repair work on rivers. It forbade discharge of any refuse matter (excluding that from municipal sources) into the nation's navigable waters without a permit issued by the Chief of the U.S. Army Corps of Engineers. The Act was generally unenforced until 1970; thereafter, as concern with pollution increased, the Government began bringing both criminal and civil lawsuits against individual polluters, basing its authority on a 1960 Supreme Court decision which held that, under the Refuse Act, the U.S. could sue industries to stop them from discharging pollutants into navigable waters without a discharge permit. The Act became unimportant following passage of the FWPCA amendments of 1972, which included provisions which required permits for all industrial and municipal dischargers.

b. Federal Water Pollution Control Act Amendments of 1972

The Federal Water Pollution Control Act Amendments of 1972 represented a significant policy departure from prior Federal Government approaches to correction of the national water pollution problem. The amended law embodied several significant alterations in the specific objectives, implementation, and enforcement procedures of the Federal Government's anti-pollution program for the nation's waterways.

As amended, the law aims "to restore and maintain the chemical, physical, and biological integrity of the Nation's water." As national goals to achieve this objective, it calls for eliminating pollutant discharges altogether by 1985, and, whenever attainable in the interim, achieving water quality providing for protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water by 1983 (Section 101a). The law does not, however, actually mandate attainment of these objectives and goals. The no-discharge goal is mandated by 1983 only for categories and classes of nonmunicipal dischargers for which it is "technologically and economically achievable."

Prior law rested on a de facto goal of making individual waters clean enough to support one or more beneficial uses--such as fishing, swimming, boating and water supply for homes, farms, and industries--in each case determined by the states to be desirable and feasible. This approach recognized that different waters would, as a practical matter, support different combinations of uses which in turn would require different ambient water quality conditions.

By contrast, the amended law rejects, for the purpose of policy objectives, distinctions among water bodies in terms of use as well as the concept that contaminants can be rendered harmless and thus tolerated below certain concentrations.

In several respects (e.g., citizen suits, monitoring, retention of local authority) the provisions of the FWPCA roughly parallel those of the Clean Air Act. The Water Act's special provisions are discussed below.

(1) Establishment of Water Quality Standards

The 1972 Amendments provided that EPA and the states establish water quality standards for the nation's navigable waters. These, however, are secondary, rather than principal criteria for regulating pollution in the nation's waterways. The amended Act no longer focused principally on ambient quality and assimilative capacity of receiving waters, but instead directed EPA and the states to establish minimum discharge requirements for individual industrial and municipal polluters.

By June,1974 the initial process of reviewing and revising interim standards was completed. In October, 1974, EPA proposed water quality criteria defining maximum limits of acceptability for chemical and physical constituents in U.S. waters. These criteria are intended to form the scientific basis for any future revision of water quality standards, and in particular the establishment of the 1983 interim goal of providing for the protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water. EPA emphasized, however, that decisions on standards and control measures must also consider the economic and social impact of controlling water pollutants and the practicality and enforceability of the standards and control measures.

(2) Establishment of Effluent Limitations

As mentioned above, the amended Act directed the EPA and the states to establish discharge requirements for industrial and municipal plants as the principal means for regulating water quality. The predominant influence behind this approach was the universal recognition that basing compliance and enforcement efforts on a case-by-case judgment of a particular facility's impacts on ambient water quality is both scientifically and administratively difficult. To minimize the difficulties in relating discharges to ambient water quality, the law requires minimum effluent limitations for each category of discharger, based on technological and economic feasibility, regardless of receiving water requirements.

Three critical provisions of the 1972 amendments govern the establishment of effluent standards for water quality control.

First, a 1977 deadline is set for achieving "effluent limitations for point sources, other than publicly owned treatment works, ... which shall require the application of the best practicable control technology currently available. . ." (Section 301b). This has been called the best-practicable-technology (BPT) standard.

Second, a 1983 deadline is set for achieving "effluent limitations for categories and classes of point sources, other than publicly owned treatment works, which ... shall require application of the best available technology economically achievable for such category or class, which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants ... such effluent limitations shall require the elimination of discharges of all pollutants if the Administrator finds ... that such elimination is technologically and economically achievable for a category or class of point sources . . ." (Section 301b). This has been called the best-available-technology (BAT) standard.

Third, in establishing guidelines for BPT and BAT, EPA is charged to take into account "the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, non-water quality environmental impact (including energy requirements), and such other factors as the Administrator deems appropriate. . ." (Section 301b). In addition, in determining BPT, but not BAT, the Administrator is to consider "the total cost of application of technology in relation to the effluent reduction benefits. . ." The use of the term "economically achievable" in the BAT definition, however, does introduce similar economic considerations.

Thus, technology and cost considerations are mandatory in the establishment of BPT and BAT limitations. In addition to these considerations, formal public hearings must, by law, be held in conjunction with the establishment of <u>water-quality-related</u> limitations more restrictive than BPT requirements (i.e., limitations imposed where water quality standards are not satisfied by generally applicable minimum effluent standards). These hearings are to focus upon the "reasonable relationship of the economic and social costs and the benefits to be obtained (by the proposed effluent limitation)" (Section 302b).

The Act does not specify that effluent limitations should consist of single numbers (vs. a range) for each industry category, though in practice state authorities have generally preferred to use single numbers in establishing effluent guidelines.

(3) <u>Establishment of New Source Performance Standards</u>

In addition to issuing effluent guidelines for existing point sources, under the amended Act, EPA must set special effluent standards for new industrial point sources.

The Act implies that process units, as well as entire plants, are subject to new source effluent standards. Distinctions in the setting of new source standards among classes, types, and sizes of facilities are allowed by the terms of the Act.

Best available technology, along with considerations of cost, non-water-quality environmental impact, and energy requirements form the basis for the new source performance standards. Permits granted on this basis exempt permittees from compliance with any more stringent standards for up to 10 years.

Whether a facility is deemed an existing source or a new source is important for two reasons. First, new source performance standards are for the most part stricter than 1977 standards for existing sources because it is assumed that the latest technology is more easily built into a new facility. Second, the new source permit is issued for a longer period than other permits, thus reducing the potential for periodic tightening of permitted effluent levels. EPA has to prepare and circulate environmental impact statements on major new source permit actions and in the process should review all aspects of the siting decision for the source.

(4) Establishment of Toxic and Pretreatment Effluent Standards

The EPA Administrator must publish a list of toxic pollutants and effluent limitations or prohibitions for them. Toxic pollutants are defined as those which, when assimilated either directly from the environment or indirectly by ingestion through food chains, will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions, or physical deformities in any organism or its offspring.

Spills of toxic or other hazardous materials are now subject to the same regulatory framework--for prevention and Federal cleanup costs--that previously existed only for oil spills.

The criteria for these standards are to be developed so as to protect any potentially affected organisms in any receiving waters. Economic considerations are absent from this statutory standard-setting procedure.

In July, 1973, EPA designated 12 chemicals used in manufacturing as toxic water pollutants, including the pesticides aldrin, dieldrin, endrin, DDT and its derivatives DDE and DDD; the pesticide compound toxaphene; cadmium, mercury and cyanide; and the industrial chemcials benzidine and PCB (polychlorinated biphenyls). These pollutants are toxic in very low concentrations, with the exception of benzidine, which was included because of its ubiquity and known carcinogenic properties. EPA is currently developing effluent standards governing the discharge of these toxic pollutants. EPA has been studying additional chemicals such as arsenic, selenium, chromium, lead and asbestos for possible inclusion on the list.

The Administrator must also issue pretreatment standards requiring an industrial facility discharging into a municipal sewage treatment plant to pretreat its effluent so that it does not interfere with the operation of or pass through the plant without adequate treatment. Because roughly one-half of all industrial facilities discharge their wastes into municipal systems, pretreatment standards are considered essential to achieving control over industrial effluents.

C. RECENT EPA REGULATIONS AND THEIR IMPLICATIONS FOR THE GROWTH OF THE DOMESTIC COPPER INDUSTRY

1. Recent Regulations

Of all the environmental regulations affecting the four segments of the domestic copper industry, the air pollution regulations affecting the smelters are the most important in terms of cost and potential impact. With Clean Air Act requirements as interpreted in EPA regulations effectively constraining smelter capacity growth, the available smelter capacity has become a bottleneck to overall industry expansion in the near term (i.e., at least until 1983).

The regulations which cover permissible modes for expanding existing smelters or for building new smelters are the New Source Performance Standards including the Modification and Reconstruction Provisions (41 FR 2332 and 40 FR 58416) and that aspect of the Tall Stack Guidelines (41 FR 7450) which prohibits the permanent use of SCS at a smelter (whether or not it uses Best Available Control Technology) as a means of meeting NAAQS.

In the remainder of this section, we will show how these regulations allow only certain modes for smelter expansion, effectively constraining smelter capacity growth. Since a part of the problem may be due to fugitive emissions, this problem will also be addressed. This will be followed by a smelter-by-smelter analysis of the expansion potential at existing smelter locations. This analysis shows that even if energy costs were not a constraint on methods for expanding capacity, such traditional methods can no longer be used as a result of these regulations. Finally the results of this analysis will be used to define two scenarios for the economic impact analysis which cover the time span until 1985.

Incremental smelting capacity can be achieved in two ways:

- Construction of new grass roots or greenfield smelters (i.e., a smelter in a new location which was previously undeveloped); and
- modification of existing smelters to achieve expanded throughput (This can be coupled with the replacement of obsolete capacity in some instances).

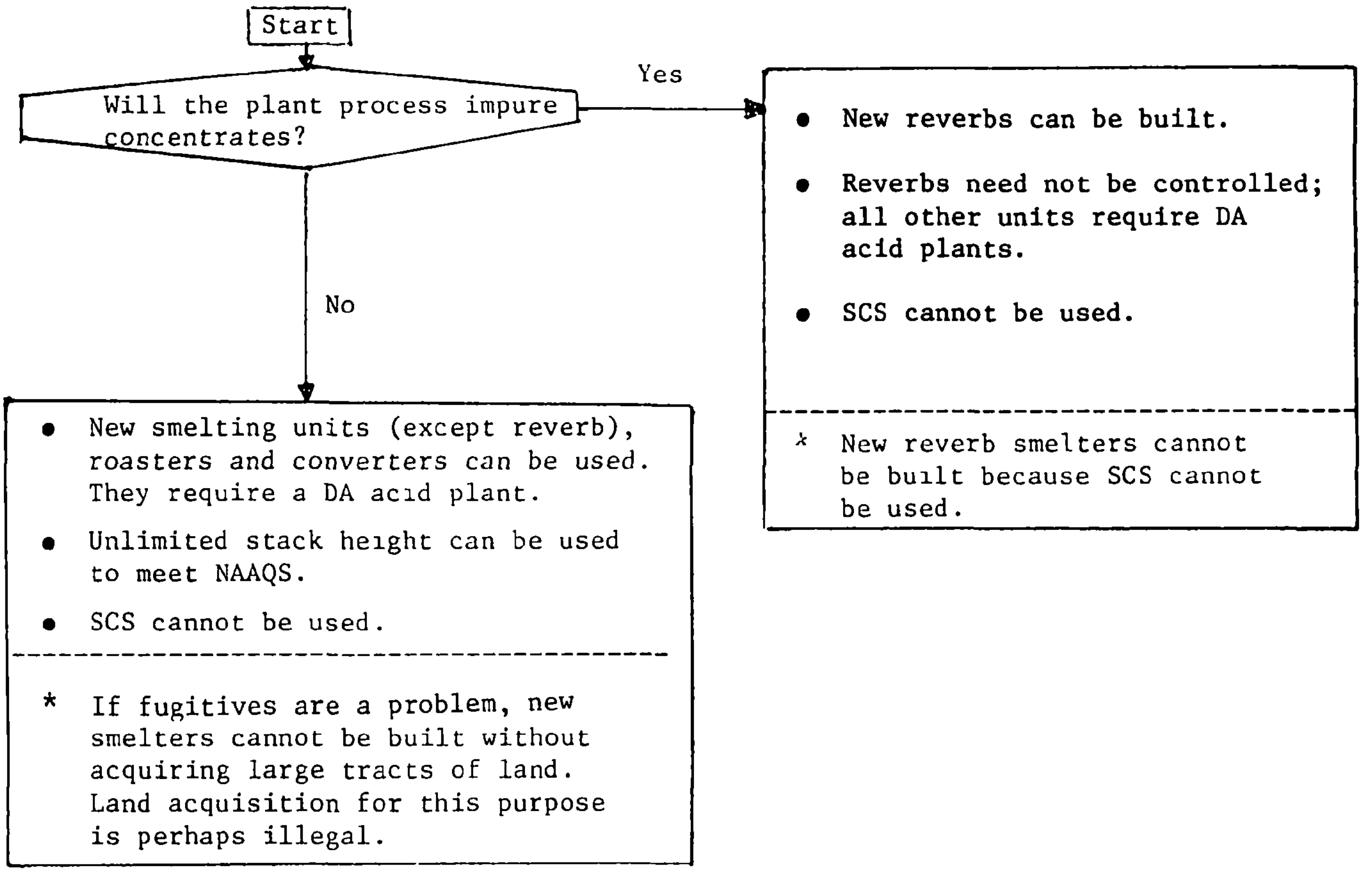
As discussed in detail in Chapter 4, the copper industry has traditionally preferred the latter approach. The effect of regulations on these two approaches will be discussed separately.

a. Grass Roots Smelters

Figure 1 shows a logic diagram for grass roots smelters. For impure concentrates (see Figure 1 for the definition of such concentrates), New Source Performance Standards (NSPS) allow reverbs to be used without SO_2 control. All other units (roasters and converters) require a DA (dual absorption) acid plant. However, the Tall Stack Guidelines do not allow the use of SCS (i.e., production curtailment) for meeting ambient air quality standards. A reverb-based smelter would require SCS to meet NAAQS. Since SCS cannot be used we conclude that new reverb-based smelters for impure concentrates cannot be built in most locations. Electric furnace smelters for impure concentrates are functionally similar to clean concentrate smelters discussed in the next paragraph.

For clean concentrates, NSPS require that all units (smelting units, roasters and converters) be controlled with DA acid plants. Since the control of the dilute reverb gases is prohibitively expensive, reverbs would not be used as smelting units. This is not a constraint since

FIGURE 1: LOGIC DIAGRAM FOR GRASS ROOTS SMELTERS



Footnotes:

Impure concentrates - These are defined to contain more than 0.2% As, 0.1% Sb, 4.5% Pb and 5.5% Zn.

NAAQS - National Ambient Air Quality Standards.

SCS - Supplementary Control System, the use of production curtailment to meet NAAQS.

* - Asterisks denote inferences or conclusions by ADL.

alternate technology is well established and will generally also result in fuel savings.

Preliminary diffusion modeling shows that new flash or electric smelters using DA acid plants, state-of-the-art tall stacks (800-1200 ft) and using some secondary hooding for capturing fugitive emissions, might violate NAAQS for several kilometers around a smelter. This problem is caused by fugitives rather than stack emissions. Fugitives are essentially converter aisle emissions and result from smelting furnace tapping and converter operations. Thus, the fugitives problem is common to existing smelters, new reverb smelters and new smelters using new technology since they all contain a converter aisle. The use of SCS might alleviate this problem if converter aisle operations are stopped under adverse weather conditions (i.e., each night), and a matte reserve built up in the smelting unit during this period. SCS strategy for controlling fugitives would be different from SCS strategy for controlling stack emissions. It would succeed only if the periods of adverse meteorology are short. Also, the use of SCS for fugitives control would result in large fluctuations in the volume of gases to the acid plant, perhaps causing operating problems. Thus, it is not clear whether new grass roots smelters have a fugitives problem and whether SCS can be used for fugitives control. In any case, this discussion is academic at the present time since the Tall Stack Guidelines prohibit the use of SCS.

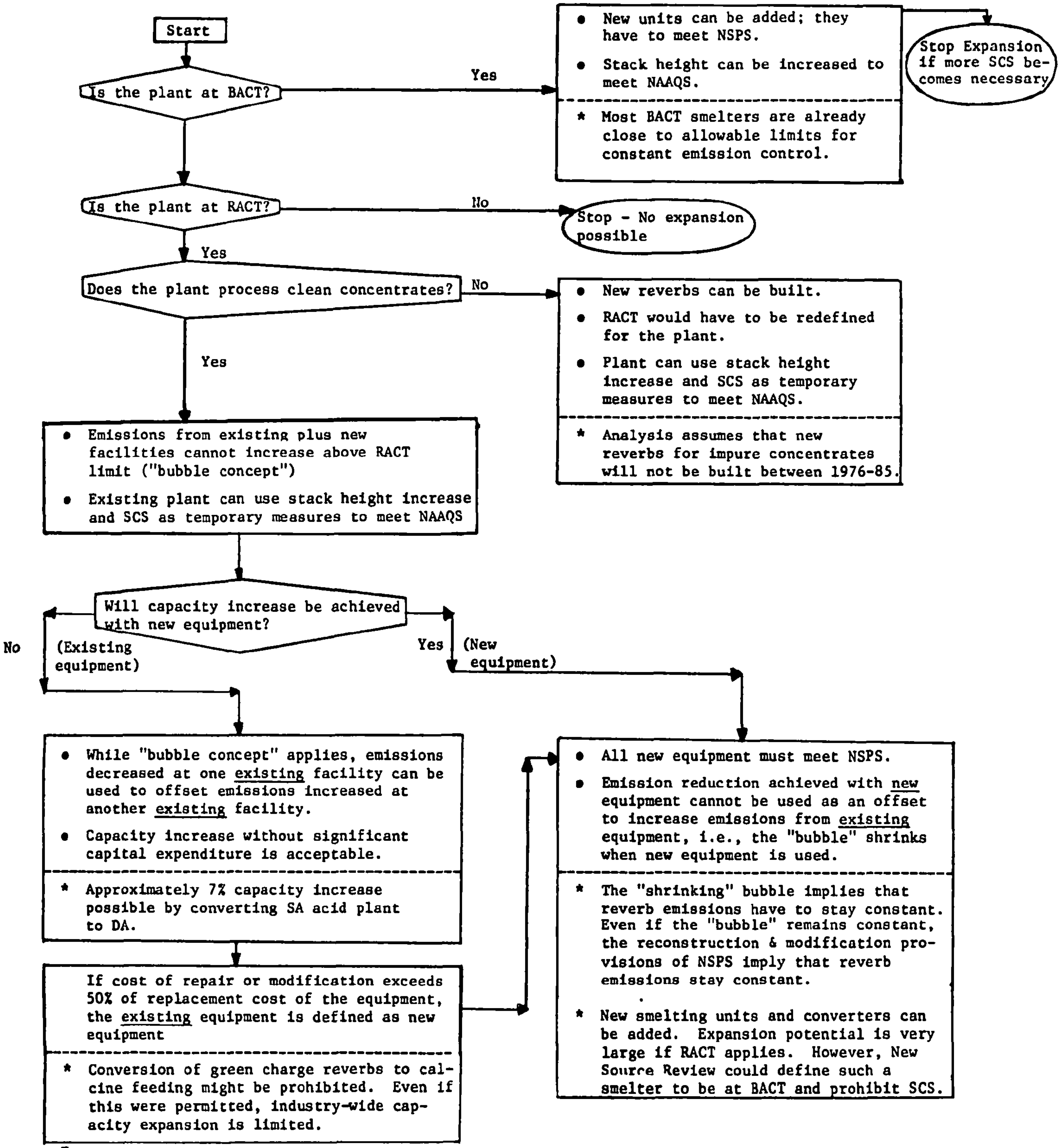
In summary, it appears that the grass roots smelters of minimum economic size (100,000 tons/year of copper) might not be built since they would violate existing regulations. At first glance, it appears that the inability to use SCS is a major constraint. Without SCS, reverb-based smelters would violate NAAQS because of stack emissions. In addition, all smelters might violate NAAQS because of fugitive emissions and it is not clear whether all constrains disappear when SCS is permitted. A preliminary survey of land values in Arizona suggests that land acquisition (as a means of removing the influence of fugitive emissions from the reach of NAAQS) in remote rural areas is not economically prohibitive. However, since the major portion of Arizona land is under Federal control, such a move might not be feasible and might even be illegal. In spite of these unknowns, we assume that grassroot smelters will be built in the future. However, because of the lead time requirements, such smelters could not be in operation before 1984.

b. Expansion/Modifications at Existing Smelters

Figure 2 shows the logic diagram for determining the potential for expansion at existing smelters. Initially, plants using Best Available Control Technology (BACT) are considered. BACT is the same as NSPS and refers to non-reverb smelters where all units are controlled by DA acid plants. The Inspiration smelter is an example of such a smelter where an electric furnace, Hoboken converters and DA acid plant were built at the site of an existing reverb smelter.

For existing smelters, two types of emission limitations have been proposed (see 40 FR 49362 for details on Arizona smelters). The first is based on available air quality data and diffusion modelling and sets an emission limit to be achieved by constant emission control. The second is a less stringent temporary limitation based on Reasonably Available Technology (RACT) discussed in the next paragraph. The constant emission control limitation is based on diffusion modeling which assumes that fugitives will be captured and vented through the tallest available stack. It is doubtful whether all fugitives can be captured and vented in this

FIGURE 2: LOGIC DIAGRAM FOR CAPACITY INCREASE AT EXISTING SMELTERS



Footnotes:

BACT - Best Available Control Technology - roasters, new smelting furnaces and converters controlled with Dual Absorption (DA) acid plants - same as NSPS.

NSPS - New Source Performance Standards.

RACT - Reasonably Available Control Technology - control of strong (converter and fluid bed roaster) streams using SA or DA acid plants. No control of reverb or multiple hearth roaster streams. Use SCS as necessary. R&D program required.

SCS - Supplementary Control System - the use of production curtailment to meet NAAQS.

NAAQS - National Ambient Air Quality Standards.

* - Asterisks denote inferences or conclusions by ADL.

fashion. Even smelters meeting the constant emission limitations might exceed NAAQS because of low level fugitive emissions. Thus, the uncertainties facing existing BACT smelters are essentially the same as discussed earlier for grass roots smelters based on clean concentrates (i.e., they may exceed NAAQS because of fugitives). While it appears at first glance that the inability to use SCS is a major constraint, additional analysis is necessary to determine whether all constraints disappear when SCS is permitted. It should be noted that Figure 2 shows that stack height increase might be permitted. The regulations are somewhat ambiguous on this point. The Tall Stack Guidelines (41 FR 7451, 2nd column, second full paragraph) state "... stack height increases and/or SCS are acceptable control strategy measures only after the application of available control measure and are never permitted as a means of allowing the increase of emissions at any source (emphasis added)." Either way, the NAAQS violations might result from uncaptured fugitives. The remainder of this section assumes that this potential fugitives problem will be resolved without major cost consequences to the industry. In any case, the potential for capacity increase at BACT smelters is small since they are already close to the allowable limits for constant emission control.

Reasonably Available Control Technology (RACT) is defined as control of strong streams (new multiple hearth roasters, new or old fluid bed roasters and converters) and no control of weak streams (reverbs and old multiple hearth roasters). A SA acid plant (96.1% efficiency) is sufficient for controlling strong streams at locations that already have such a plant. For locations without an acid plant, a new DA acid plant

(99.5% efficiency) is necessary. Thus, using maximum production rates in 1973-1974, and observed or calculated sulfur distributions at each smelter, a RACT emission limitation can be calculated as follows:

$$\text{Emission Limit (Tons } SO_2\text{/Day)} = 2 \times I \, (R + F + S \, (I - E))$$

Where

Emission limit in tons SO_2/day is multiplied by (2000/24) to convert it to lb SO_2/hour.

I = Total sulfur input into the plant at maximum design rate in tons of S/day.

R = Fraction of total sulfur in weak streams (reverb and others).

F = Fraction of total sulfur emitted as fugitive emissions.

S = Fraction of total sulfur in strong streams, i.e., sulfur in acid plant feed.

E = Fractional efficiency of the acid plant, i.e., 0.961 for SA and 0.995 for DA.

The factor 2 converts tons of S to tons of SO_2.

The emission limit calculated by the above procedure defines a "bubble" or "umbrella," i.e., it is an upper bound for emissions from that source. Any changes that increase emissions above this limit are prohibited. On the other hand, a smelter at RACT can use unlimited stack height increase and SCS as temporary measures until economic BACT calibre technology becomes available. The regulations are vague regarding criteria for defining BACT calibre technology, its economics or its availability. We assume that these "temporary" measures will be utilized throughout the period of analysis (i.e., until 1985).

Figure 2 shows that the regulations might allow new reverbs to be built for processing impure concentrates. This is a somewhat speculative interpretation of the regulations since this issue (new reverbs for impure concentrates in a smelter at RACT) is never directly addressed in any of the regulations. This point is less important since, based on our knowledge of the industry, we assume that new impure concentrates will not become available and this potential mode of capacity expansion will not be utilized.

Under the "bubble" concept, emissions decreased at existing equipment are used to offset emissions increased at other existing equipment. However, the allowable expansion appears small. After analyzing all possibilities we find that this case applies only when a SA acid plant is converted to DA and the reverb emissions are increased to offset the decrease in acid plant emissions. This allows a 6-7% increase in capacity. See Arthur D. Little, Inc., "Economic Impact of New Source Performance Standards on the Primary Copper Industry: An Assessment," Report to EPA, October 1974, page M-4 for detailed calculations. (This report will be referred to as the NSPS report in the subsequent discussion).

The NSPS report (page M-8) shows how a green charge reverb can increase capacity by 50% by installing fluid bed roasters. However, a green charge reverb would have to be reconstructed to handle hot calcines and such reconstruction could be prohibited since a reconstructed reverb is a new source and would have to be controlled. Even if reverb reconstruction is permitted, it is not certain that industry would utilize this approach for capacity expansion. The copper companies with experience with fluid bed roasters consider them to be unreliable and requiring a high degree of maintenance. In particular, there are four green-charge smelters who could utilize this approach. Three of these belong to companies who already have poor operating experience with such roasters. Thus, this approach, even if permitted, has a low expansion potential.

When emission reduction is achieved by using new equipment, the regulations suggest that such reduction cannot be used to offset emission increases from existing equipment, i.e., the "bubble shrinks." The regulations are ambiguous on this point. However, the regulations clearly treat construction of new reverbs or significant reconstruction of old reverbs as falling within NSPS. Because of this, capacity expansion is essentially limited by the smelting capacity of existing reverbs. As noted in the NSPS report (p. 42) up to 20% capacity increase could be obtained by modifying a reverb to use preheated combustion air or by oxygen enrichment of combustion air. However, if the smelting rate of any reverb is increased by 20%, its emissions also increase by 20%, but the latter is not permitted at RACT sites under the bubble concept. Smelters with multiple hearth (M-H) roasters could install new fluid bed (F-B) roasters and not require reverb reconstruction for calcine handling. However, capacity expansion is not possible since the smelting rate in the reverbs cannot be changed.

Finally, when a new smelting furnace (and the necessary accessories) are built in an existing reverb location, such a conversion could markedly decrease emissions. However, such a conversion would be subject to the New Source Review which could classify the smelter to be at BACT and therefore disallow the use of SCS. We believe this to have a low probability of occurring. This approach is potentially a major expansion route for the industry. However, this type of expansion has about the same lead time requirements as grass roots smelters and such capacity could not be available before 1984.

In summary, the analysis of the regulations show the following general modes for expansion at existing smelters:

- BACT Smelters
  - low apparent potential for expansion since BACT smelters are close to constant emission control limitations.
- RACT Smelters
  - 6 to 7% expansion possible at all smelters by converting SA acid plants to DA. The capacity increment is too small to interest most smelters.
  - Major expansion possible if new smelting units (meeting NSPS) in existing locations can use SCS and operate under the original RACT bubble. On the other hand, if such smelters are classified as BACT smelters via New Source Review, SCS cannot be used and expansion potential might be low. We assume that this type of expansion will be allowed. However, this type of capacity will be available only after 1983.

c. Smelter-by-Smelter Analysis of Short-term Capacity Growth

The findings from the previous section are used here for a smelter-by-smelter analysis of short-term (pre-1983) expansion potential of existing smelters. While major expansion appears possible by building new smelting units (meeting NSPS) and operating under the original RACT umbrella in existing locations, such smelters could not be at full production before 1983. Because of this, the discussion to follow focuses on the other short-term routes which could potentially provide incremental capacity before then.

Readers unfamiliar with the locations of existing smelters should consult the maps and tables in Chapter 4.

Asarco, Hayden (Central Arizona)

(1) RACT

Smelter has multiple hearth roasters, reverbs, converters, a SA plant on converter gases. The smelter is at RACT; uses SCS to meet NAAQS.

(2) Expansion Routes

No significant expansion possible.

Phelps Dodge, Douglas (Southern Arizona near the Mexican border)

No expansion possible because the smelter is not at RACT (i.e., control of converter gas). The smelter contends that such control is not reasonable for Douglas. Given that RACT for Douglas is yet to be defined, we assume that Douglas will not expand.

Phelps Dodge, Morenci (Southeastern Arizona)

(1) RACT

The plant has a small F-B roaster. RACT is based on control of strong streams using SA plant.

(2) Expansion Potential

- A 7% expansion is possible by converting the SA acid plant to DA.
- While the smelter might be permitted to convert completely to a fluid bed roaster-calcine charging, we believe that this conversion will not occur for reasons discussed on pages 8-31 and 8-32.

Kennecott, Hurley, New Mexico (Western New Mexico)

(1) RACT

The plant is a green charge smelter. Converter gases are controlled in an SA acid plant.

(2) Expansion Potential

- A 7% expansion is possible by converting the SA plant to DA.
- The plant is not likely to convert to F-B roasters for reasons mentioned on pages 8-31 and 8-32.

Asarco, Tacoma (Tacoma, Washington)

(1) RACT

The plant uses M-H roasters, reverbs, and converters to smelt impure concentrates. Converter gases are controlled.

(2) Expansion Potential

- A 7% expansion is possible by converting the SA plant to DA.
- Because impure concentrates cannot be roasted in F-B roasters, any options based on such roasters are unrealistic.
- Under NSPS, Asarco could construct new reverbs to smelt impure concentrates. However, the shortage in domestic smelting capacity is for smelting clean concentrates. Such concentrates cannot be smelted in uncontrolled new reverbs.

Asarco, El Paso (El Paso, Texas)

Same comments as Asarco, Tacoma above.

Kennecott, Hayden (Central Arizona)

(1) RACT

The smelter uses F-B roasters, reverbs and converters. Roaster and converter gases into a DA acid plant.

(2) Expansion Potential

A 7% expansion is possible by changing SA acid plant to DA.

Magma, San Manuel (South Central Arizona)

(1) RACT

The smelter uses green charge smelting. Converter gases are controlled. Acid plant is SA.

(2) Expansion Potential

The plant is not likely to convert to F-B roasters for reasons mentioned on pages 8-31 and 8-32.

Kennecott, McGill (Eastern Nevada)

(1) RACT

This is a green charge smelter. Converters are not controlled at present. Kennecott's latest position is that, given the limited reserves and age of the smelter, control of converter gas might not be economically justified.

(2) Expansion Potential

No expansion.

Phelps Dodge, Ajo (Southwestern Arizona)

(1) RACT

This is a green charge smelter. The plant has an experimental DMA unit that concentrates converter (and reverb) gases prior to feeding into an acid plant. The experimental system had not operated often. We believe that the DMA system will not be used in the future because of its high costs and operating problems.

(2) Expansion Potential

- A 7% expansion is possible by converting SA acid plant to DA.
- The plant is not likely to convert to F-B roasters for reasons mentioned on pages 8-31 and 8-32.

Inspiration, Anaconda, Kennecott in Garfield and Phelps Dodge in Hidalgo

These four are new smelters using electric furnace (Inspiration and Anaconda), Noranda (Garfield), and Outokumpu flash smelting (Hidalgo). The expansion potential at each smelter is unknown. As such, they can use unlimited stack height to increase dispersion but may not use SCS. Thus, the expansion limit will be defined on the basis of modeling studies which would indicate the maximum permissible emissions to meet NAAQS without using SCS. Fugitives might cause NAAQS to be exceeded. If this occurs, no expansion is possible.

2. Capacity Expansion Until 1985

The discussion in the previous section, summarized below in Table 1, shows that the existing regulations allow little or no room for expansions in the short term (i.e., before 1983). Beyond 1983, there is the necessary lead time required for planning, building, and commissioning of a NSPS calibre smelter in a grass roots or existing location.

TABLE 1

SUMMARY OF THE EXPANSION POTENTIAL OF EXISTING SMELTERS PRIOR TO 1984

	Smelter	% Expansion	Mode of Expansion	Probability that This Route Will be Followed
1.	Asarco, Hayden	0-7%	SA to DA Acid Plant	Low[1]
2.	PD, Douglas	0%	RACT is undefined	Low[1]
3.	PD, Morenci	0-7%	SA to DA Acid Plant	Low[1]
4.	KCC, Hurley	0-7%	SA to DA Acid Plant	Low[1]
5.	Asarco, Tacoma	0-7%	SA to DA Acid Plant	Low[1]
6.	Asarco, El Paso	0-7%	SA to DA Acid Plant	Low[1]
7.	KCC, Hayden	0-7%	SA to DA Acid Plant	Low[1]
8.	Magma, San Manuel	0%		
9.	KCC, McGill	0%	RACT is undefined	Low[1]
10.	PD, Ajo	0-7%	SA to DA Acid Plant	Low[1]
11.	Inspiration			
12.	Anaconda			
13.	KCC, Garfield		Expansion potential defined by NAAQS	Low[2]
14.	PD, Hidalgo			

NOTES: [1]Low; 7% expansion is too low
[2]Expansion may be constrained by the fugitive emissions.

Source: Arthur D. Little, Inc. estimates.

A major smelter construction project requires the following steps:

- Decision that extra capacity is needed;
- prefeasibility studies--preliminary evaluations of several alternatives;
- process design and detailed engineering of the selected approach;
- construction;
- startup and shakedown; and
- bringing the plant to full capacity.

We believe that the time span for this to occur is about seven years. Construction alone typically takes three years and it can be a year or more after construction is complete before full capacity is reached.

At the present time, we are not aware of any major smelter construction projects that are under active consideration. Thus, given the time lags in the system and the uncertainties on the regulatory scene, new capacity will not come on-stream until 1984.

Based on the above, we have defined two scenarios for smelter and refinery capacity in the U.S. over the study period, i.e., until 1985.

1. "Constrained Capacity"

This scenario assumes no capacity expansion until 1984 for reasons discussed above. We assume 200,000 short tons per year of copper in new smelting (and refining) capacity will come on-stream in 1984 and another 200,000 short tons per year in 1985. We also assume that none of the existing smelters will shut down.

2. "Reduced Capacity"

This scenario assumes that the uncertainties in the regulations or economic conditions will delay any new smelting capacity until after 1985. We also assume that two smelters (i.e., McGill and Douglas) will close in 1977 and 1979, respectively.

D. ESTIMATES OF COMPLIANCE COSTS

Pollution abatement costs were estimated for the historical period (1970-1975) and for the impact analysis period (1976-1985) using information from several sources. Initially, we circulated questionnaires to individual firms in the industry to obtain their data for the historical period and their anticipated future outlays (both pollution control-related capital expenditures and operating and maintenance costs). This approach, however, was relatively unsuccessful. Several companies did not respond to the questionnaire. As a result, the responses covered less than half the industry. Many of the companies that responded provided only aggregated costs that could not be verified independently. For the forecast period, most companies would not speculate about their expected costs of compliance with the currently promulgated and/or pending regulations. The questionnaire returns did indicate that almost all the pollution control-related cost was a result of Federal regulations. Local regulations did not appear to play a major role. Many in the industry anticipate large potential costs resulting from future OSHA regulations. However, given the uncertainties in this area, it is not possible to estimate these costs at the present time.

The pollution abatement compliance costs shown in Table 2 were estimated year-by-year for existing facilities using information on individual smelters in our files and published EPA Development Documents.

The bulk of the cost reflects cost of monitoring and controlling ambient and fugitive emissions. Since most plants in the west are close to zero aqueous discharge, the cost of water pollution control is low (less than a third).

These estimates are for meeting the following regulations:

- The application of Reasonably Available or Best Available Control Technology (RACT or BACT) at existing and new facilities for control of air pollution. For most existing smelter locations these expenditures occurred in the period 1971-1976.
- Effluent limitation Guidelines for 1977 and 1983.
- Order-of-magnitude numbers, i.e., $40 million for meeting future EPA regulations in the areas of toxic and hazardous emissions.

Table 3 presents estimates of "upper bound" pollution abatement compliance costs for purposes of sensitivity analysis.

The estimates of pollution abatement and control costs shown in Tables 2 and 3 represent "cash outflows" in the years indicated. They are translated into annualized fixed costs within the model for impact analysis (Refer to Tables 2-5 for a translation of the capital expenditures shown here in Table 2, under the Constrained Capacity and Reduced Capacity scenarios, into annualized fixed costs).

TABLE 2

EXPECTED POLLUTION ABATEMENT AND CONTROL EXPENDITURES BY THE U.S. COPPER INDUSTRY,[a] 1976-1985

(in millions of 1974 dollars)

Years	Capital Expenditures[b]		Operating and Maintenance Costs[c]		Total	
	Constrained Capacity[d]	Reduced Capacity	Constrained Capacity	Reduced Capacity	Constrained Capacity[d]	Reduced Capacity
1976	156.0	156.0	99.5	99.5	255.5	255.5
1977	90.0	90.0	112.4	112.9	202.4	202.9
1978	60.0	60.0	115.8	111.8	175.8	171.8
1979	40.0	40.0	116.2	112.2	156.2	152.2
1980	40.0	40.0	115.1	108.4	155.1	148.4
1981	60.0	40.0	115.9	109.1	175.9	149.1
1982	100.0	40.0	117.2	110.3	217.2	150.3
1983	100.0	40.0	117.8	110.9	217.8	150.9
1984	60.0	40.0	126.5	110.9	186.5	150.9
1985	40.0	40.0	135.8	111.1	175.8	151.1
1976-1985	746.0	586.0	1,172.2	1,097.1	1,918.2	1,683.1

NOTES: [a]Not including secondary smelters/refiners.

[b]Figures given here refer to expenditures (dollar outflows), not to increased fixed costs. In the model, these investment figures are translated into annualized fixed costs through the use of capital charge coefficients (refer to Arthur D. Little, Inc. [ADL], Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry. Technical Appendix to this report.

[c]Increases in variable costs due to pollution abatement and control, estimated at about 2.5 cents per pound of refined copper. These figures are obtained by multiplying 2.5 cents per pound by model solutions for primary refined copper output.

[d]These estimates reflect pollution control capital expenditures at existing facilities plus pollution control invesment associated with capacity expansion coming on-stream in 1984 and 1985. The latter would add about $80 million associated with capacity growth expected to come on-stream in 1984 (200,000 annual short tons) and roughly another $80 million associated with capacity growth expected to come on-stream in 1985 (200,000 annual short tons). These two latter amounts are time-phased as follows:

Year of Spending	Associated with capacity growth coming on-stream in ($ millions): 1984	1985	Total ($ millions)
1981	20		20
1982	40	20	60
1983	20	40	60
1984		20	20

SOURCE: Arthur D. Little, Inc., estimates.

TABLE 3

EXPECTED POLLUTION ABATEMENT AND CONTROL EXPENDITURES BY THE U.S. COPPER INDUSTRY,[a] 1976-1985

(in millions of 1974 dollars)

(upper bound estimates for purposes of sensitivity analysis)

Years	Capital Expenditures[b] Constrained Capacity[d]	Capital Expenditures[b] Reduced Capacity	Operating and Maintenance Costs[c] Constrained Capacity	Operating and Maintenance Costs[c] Reduced Capacity	Total Constrained Capacity[d]	Total Reduced Capacity
1976	156.0	156.0	99.5	99.5	255.5	255.5
1977	130.0	130.0	112.4	112.9	242.4	242.9
1978	100.0	100.0	115.8	111.8	215.8	211.8
1979	80.0	80.0	116.2	112.2	196.2	192.2
1980	80.0	80.0	115.1	108.4	195.1	188.4
1981	100.0	80.0	115.9	109.1	215.9	189.1
1982	140.0	80.0	117.2	110.3	257.2	190.3
1983	140.0	80.0	117.8	110.9	257.8	190.9
1984	100.0	80.0	126.5	110.9	226.5	190.9
1985	80.0	80.0	135.8	111.1	215.8	191.1
976-1985	1106.0	946.0	1172.2	1097.1	2278.2	2043.1

NOTES: [a]Not including secondary smelters/refiners.

[b]Figures given here refer to expenditures (dollar outflo ·), not to increased fixed costs. In the model, these investment figures are translated into annualized fixed costs through the use of capital charge coefficients (refer to Arthur D. Little, Inc. [ADL], Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry. Technical Appendix to this report.

[c]Increases in variable costs due to pollution abatement and control, estimated at about 2.5 cents per pound of refined copper. These figures are obtained by multiplying 2.5 cents per pound by model solutions for primary refined copper output.

[d]These estimates reflect pollution control capital expenditures at existing facilities plus pollution control invesment associated with capacity expansion coming on-stream in 1984 and 1985. The latter would add about $80 million associated with capacity growth expected to come on-stream in 1984 (200,000 annual short tons) and roughly another $80 million associated with capacity growth expected to come on-stream in 1985 (200,000 annual short tons). These two latter amounts are time-phased as follows:

Year of Spending	Associated with capacity growth coming on-stream in ($ millions) 1984	1985	Total ($ millions)
1981	20		20
1982	40	20	60
1983	20	40	60
1984		20	20

SOURCE: Arthur D. Little, Inc., estimates.

CHAPTER 9

METHODOLOGICAL APPROACH: GENERAL ORIENTATION AND OVERVIEW OF THE ECONOMETRIC SIMULATION AND IMPACT ANALYSIS MODEL OF THE U.S. COPPER INDUSTRY

A. INTRODUCTION AND GENERAL ORIENTATION

The purpose of this chapter is to provide a nontechnical discussion of the methodological approach used to assess the economic impact of environmental regulations on the U.S. copper industry. To this end, we would like to briefly describe our general methodological orientation and present an overview of the Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry developed and used by ADL for economic impact assessment.[1]

The general methodological approach adopted in this study to assess the industry-wide economic impact of environmental regulations can be characterized as the development of a dynamic nonlinear simultaneous-equation econometric simulation model of the U.S. copper industry. The model is designed, estimated and programmed to simulate the industry's growth and evolution annually over the impact analysis period (1976-1985)[2] under alternative scenarios (baseline conditions, as well as alternative environmental policy scenarios).

The model considers, within an interdependent framework, such variables as demand (paying attention to substitution from aluminum), costs of production facing the primary producers, the relationship between the primary and secondary producers, supply functions of secondary producers (refined and scrap), prices, inventories, investment, and international trade. It also allows analyses of the industry's financial performance annually (e.g., cash-flow, rates of return on assets and/or sales, outside financing requirements, etc.). It represents, in short, a rigorous internally consistent, comprehensive analytical approach for simulation, forecasting and economic impact analysis.

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[1] For a technical description of the model, refer to the Technical Appendix of this report, Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry.

[2] The base year in the model is 1974; the model has been used to simulate the historical period (1964-1975); it has also been programmed to simulate the industry's growth annually beyond 1985 (up to 1990).

In the remainder of this chapter, we will present a nontechnical overview of the model, by touching on the following topics:

(B) Basic components of the model;
(C) Linear and nonlinear versions of the model;
(D) Microeconomic considerations: rationale, for a parametric approach to bound the model's solutions;
(E) Data sources and problems;
(F) Econometric estimation techniques used;
(G) Mathematical solution of the model; and,
(H) Basic differences between this and other econometric models of the copper industry.

B. BASIC COMPONENTS OF THE MODEL

Very briefly, the model consists of two basic components:

- The Market Clearing Module, and
- The Investment Module.

The Market Clearing Module, which consists of thirteen (13) simultaneous equations, simulates every year the production and pricing behavior of the major producing groups in the industry, the inventroy behavior of the major participants in the industry, the demand behavior of the users of copper and the balance of trade effects. The market is cleared in each year through materials balancing and price equilibrium equations.

The Investment Module serves as the year-to-year "transit" connecting the solutions of the Market Clearing Module for successive years, by simulating how smelting/refining capacity changes over time. Thus, the dynamic Investment Module simulates the evolving short-run, by taking into account the early solutions from the Market Clearing Module, in addition to certain exogenous as well as current and lagged endogenous factors. Smelting/refining capacity changes are estimated, translated into total fixed costs (along with increases in total fixed costs due to mining and milling investment, pollution abatement investment, etc.), which are then built into the cost functions of the primary producers.

Since mining and milling investment decisions typically require profitability considerations extending over quite a long time-horizon (typically 25-30 years), the model treats such investment as exogenous. However, capacity expansion and replacement investment at the smelting and refining level is made endogenous. Pollution abatement investment, as well as pollution-abatement related increases in variable costs enter the model exogenously.

Once the model is solved for the entire period (e.g., 1974-1983 or 1974-1990), external checks are performed on the model's results, focusing directly on the industry's overall financial performance. Exogenously specified mining and milling investment behavior is analyzed in terms of various measures of profitability, given the price forecasts. Likewise, overall cash-flow and flow-of-funds (sources vs. uses) analyses are performed, by analyzing financial data computed directly from the model's results, as well as on the basis of detailed historical industry-wide and specific company-by-company financial data. Various types of standard financial checks are hence exercised, by examining debt-to-equity ratios, amount of external borrowing required, profits on sales, rate of return on assets, and so forth. Hence, this procedure provides, in effect, a general "block-recursive" financial analysis framework which permits external checks on the model's performance, from a strictly financial standpoint, which can in principle be internalized. The "feedback loop," as a result, works as follows. If, under the baseline runs, the external financial checks indicate possible overinvestment at the mining and milling level, for example, this behavior is modified through a number of iterations until the results, judged by their financial implications, appear the most plausible. This completes the model runs to develop simply a baseline scenario on the industry's performance over the impact analysis period, in the absence of environmental standards or constraints. Next, these baseline solutions are "perturbed," by introducing into the model new scenarios explicitly built around environmental costs/issues. The resulting differences under these scenarios from the baseline solutions over the impact analysis period are imputed to the specific environmental costs/issues embedded in the various scenarios.

Although the model specifically deals with both the primary producers and with the secondary copper industry (secondary refined, scrap), its major focus is directed at the primary producers, with careful attention paid to their discretionary price and output behavior.

C. LINEAR AND NONLINEAR VERSIONS OF THE MODEL

The model has both a linear and a nonlinear version. The nonlinear version of the model, which represents a more reasonable approximation of the variables and relationships being modeled, is by far the more useful analytical system. The nonlinear version, for example, permits the introduction of capacity constraints in supply and cost curves with smooth continuously differentiable functional forms, while the linear versions yields unconstrained production estimates. Essentially, this means that in the linear case demand curves intersect cost or supply functions beyond capacity. By contrast, in the nonlinear case, cost and supply functions rise roughly around 86-90 percent of installed capacity (smelting/refining capacity) and very steeply beyond this region as physical capacity is approached.

D. MICROECONOMIC CONSIDERATIONS: RATIONALE FOR A PARAMETRIC APPROACH TO BOUND THE MODEL'S SOLUTION

A unique feature of the model is that it deals explicitly with the central and vexing analytical problem present in any microeconometric modeling effort where price-output determination does not follow the textbook simplicity of perfectly competitive behavior. That is, the structure of the domestic copper industry has been characterized basically in terms of a core group of oligopolistically-behaving primary producers (including a dominant group of vertically integrated firms plus a much smaller group of non-integrated mining firms or independents), surrounded by a "workably" competitive fringe (i.e., the "outside" market) consisting of a subset of secondary or custom smelters/refiners selling on the "outside" market, the producers/sellers of non-refined scrap, and the merchants.[1] The model is designed to take into account explicitly not only the discretionary pricing behavior of the primary producers but also the interaction between the primary producers and the two "workably" competitive[2] sectors within an interdependent or simultaneous equation framework.

The analysis of the two competitive sectors is theoretically and econometrically straightforward. Deterministic price and output solutions for a competitive industry or competitive sector of an industry occur at the intersection of supply and demand curves, where supply curves represent the horizontal summation of the marginal cost curves of the member firms. Economic rents may accrue in light of differential cost conditions across members. However, no member of a competitive sector can affect price; they are all price-takers. Short-run production decisions on the part of a given firm are made by comparing the market price with production costs.

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[1] The activities of the merchants may include the following: importing, buying concentrate, blister or scrap copper for toll smelting/refining for sale on the "outside" market.

[2] For some discussion of this concept, see J.M. Clark, "Toward a Concept of Workable Competition," The American Economic Review, June 30, 1940, pp. 241-256; J.M. Clark, Competition as a Dynamic Process (Washington D.C.: The Brookings Institution, 1961); C.E. Ferguson, A Microeconomic Theory of Workable Competition (Durham: Duke University Press, 1964); or F.M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally, 1971), pp. 33-38.

In oligopolistic[1] markets, by contrast, microeconomic theory no longer supports the concept or use of a supply function. Deterministic market solutions, based upon the supply and demand functions alone, are no longer possible. The reason is, of course, that members of an oligopolistic industry are no longer price-takers. They are price-setters. An individual member firm or group of firms in an oligopolistic industry have pricing discretion. Costs, particularly short-run variable costs, provide a reasonably solid lower bound to pricing behavior,[2] however, many factors can contribute to pricing behavior and pricing strategies well above costs.[3]

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[1]We should make it clear, for the general reader, that the term "oligopoly" or "oligopolistic" covers a wide spectrum of markets, technically speaking, between the polar conditions of perfectly competitive markets in one extreme and monopolistic behavior in the other.

"Oligopoly" as a technical economic term is used to describe an industry or market structure characterized by a great deal of interdependence, actual or perceived, among the firms in that industry in their capacity as sellers. By this is meant that the number of firms is small enough so that the selling price and output decisions or actions of any one firm will depend on and will affect the policies of its rivals. The oligopolist is like a person who is playing chess: before taking any action, he must consider the possible reactions on the part of his opponent and how to counter them.

In our purely technical usage of the terms "oligopoly" or "oligopolistic," we refrain from even remotely rendering any value judgement on the behavior of the firms involved. We are not unaware of the fact that these terms, common as they are among economists as purely technical constructs, have seemingly gained among businessmen a certain pejorative connotation. None is intended by our use of these terms. Some comfort may be found in the fact that oligopoly is probably the main market structure of the business world, a fact noted to the surprise of many in 1939 by Hall and Hitch as part of the studies of "The Oxford Economists Research Group." See R. L. Hall and C. J. Hitch, "Price Theory and Business Behavior," Oxford Economic Papers (1939); reprinted in T. Wilson and P. W. S. Andrews (eds.), Studies in the Price Mechanism (Oxford University Press, 1951).

[2]In a dynamic model, even this lower bound could be broken.

[3]Witness the details of R. F. Lanzillotti, "Pricing Objectives in Large Companies" American Economic Review, December 1958, pp. 921-940. Also, see any modern microeconomics textbook, preferably one which deals with oligopolistic behavior in more than a few pages. For an excellent reference, see A. Koutsoyiannis, Modern Microeconomics (New York: John Wiley and Sons, 1975).

Given that inevitably a range of possible price and output outcomes can be expected in oligopolistic markets purely on theoretical grounds, we have chosen to "bound" the "solution space" or possible (and most plausible) outcomes analytically in our own modeling work. These limits, defining the range of possible and plausible outcomes, would enable us to examine or measure the industry impacts at what we might call extreme points; this would, then, by definition map out for us the range of "in-between" outcomes or impact results. This is what we mean by parametric approach: we effectively define the parameters (outer boundaries) of possible outcomes and assess the sensitivity of the impact results to variations in behavioral parameters.

Both microeconomic theory and a substantial body of empirical literature on price formation behavior in industries characterized by oligopolistic features strongly suggest the following three points, corresponding to three different possible pricing strategies of the primary producers, to define the parametric solution bounds:

- Average variable cost pricing (AVC = AR, where AVC is the average variable cost schedule and AR is the net demand schedule facing the primary producers);
- Full cost pricing (ATC = AR, where AR is as defined and ATC is the average total cost schedule facing the primary producers); and,
- Implicit monopolistic pricing (obtained via the intersection of the marginal cost, MC, and marginal revenue, MR, schedules).

The first and third solution points provide the most plausible theoretical boundaries of the expected market solutions with respect to prices and output,[1] conditioned to great extent by the prevailing macroeconomic factors shaping demand. We lay no claim to any argument that

[1] Another possible solution point is given at MC = AR, since under "normal" market conditions there would be little micro-theoretic reason for producing to the right of the intersection of the MC and AR schedules (i.e., in this region, marginal cost would exceed price). However, it would seem that, such a solution point, while reasonable from a theoretical standpoint, does not appear to have a basis in reality, as we understand the industry, and would provide only a marginal improvement over the range of solutions that can be expected.

solutions (price, output) would never fall outside this range. In fact, the model's simulation results over the 1964-1976 period indicates some years (two or three) when solutions do fall outside such a range, fully consistent with reality. We are only happy to report that the model has picked this up very well, indeed.

In summary, the pricing strategies or modes of pricing behavior utilized in the model for analyzing the primary producers identify, first, the "most likely" or "normal" pricing behavior of the primary producers in a given year and, second, define reasonably solid bounds around that "most likely" or "normal" pricing behavior.

"Full cost pricing" (or "average cost pricing") characterizes the "normal" behavior of the primary producers in a normal year.[1] By this formulation, price is set equal to average total cost, ATC, where average total cost includes average operating costs (i.e., average variable costs) plus average fixed costs (which include a target or desired rate of return on investment). The desired or target rate of return on investment can be thought of as that return required to maintain and expand the capital stock of the primary producers.[2] In a public utility sense, that target rate of return is the "fair rate of return" required to attract sufficient new capital.[3]

While "full cost pricing" appears to realistically characterize the pricing strategy of an oligopolistic firm or group of firms in "normal" years, with "normal" demand and supply conditions, there are going to be short-run conditions that deviate such a pricing strategy from its target. For the primary producers, unforeseen developments including strikes,

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[1]For a discussion and bibliography on "full cost pricing," see F. M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally, 1971) pp. 173-179, 223-224, 290, 305-306; and Edwin Mansfield, Microeconomic Theory and Applications (New York: W. W. Norton and Co., Inc., 1975).

[2]For greater elucidation of the use of a target or desired rate of return see Lanzillotti, op. cit.,; A. D. H. Kaplan, J. B. Dirlam and R. F. Lanzillotti, Pricing in Big Business (Washington, D. C.: The Brookings Institution, 1958), Scherer, op. cit., Chapters 6-9.

[3]See Scherer, op. cit., Chapter 22; and Alfred Kahn, The Economics of Regulation, Vols. 1 and 2 (New York: John Wiley and Sons, 1970).

collapse of world demand, nationalization of ore deposits, and/or overheating of world demand during the Vietnamese War years, can impinge themselves upon pricing and production decisions and prevent the primary producers from realizing the expected "full cost pricing" strategy. To take account of the effects of such developments, we have attempted to provide a bound around the short-run "full-cost pricing" solution with the "average variable cost" pricing solution (demand-slack solution) and the "monopolistic" pricing solution (depicting the extreme case of perfect collusion among the primary producers).

The lower bound on price in a given year has been identified as the equality of price and average variable costs (AVC). At this point, the unit price is covering average operating costs alone without any fixed cost coverage. While this lower bound reflects a possibility in the short-run, a firm or group of firms cannot price at this lower bound for very long without going bankrupt.

The short-run upper bound upon price identified for our analysis is the "monopolistic" point determined by the intersection of primary sector's marginal cost and marginal revenue curves. Of course, this is a theoretical upper bound only in the hypothetical sense that perfect collusion exists, that profit sharing agreements were operative and worked perfectly and that the marginal cost curve fully articulates this collusive behavior.[1]

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[1] As a matter of fact, the simulation results of the model indicate that the "monopolistic" price solutions are considerably above the "full cost pricing" solution in most years. This provides little evidence, if any, of industry behavior that comes anywhere close to short-run monopolistic pricing behavior. Both because of legal reasons and because of the real limit-pricing concern about long-run substitution in demand to aluminum, it was not, at any rate, expected that the primary producers would gravitate consistently to a short-run collusive monopolistic price solution. However, this upper bound has been included for theoretical reasons, if not for its practical significance.

These three modes of price-setting behavior for the primary producers are identified as parametric solutions 1, 2 and 3:

(1) Average variable cost pricing (P = AVC);

(2) Full cost pricing (P = ATC);

(3) Collusive monopolistic pricing (MR = MC).

Clearly, the parametric solutions 1 and 3 bound the parametric solution 2 ("normal year, full cost pricing with a target rate of return" solution). Bounds exist for both price (P_1 - P_3) and quantity (Q_3 - Q_1) solutions. The width of the bounds in a given year are determined by many factors: the elasticity of demand, the elasticity of supply in the two competitive sectors, the level of total copper demand, the assumptions regarding the oligopolistic structure of the primary producers as reflected in the shape and level of their cost curves.

E. DATA SOURCES AND PROBLEMS

Numerous data sources have been used in our modeling effort, including published data from the Copper Development Association (CDA), American Bureau of Metal Statistics (ABMS), U.S. Bureau of Mines, Engineering and Mining Journal, results of a questionnaire survey of the industry, and the annual company reports, among others, (e.g., such as internal ADL data sources). The CDA time-series data on quantities (e.g., total copper consumption, output of primary refined copper, etc.) were used, with certain modifications, mostly because this procedure provided some semblance of accounting consistency.

The basic point to be made regarding data problems in the copper industry is that it would take no less than a herculean effort to develop a comprehensive set of internally consistent data accurately depicting this industry's activities. Existing data sources, are, to say the least, incomplete and inconsistent. We hence had to devote a good deal of effort to make sure the data used were largely internally consistent and of reliable accuracy. This could not, however, be guaranteed across-the-board.

For example, we pretty much had to accept the available data on inventory changes. Estimates of productive capacity at the mining/milling and smelting/refining levels required far greater effort than originally thought.

Finally, while there is obviously room for improvement as far as the data base is concerned, we have made every effort to use the available data only after careful checking and verification.

F. ECONOMETRIC ESTIMATION TECHNIQUES USED

Both the linear and nonlinear versions of the model are linear in the parameters. Hence, linear estimation techniques were used. The data for the estimation usually covered the period 1947-1974.

The equations in the model contain endogenous variables and a lagged dependent variable on the right hand side. The technique used in the model recognizes both these problems. The technique is that suggested by Fair and is essentially a combination of 2SLS and a correction for autocorrelation.[1] In general, the autocorrelation correction used was the iterative Cochrane-Orcutt technique.[2] There is the danger, however, that this technique may lead to a local rather than global minimum of the sum of squared residuals.[3]

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[1] R. C. Fair, "The Estimation of Simultaneous Equation Models with Lagged Endogenous Variables and First Order Serially Correlated Errors," Econometrica, Vol. 38, May 1970, pp. 507-516.

[2] D. Cochrane and G. H. Orcutt, "Application of Least Square Regressions to Relationships Containing Autocorrelated Error Terms," Journal of the American Statistical Association, Vol. 44, 1949, pp. 32-61.

[3] R. S. Pindyck and D. L. Rubinfeld, Econometric Models and Economic Forecasts, (New York: McGraw-Hill, 1976), pp. 111-112.

When this likelihood arose, the Hildreth-Lu scanning technique was used.[1] The Hildreth-Lu technique, given the use of a fairly refined grid, will give a global minimum.[2] Full information (3SLS) techniques or mixed 2SLS/3SLS techniques were not utilized, because the increased computational and analytical effort was judged unnecessary.

At several junctures in the course of our econometric analysis, the natural desire to fully analyze, formulate and test sharp behavioral hypotheses could not be completely fulfilled. The greatest analytical effort and consequently most thorough hypothesis testing has focused on demand for refined copper by fabricators and semi-fabricators, inventory behavior, the supply curves for the secondary producers, and the cost functions for the primary producers. On the whole, the principal focus of the econometric analysis has been to develop sound behavioral specifications into a well-functioning simulation model. As a result, the econometric analysis was conducted until the behavioral specifications worked well in the model.

G. MATHEMATICAL SOLUTION OF THE MODEL[3]

In spite of their functional, as well as pragmatic desirability, the use of simultaneous nonlinear equations presented solution difficulties that were not easily overcome. We finally used a modified Newton-Raphson technique that is insensitive to the initial guess for the root. It so happens that solution convergence using a Newton-Raphson technique is highly dependent upon the initial guess for the root. It was discovered fairly

[1] G. Hildreth and J. Y. Lu, "Demand Relations with Autocorrelated Disturbances," Michigan State University, Agricultural Experiment Station, Technical Bulletin 276, November, 1960.

[2] R. S. Pindyck and D. L. Rubinfeld, op. cit., pp. 112.

[3] For a more detailed discussion, refer to Supporting Paper 6: "Mathematical Solution of the Model," given later in this volume.

early that the use of the previous year's nonlinear parametric solutions and/or the use of the previous year's linear model solutions did not provide an "initial guess" good enough for consistent convergence. In order to annually simulate an unfolding reality over a ten-to-twenty year period, it was hence necessary to develop a Newton-Raphson technique that is essentially independent of the initial guess for the root. In spite of this solution technique, the set of nonlinear equations were found to become ill-conditioned given some extreme values of the exogenous variables. For these reasons, the linear form of the model has been retained in order to back up the nonlinear model if "convergence" or "ill-conditioning" problems arise.

H. BASIC DIFFERENCES BETWEEN THIS AND OTHER ECONOMETRIC MODELS OF THE COPPER INDUSTRY

Before designing, econometrically estimating and making operational the present model, we have reviewed carefully not only past econometric studies of the copper industry but also the basic facts concerning the industry's organization, structure and operation. A critical review of the major recent econometric studies of the copper industry is presented later in this volume in our Supporting Paper 1: "Econometric Analyses of the Copper Industry: General Theoretical Considerations and Critical Review of Selected, Empirical Studies." Among these past econometric attempts, the work of Charles River Associates, Inc. (CRA) has been of a continuing nature, resulting in an operational model which, as far as we are aware, is still very much in use. Although, in our own work, we have benefited substantially from these past efforts on which we have reported (and a few on which we have not reported to avoid excessive repetition),[1] we would like to use the CRA model as a point of comparison,

[1] For example, the following: Tumay Ertek, "World Demand for Copper, 1948-1963: An Econometric Study," Unpublished Ph.D. Thesis, The University of Wisconsin, 1967; and some econometric work reported in Ferdinand E. Banks, The World Copper Market: An Economic Analysis (Cambridge, Mass.: Ballinger Publishing Company, 1974).

mostly as a way of conveying our intellectual debt.

First, we have made an effort to develop a dynamic model of the industry, by explicitly embedding into the model the industry's investment behavior. This was particularly important in this case in order to cope in an analytically satisfactory way with the implications of pollution abatement investment. As indicated earlier, smelting/refining capacity expansion was made endogenous in the present model; for reasons already cited, mining/milling capacity expansion was treated exogenously, along with pollution abatement investment. The incorporation of investment behavior in the model enables us to trace through the effects of increases in investment year-by-year on the cost functions of the primary producers.[1]

Second, going beyond the essentially static linear case, we have attempted to develop a nonlinear model of the U.S. copper industry, which we feel introduces a far greater element of realism into our modeling effort.

Third, the supply curve utilized by CRA (as well as others) for the primary producers is not supported by microeconomic theory under conditions where (as here) the behavior of the firms in the industry is not characterized by perfect competition. We have hence explicitly attempted to deal with the problem of a non-existent industry supply function by taking two direct approaches. We have first focused attention on the cost schedules of the primary producers, by estimating engineering cost functions and by building a link between capacity expansion and shifts in these cost functions. We have secondly introduced the "parametric approach" to bound the model's solutions in any given year, as explained above.

Fourth, the model presented here is a fully simultaneous system. The CRA approach was essentially block-recursive,[2] with the attendant

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[1] How this process is computationally accomplished is detailed in Supporting Paper 4: "Analysis of Capital Charge Coefficients and Fixed Costs for the Primary Producers."

[2] On this point, it must be pointed out that the CRA September, 1970 report is not as explicit as the earlier March, 1970 report.

problems of simultaneity. The price of primary copper is determined by exogenous variables and primary copper production is determined by that price and the exogenous variables. The second equation block determines Q_T (total consumption of copper), P_s (price of scrap), Q_{OS} (recovery of copper from old scrap), Q_{NS} (generation of new scrap), NE_R (net exports of refined copper), and changes in I_F (fabricators' end of year inventories of refined copper), and $\overline{P}$ (weighted average price of copper) simultaneously.

Fifth, the CRA treatment of all secondary copper as old and new scrap ignores the distinction between secondary refined copper and non-refined scrap, which we have tried to retain in our analysis.

Sixth, the categorization of ASARCO as a secondary refiner by CRA displays a basic confusion not only between custom-refining and toll-refining but also concerning ASARCO's role in the domestic copper industry. Quite apart from its role as a producer of secondary refined copper, ASARCO's activities have in the past included the smelting and refining of its own mine output, as well as custom and toll smelting/refining. As far as we have been able to ascertain, ASARCO's behavior over the entire historical period has not warranted its classification as a secondary refiner (and, hence, its inclusion as part of the "outside" market).

There may remain other differences in approach between the model presented here and the CRA model (as well as other previous modeling attempts); these can be gleaned by reading Supporting Paper 1: "Econometric Analyses of the Copper Industry: General Theoretical Considerations and Critical Review of Selected Empirical Studies."

CHAPTER 10

ECONOMIC IMPACT ANALYSIS

A. INTRODUCTION

This chapter presents an assessment of the economic impact of the presently promulgated air and water pollution abatement and control regulations on the U.S. copper industry over the period 1976-1985.

The objective of economic impact analysis is to identify and assess what effects, if any, environmental regulations would have on such key economic variables as prices, output, consumption, investment, employment and international trade, among others. At the industry level, the impact analysis might further focus, as appropriate, on the financial performance of the industry, by considering the cost of capital and capital availability, as well as the cash-flow position, external financing requirements and profitability of the firms in the industry. It is also important to analyze the impact of compliance on the industry's structure, by considering effects on the degree of competitiveness or concentration. Effects on the supplier as well as the consumer industries may also require examination. In addition, effects on the international competitive position of the domestic industry or industries deserve emphasis. Finally, it is necessary to identify possible plant closures and assess regional or community impacts.

One main causal route through which environmental regulations may lead to such economic impacts is the additional cost borne by the industry to meet environmental regulations. The costs of compliance with environmental regulations, defined narrowly to include both capital expenditures (fixed costs) and operating and maintenance expenses (variable costs), cause an upward shift in the industry's pertinent cost schedules, thus ultimately affecting prices, production, and the whole range of economic variables indicated earlier. How precisely compliance costs affect production costs (or supply) becomes, therefore, analytically important for economic impact analysis.[1] Compliance costs, serving generally as the central causal instrument, hence represent an input into economic impact analysis; compliance costs and economic impacts are, in this sense, not synonymous.

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[1]For a review of how the cost schedules are affected by compliance costs, refer to Technical Appendix to this report, Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry, Supporting Paper 5: "Effects of Pollution Abatement and Control Costs on Industry-Wide Cost Functions."

As indicated here, in the short-term (e.g., a year), the case of pollution abatement cost impact is perfectly analogous to the case of a specific tax levied on the output of the firms in the industry (e.g., x cents per pound of refined copper) only in the restricted instance of an upward shift in the industry's total variable cost function. Consequently, the average variable cost (AVC), average total cost (ATC), and marginal cost schedules (curves, functions) shift upward by a constant.

However, in the case of pollution abatement and control capital investment only, average fixed cost (AFC) and ATC schedules shift upward (which increases in severity at lower levels of capacity), while the AVC and MC schedules are not affected.

If compliance costs involve both capital expenditures and variable costs, then assuming linear total cost, total fixed cost, and total variable cost functions, the AVC, MC, AFC and ATC schedules all shift upward; while AVC and MC shift upward by a constant, the shift in AFC and ATC becomes increasingly severe at lower levels of production. Given a typical downward-sloped industry demand schedule, these results have different implications for industry price-output determination behavior and therefore impact results, depending on market structure.

Over time, while the demand schedule would be expected to shift secularly to the right, the relevant cost functions would be shifting not only to the right (with capacity expansion) but also upward, both secularly (in the case of an increasing cost industry) and because of compliance costs (in each year as well as in prior years).

Another route through which environmental regulations may lead to such economic impacts is by adversely affecting, directly or indirectly, expansion in the industry's productive capacity. The promulgated environmental regulations may directly affect capacity growth by specifying in technical detail the conditions under which the industry may or may not expand existing capacity or build new capacity. The effects on capacity growth may also take a slightly indirect form, with potentially equal consequences: compliance costs may cause the actual shutdown of plants or may slow down capacity growth. Alternatively, the uncertainty caused by both the evolving (i.e., "moving target") nature of environmental regulations plus costs of compliance may together impede capacity growth by influencing the timing of investment as well as perceptions concerning the riskiness of investment.

In examining the economic impact of environmental regulations on an industry, it is necessary to assess not only (or simply) the economic impacts of costs of compliance as such but also the economic impacts of constraints on capacity growth caused directly or indirectly by environmental regulations. This could prove quite difficult analytically, however, and is often not addressed in most industry impact studies.[1] In certain situations (such as in the case of the domestic copper industry, as detailed in Chapter 8 and further noted below), the economic impacts of capacity-constraining or capacity-reducing influences of environmental regulations may far outshadow the economic impacts of compliance costs as such.

Generally, it is necessary to develop a model of the real world (i.e., the industry under consideration) which can be used for impact analysis.

[1] The analytical difficulty lies chiefly in quantifying the negative effects of compliance costs on future investment behavior and therefore capacity growth.

This is primarily because model building forces us to think clearly about and account for all the important interrelationships involved in a problem. With or without models, the basic analytical issue at hand is to assess to what extent compliance with environmental regulations will influence the course of a set of pertinent economic variables (at the national, industry and regional levels), over a period of time in the future.

Economic impacts are typically measured as differences from a set of baseline forecasts. Baseline forecasts trace out the values that all pertinent variables would take, over a period of time, in the absence of environmental regulations.[1] With the regulations, both because of increased costs of production due to compliance costs and the adverse effects, if any, of environmental regulations on capacity growth, the same variables would take new values, over the same time period. The differences are attributed to the environmental regulations.

With these introductory considerations in mind, it should be noted that we have assessed the economic impacts of the presently promulgated air and water regulations on the U.S. copper industry by developing and using a computerized model which can be described in more technical terms as a dynamic nonlinear simultaneous-equation econometric model of the U.S. copper industry. An overview of this model is presented in Chapter 9. A technical description of the model is given in a separate volume prepared as a technical

[1]At least in substantial absence of environmental regulations.

appendix to this report.[1]

Very briefly, the model considers, within an interdependent framework, such variables as demand (paying attention to substitution from aluminum), costs of production facing the primary producers, the relationship between the primary and secondary producers, supply functions of secondary producers (refined and scrap), prices, inventories, investment and international trade. It also allows analyses of the industry's financial performance annually.[2] Costs of production are directly factored into the model through engineering cost functions so that technological developments affecting mining, milling, smelting and refining operations can be readily assessed.

The model is currently programmed to simulate the growth and evolution of the industry year-by-year through 1985. The model is used to develop annual forecasts over the period 1976-1985, which defines the impact analysis

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[1]Refer to Technical Appendix to this report, Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry. The model is econometrically estimated (including demand functions, investment/capacity expansion behavior, supply functions for the competitive secondary copper sectors, inventory equations, etc.) by using a combination of 2SLS with a correction for autocorrelation (iterative Cochrane-Orcutt technique, augmented by the use of the Hildreth-Lu scanning technique when the former led to a local, rather than global, minimum of the sum of squared residuals).

The model is mathematically solved by developing and using a modified version of the Newton-Raphson technique where the solution is made essentially independent of the initial guess for the root.

[2]The financial analysis module is block-recursive with respect to the econometric model. Overall cash-flow and flow-of-funds (sources vs. uses) analyses are performed, by analyzing financial data computed directly from the model's results, as well as on the basis of detailed historical industry-wide and specific company-by-company financial data. Various types of standard financial checks are exercised, by examining debt-to-equity ratios, amount of external borrowing required, profits on sales, rate of return on assets, and so forth.

period, under baseline conditions as well as under alternative environmental scenarios (described below). Under baseline conditions, the model internally (endogenously) forecasts the industry's capital expenditures for both replacement and expansion and therefore the industry's capacity growth.[1] Under environmental scenarios, the industry's capacity growth is no longer internally forecasted by the model since, as detailed in Chapter 8 and summarized below, the presently promulgated environmental regulations effectively constrain capacity expansion. That is, capacity expansion routes available in the past can no longer be used. Hence, it was necessary to conduct a smelter-by-smelter analysis outside the model, build the results into the model and subsequently use the model to determine the economic impacts of both compliance costs and constraints on capacity growth simultaneously. What the model does for impact analysis purposes, therefore, is simply to spell out in quantitative terms, in an internally consistent and comprehensive manner, the implications of both compliance costs and constraints on capacity growth.

In the rest of this chapter, our aim is to present and interpret main economic impacts of alternative environmental scenarios. To this end, we start with a definition of the baseline conditions and forecasts which provide a point of reference for impact analysis. Following this, we define two

[1] The starting year for both baseline and impact analysis forecasts using the model is chosen as 1976, for both practical and theoretical reasons. Practically speaking, the analysis is focused on the future and not on the past, so that the future implications of the presently promulgated environmental regulations can be clearly spelled out.

Theoretically speaking, how the course of the U.S. copper industry might have been different in years prior to 1976 (most importantly, over the period 1970-1975, when the industry was required to allocate resources towards compliance with environmental regulations) poses a nearly intractable analytical problem. At any rate, any past impacts of environmental regulations, as will be seen, in no way diminish the dimensions of economic impacts expected in the future.

basic environmental scenarios (i.e., "constrained capacity" and "reduced capacity") for economic impact analysis. These two environmental scenarios effectively represent two different pictures as to the industry's ability to expand domestic smelter capacity, over the 1976-1985 period, under the presently promulgated environmental regulations. A discussion of the economic impact results under these two basic environmental scenarios, using the model, is presented next. We also examine, in this connection, the sensitivity of key impact results to a hypothetical relaxation of EPA's present regulations (which is labelled the "roll-back" scenario), not only for pedagogical reasons but also to investigate the highly practical question of what the consequences might be of a significant relaxation in EPA's present regulations.

The quantifiable impact results derived from the model have broader implications or raise certain issues that we have attempted to identify next. These unquantified (unquantifiable) issues/implications, some of which would be of obvious policy concern, are identified by reference to three major areas: (a) the present regulatory environment, (b) issues pertaining to the growth of the domestic copper indsutry, and (c) international economic implications.

Appendices A, B and C contain model printouts giving baseline forecasts and the results of the two environmental scenarios tested (i.e., "constrained capacity" and "reduced capacity"). Appendix D provides a list of all model variables.

B. BASELINE CONDITIONS AND FORECASTS

Baseline conditions, or forecasts, provide a point of reference from which comparisons can be made in order to gauge the relative and absolute magnitude of economic impacts. Such a reference point helps define the evolution, growth and performance of the U.S. copper industry over the impact analysis period. The baseline assumes the existence of National Ambient Air Quality Standards[1] but the absence of additional restrictions regarding how such standards might be achieved.

The baseline therefore assumes that the industry would have expended capital investment over the 1972-1975 period in order to have capacity expansion come on stream in 1976 and thereafter, even after allowing for the industry's pollution abatement investment during this period, and that the uncertainties associated with environmental regulations affecting investment decisions over this period were largely absent.

The baseline costs for new productive capacity take into account technological changes and associated pollution control. Pollution control costs are hence treated as part of costs of production. Other Federal regulatory programs (e.g., OSHA, etc.) are excluded. However, any future effects on the industry of past pollution control efforts implicitly remain a part of the baseline conditions.

A detailed set of the baseline forecasts of the U.S. copper industry is given in Appendix A to this chapter, together with a list of the forecasted values of the exogenous variables.

[1] This assumes, in other words, voluntary industry compliance with the National Ambient Air Quality Standards through minimal permanent control and extensive use of SCS.

Before testing for the economic impacts of the various environmental policy options, the model was run under numerous baseline scenarios. These have included:

- alternative macroeconomic recovery and growth scenarios ("slow", "moderate", "robust"), including expected economic recovery and growth in Europe;
- alternative sets of forecasts of LME refined copper prices, consistent with the forecasted macroeconomic conditions (both in the United States and Europe) and reflecting expected growth in mined copper output in the rest of the world;
- alternative estimates of increases in costs of production at production levels near full capacity (e.g., in the region beyond roughly 86 percent of installed capacity);
- alternative mining/milling investment levels, estimates of the cost of capital, target rates of return, machinery/equipment retirement rates, capital charge coefficients on existing and new (both productive and pollution control) investment.

Broadly speaking, the results of the model under a fairly wide range of assumptions are found to be internally consistent, directionally correct and, perhaps most importantly, extremely stable.

The baseline forecasts used for impact analysis reported in this chapter are based, in part, on macroeconomic forecasts (e.g., growth in overall industrial production, inflation, interest rate, etc.) over the period 1976-1983, prepared by Chase Econometrics, Inc., under contract with U.S. Environmental Protection Agency (EPA).[1] Macroeconomic forecasts beyond

[1] The May 17, 1976, version of the Chase Econometrics, Inc., forecasts are used.

1983 reflect ADL growth assumptions. Some of the key Chase Econometrics, Inc., forecasts are summarized in Table 1. A complete listing of the baseline macroeconomic growth variables and other independent variables over the 1976-1985 period, as well as the associated baseline model forecasts are presented in Appendix A to this chapter.

The macroeconomic forecasts prepared by Chase Econometrics, Inc., for EPA and used in this study for baseline forecasts in order to provide consistency with other EPA studies generally anticipate moderate economic recovery (in 1976 and 1977) followed by a slowdown or mini-recession (in 1978, 1979), in turn followed by a strong recovery and steady growth (1980-1983).

The impact results reported in this chapter assume cyclical, but robust, recovery and growth, as noted above; the impacts under macroeconomic projections reflecting much less robust economic recovery and growth are similar, although slightly smaller in absolute terms but remain generally the same in relative terms (as percent differences from the baseline).

Selected baseline forecasts over the period 1976-1985 using the Chase Econometrics, Inc., macroeconomic growth scenario (with ADL macroeconomic assumptions beyond 1983 plus ADL assumptions on other independent variables) are presented in Table 2, under the column "Macro II." In order to test for the sensitivity of baseline forecasts to a considerably less robust macroeconomic growth scenario, we have prepared a new or modified set of baseline forecasts by judgmentally modifying the Chase forecasts. The results of this modified macroeconomic scenario are given in Table 2 under the column "Macro I." The basic difference between Macro I and Macro II is that the growth in industrial production over the 1976-1985 period is 2.43 percent per year under Macro I, while it is 4.56 percent per year under Macro II.

The baseline results, consequently, show considerable spread over the 1976-1985 period, as given in Table 2. The major point to which we would like to draw attention here is that the baseline scenario used for impact analysis purposes should be viewed not as precise predictions of the future but as directionally plausible forecasts. Since obviously there exists considerable variability in what the future might hold under baseline conditions (as just indicated), our basic interest for analytical purposes is to focus on percent deviations from baseline forecasts, under alternative environmental scenarios, and not as much on absolute deviations from baseline forecasts. We can report at this point, anticipating the impact analysis discussion given below, that the impact results (defined as percent deviations from baseline forecasts) are fairly invariant under different macroeconomic growth scenarios.

TABLE 1

SUMMARY OF BASELINE MACROECONOMIC FORECASTS PREPARED BY CHASE ECONOMETRICS, INC., 1976-1983

(Percent Change Given in Parentheses)

	1976	1977	1978	1979	1980	1981	1982	1983
GNP (billions, 1972 dollars)	1,263.3 (-)	1,324.1 (4.8)	1,331.4 (0.6)	1,344.1 (1.0)	1,417.9 (5.5)	1,508.8 (6.4)	1,584.6 (5.0)	1,651.8 (4.2)
Index of Industrial Production (1967 = 100.0)	124.2 (-)	136.0 (9.5)	134.7 (-0.9)	131.6 (-2.3)	140.6 (6.9)	155.5 (10.6)	167.3 (7.6)	176.8 (5.7)
Prime Interest Rate	7.5	10.1	10.0	7.1	7.2	7.7	7.8	8.0
GNP Implicit Deflator (1972 = 100.0)	133.2 (-)	141.6 (6.3)	150.4 (6.2)	157.6 (4.8)	165.5 (5.0)	174.2 (5.3)	183.3 (5.2)	192.9 (5.2)
Wholesale Price Index--Industrial Commodities (1967 = 100.0)	183.1 (-)	199.4 (8.9)	217.7 (9.2)	230.5 (5.9)	247.9 (7.5)	263.4 (6.3)	278.7 (5.8)	295.1 (5.9)

Source: Chase Econometrics, Inc. (May 17, 1976).

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TABLE 2

SELECTED BASELINE FORECASTS UNDER TWO ALTERNATIVE MACROECONOMIC GROWTH SCENARIOS, 1976-1985

Variable Description	1976 Macro I	1976 Macro II	1985 Macro I	1985 Macro II
Primary refined copper prices (cents per pound)	67.4	66.3	81.4	105.3
Primary refined copper production[a]	1,973.7	2,066.2	2,741.3	3,110.9
Net imports[b]	52.6	134.7	247.0	377.0
Total consumption[c]	3,424.4	3,587.5	4,685.7	5,350.0
Employment[d]	49,152	51,314	68,342	77,028
Domestic primary smelting/refining capacity[e]	2,605	2,605	3,148	3,449
Capacity utilization	.758	.793	.871	.902

NOTES: [a]Domestic production of refined copper by primary producers, from all sources (domestically mined copper, imported ore/concentrate/blister/scrap, domestically generated unalloyed scrap); although it contains some secondary refined copper, it is exclusive of secondary refined output produced by secondary refiners.

[b]Net of exports.

[c]Includes primary and secondary refined copper, directly consumed scrap and imports.

[d]Total full-time equivalent employment (number of persons) including mining and milling, smelting and refining employment at all domestic primary producer facilities; employment by secondary smelters/refiners are excluded.

[e]In thousands of annual short tons of refined copper.

SOURCE: Arthur D. Little, Inc., (ADL), based on the Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry.

C. DEFINITION OF INDUSTRY GROWTH SCENARIOS FOR ECONOMIC IMPACT ANALYSIS

The copper industry has traditionally increased smelting capacity via small expansions at existing smelter locations. The construction of smelters in new locations ("grass roots" smelters) or similar major expansions, have been rather the exception and not the rule in the past. The lead time required for planning, engineering, construction, shake-down and start-up for small expansions at existing sites is about three years while that for new grass roots smelters is about seven years.

Chapter 8 presented a detailed discussion of the impact of the Clean Air Act requirements (as interpreted by the EPA) on modes of capacity growth in this industry. The major findings are that existing regulations do not allow small expansions of the type used traditionally by the industry. While there are some uncertainties, the regulations do allow the construction of NSPS calibre smelters in new or existing smelter locations. At the present time, we are not aware of any major smelter construction projects that are under active consideration. Thus, given the time lags in the system, new capacity will not come on-stream until 1984.

The detailed findings from Chapter 8 are summarized below:

1. Small smelter expansions (which could occur prior to 1983) are not possible because emissions from a plant cannot increase above the limit defined by applying "Reasonably Available Control Technology" (RACT). Even if such a RACT limit did not exist the "Modification and Reconstruction Provisions" of the New Source Performance standards would prevent any significant modification of existing reverbs necessary to increase smelting capacity.

2. Existing RACT smelters could expand significantly after 1983 by installing new smelting technology but by operating under the RACT limit. There is some concern that such expansion might be disallowed under New Source Review. The probability of such disallowance is very low and we assume that this type of expansion will occur after 1983.

3. Existing BACT smelters have a low expansion potential since they cannot use SCS and they are already close to the constant emission control limitations.

4. "Grass roots" smelters for clean concentrates have to use Best Available Control Technology (BACT), such as autogeneous or electric smelting and therefore cannot use SCS. These smelters would meet NAAQS by using tall stacks for dispersing collected emissions. We assume that this type of expansion will occur after 1983. While reverb-based smelters are allowed for smelting impure concentrates, such smelters cannot be built in most locations since SCS is not allowed. This is because SCS is usually necessary to reverb-based smelters for meeting NAAQS. However, there is no demand for smelting capacity of this type.

5. All smelters (reverb-based smelters as well as new smelters based on the Best Available Control Technology) might exceed NAAQS in the vicinity of the smelter as a result of low level fugitive emissions. It is not clear whether SCS can be a useful strategy for dealing with the fugitive problem. This problem could be dealt with by acquiring land in several kilometer radius around a smelter. Such a strategy is probably impossible for existing smelters but could be feasible for new "grass roots" smelters in remote locations. We assume that this potential problem will be resolved

without major cost consequences to the industry.

In accordance with our interpretation of how recent EPA regulations affect domestic smelting capacity growth, highlighted above, we have defined two basic policy scenarios for purposes of economic impact analysis (1) "constrained capacity" and (2) "reduced capacity."

1. Constrained Capacity

This is currently the most likely scenario, reflecting restrictions on smelting capacity expansion in the short run. Accordingly, this scenario assumes no capacity expansion until 1984 for reasons discussed above. We assume 200,000 annual short tons of new smelting (and refining) capacity will come on-stream in 1984 and another 200,000 annual short tons in 1985. We also assume that none of the existing smelters will shut down.

2. Reduced Capacity

This scenario, which is the more severe, assumes that the uncertainties in the regulations or economic conditions will delay any new smelting capacity until after 1985. We also assume that two smelters (e.g., McGill and Douglas)[1] will close in 1977 and 1979, respectively.

[1]McGill: 78,000 annual short tons of refined copper equivalent; assumed to close down in 1977; domestic smelting/refining capacity is hence assumed to drop by 78,000 annual short tons at the beginning of 1978.

Douglas: 90,000 annual short tons of refined copper equivalent; assumed to close down in 1979; domestic smelting/refining capacity is hence assumed to drop by 90,000 annual short tons at the beginning of 1980.

Expected pollution abatement and control capital expenditures, as well as operating and maintenance costs over the period 1976-1985, under the two policy scenarios just described, are given in Table 3. Pollution control capital investment is $746.0 million under the Constrained Capacity Scenario and $586.0 million under the Reduced Capacity Scenario (in constant 1974 dollars) over the period 1976-1985 (compared with $868.7 million over the period 1970-1975, in constant 1974 dollars). Operating and maintenance costs are increased about 2.5 cents per pound of refined copper over baseline, requiring total expenditures of $1,172.2 million over the period 1976-1985 under Constrained Capacity and $1,097.1 million under Reduced Capacity.

Capital expenditures for pollution abatement and control undertaken in a given year do not necessarily measure actual costs incurred in that or subsequent years. This is because the useful life of a machine or equipment extends many years and the real costs associated with the acquisition of a machinery or equipment are spread over its entire useful life, encompassing depreciation, interest payments and the like. These are fixed costs, faced annually, over many years. It is therefore necessary to translate initial pollution abatement and control investment levels into fixed costs spread over many years, using fixed charge coefficients. This is accomplished in Table 4.

It can be seen in Table 4 that fixed costs faced in 1985, for example, include fixed costs due to pollution control equipment installed in all years since 1970.

Table 5 summarizes the expected annualized fixed costs and variable (operating and maintenance) costs over the period 1976-1985 (in constant

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TABLE 3

EXPECTED POLLUTION ABATEMENT AND CONTROL EXPENDITURES BY THE U.S. COPPER INDUSTRY,[a] 1976-1985

(in millions of 1974 dollars)

Years	Capital Expenditures[b]		Operating and Maintenance Costs[c]		Total	
	Constrained Capacity	Reduced Capacity	Constrained Capacity	Reduced Capacity	Constrained Capacity	Reduced Capacity
1976	156.0	156.0	99.5	99.5	255.5	255.5
1977	90.0	90.0	112.4	112.9	202.4	202.9
1978	60.0	60.0	115.8	111.8	175.8	171.8
1979	40.0	40.0	116.2	112.2	156.2	152.2
1980	40.0	40.0	115.1	108.4	155.1	148.4
1981	60.0	40.0	115.9	109.1	175.9	149.1
1982	100.0	40.0	117.2	110.3	217.2	150.3
1983	100.0	40.0	117.8	110.9	217.8	150.9
1984	60.0	40.0	126.5	110.9	186.5	150.9
1985	40.0	40.0	135.8	111.1	175.8	151.1
1976-1985	746.0	586.0	1,172.2	1,097.1	1,918.2	1,683.1

NOTES: [a]Not including secondary smelters/refiners.

[b]Figures given here refer to expenditures (dollar outflows), not to increased fixed costs. In the model, these investment figures are translated into annualized fixed costs through the use of capital charge coefficients (refer to Arthur D. Little, Inc. [ADL], Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry. Technical Appendix to this report.

[c]Increases in variable costs due to pollution abatement and control, estimated at about 2.5 cents per pound of refined copper. These figures are obtained by multiplying 2.5 cents per pound by model solutions for primary refined copper output.

[d]These estimates reflect pollution control capital expenditures at existing facilities plus pollution control invesment associated with capacity expansion coming on-stream in 1984 and 1985. The latter would add about $80 million associated with capacity growth expected to come on-stream in 1984 (200,000 annual short tons) and roughly another $80 million associated with capacity growth expected to come on-stream in 1985 (200,000 annual short tons). These two latter amounts are time-phased as follows:

Year of Spending	Associated with capacity growth coming on-stream in ($ millions) 1984	1985	Total ($ millions)
1981	20		20
1982	40	20	60
1983	20	40	60
1984		20	20

SOURCE: Arthur D. Little, Inc., estimates.

TABLE 4

TRANSLATION OF EXPECTED POLLUTION ABATEMENT AND CONTROL CAPITAL EXPENDITURES BY THE U.S. COPPER INDUSTRY INTO ANNUALIZED FIXED COSTS, 1970-1985
(in millions of 1974 dollars)

"CONSTRAINED CAPACITY" SCENARIO

(Pollution Abatement and Control Capital Expenditures, by Year, and Resulting Annual Fixed Costs in Subsequent Years)[a]

Years When Fixed Costs Are Faced	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Annualized Fixed Costs By Year
	20.9	30.0	146.4	204.6	226.0	240.8	156.0	90.0	60.0	40.0	40.0	60.0	100.0	100.0	60.0	40.0	
1970	3.55																3.55
1971	3.55	5.10															8.65
1972	3.55	5.10	24.89														33.54
1973	3.55	5.10	24.89	34.78													68.32
1974	3.55	5.10	24.89	34.78	38.42												106.74
1975	3.55	5.10	24.89	34.78	38.42	40.94											147.68
1976	3.55	5.10	24.89	34.78	38.42	40.94	26.52										174.20
1977	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30									189.50
1978	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20								199.70
1979	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80							206.50
1980	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80						213.30
1981	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	10.20					223.50
1982	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	10.20	17.00				240.50
1983	0.63	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	10.20	17.00	17 00			254.58
1984	0 63	0.90	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	10.20	17.00	17.00	10.20		264.78
1985	0.63	0.90	4.39	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	10.20	17.00	17.00	10.20	6.80	271.58

NOTES: [a]These estimates, obtained outside the model (where annualization is computed internally), reflect the following major assumptions: (1) useful economic life of 13 years, (2) fixed charge coefficient of 0.17 (i.e., 17 percent), (3) continued fixed cost at 3 percent of original cost beyond the first 13 years, to reflect continued general administrative expenses. It is implicit from these assumptions that the full initial cost is paid off in 13 years.

SOURCE: Arthur D. Little, Inc. estimates.

TABLE 5

ANNUALIZED FIXED AND VARIABLE (OPERATING AND MAINTENANCE) COSTS DUE TO POLLUTION ABATEMENT AND CONTROL, THE U.S. COPPER INDUSTRY, 1976-1985
(in millions of 1974 dollars)

CONSTRAINED CAPACITY SCENARIO

Years	Annualized Fixed Costs[a]	Variable (Operating and Maintenance) Costs	Total Annualized Costs[a]
1976	174.2	99.5	273.7
1977	189.5	112.4	301.9
1978	199.7	115.8	315.5
1979	206.5	116.2	322.7
1980	213.3	115.1	328.4
1981	223.5	115.9	339.4
1982	240.5	117.2	357.7
1983	254.6	117.8	372.4
1984	264.8	126.5	391.3
1985	271.6	135.8	407.4

Notes: [a]It should be noted that annualized fixed costs over the period 1976-1985 include annualized fixed costs due to pollution abatement and control capital expenditures incurred in earlier years.

Source: Based on Tables 3 and 4.

1974 dollars) due to pollution abatement and control under the Constrained Capacity Scenario.

Tables 6 and 7 refer to the Reduced Capacity Scenario and provide information on annualized fixed costs (Table 6), followed by a summary of both annualized fixed costs and variable (operating and maintenance) costs over the period 1976-1985 (Table 7).

TABLE 6

TRANSLATION OF EXPECTED POLLUTION ABATEMENT AND CONTROL CAPITAL EXPENDITURES BY THE U.S. COPPER INDUSTRY INTO ANNUALIZED FIXED COSTS, 1970-1985
(in millions of 1974 dollars)

"REDUCED CAPACITY" SCENARIO

(Pollution Abatement and Control Capital Expenditures, by Year, and Resulting Annual Fixed Costs in Subsequent Years)[a]

Years When Fixed Costs Are Faced	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	Annualized Fixed Costs By Year
	20.9	30.0	146.4	204.6	226.0	240.8	156.0	90.0	60.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	
1970	3.55																3.55
1971	3.55	5.10															8.65
1972	3.55	5.10	24.89														33.54
1973	3.55	5.10	24.89	34.78													68.32
1974	3.55	5.10	24.89	34.78	38.42												106.74
1975	3.55	5.10	24.89	34.78	38.42	40.94											147.68
1976	3.55	5.10	24.89	34.78	38.42	40.94	26.52										174.20
1977	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30									189.50
1978	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20								199.70
1979	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80							206.50
1980	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80						213.30
1981	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80					220.10
1982	3.55	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80				226.90
1983	0.63	5.10	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	6.80			230.78
1984	0.63	0.90	24.89	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	6.80	6.80		233.38
1985	0.63	0.90	4.39	34.78	38.42	40.94	26.52	15.30	10.20	6.80	6.80	6.80	6.80	6.80	6.80	6.80	219.68

NOTES: (See Table 2)

SOURCE: Arthur D. Little, Inc. estimates.

TABLE 7

ANNUALIZED FIXED AND VARIABLE (OPERATING AND MAINTENANCE) COSTS DUE TO POLLUTION ABATEMENT AND CONTROL, THE U.S. COPPER INDUSTRY, 1976-1985
(in millions of 1974 dollars)

REDUCED CAPACITY SCENARIO

Years	Annualized Fixed Costs[a]	Variable (Operating and Maintenance) Costs	Total Annualized Costs[a]
1976	174.2	99.5	273.7
1977	189.5	112.9	302.4
1978	199.7	111.8	311.5
1979	206.5	112.2	318.7
1980	213.3	108.4	321.7
1981	220.1	109.1	329.2
1982	226.9	110.3	337.2
1983	230.8	110.9	341.7
1984	233.4	110.9	344.3
1985	219.7	111.1	330.8

Notes: [a]It should be noted that annualized fixed costs over the period 1976-1985 include annualized fixed costs due to pollution abatement and control capital expenditures incurred in earlier years.

Source: Based on Tables 3 and 6.

D. <u>DISCUSSION OF ECONOMIC IMPACTS UNDER "CONSTRAINED CAPACITY" AND "REDUCED CAPACITY" SCENARIOS</u>

The model has been used to measure economic impacts under the Constrained Capacity and Reduced Capacity scenarios, as defined above. Model results, together with assumptions on exogenous variables, are presented as three appendices to this chapter. Appendix A contains baseline forecasts, while Appendix B and Appendix C contain, respectively, forecasts under the Constrained Capacity and Reduced Capacity scenarios.

The combined effects on both capacity constraints and pollution control expenditures in terms of their economic impacts are summarized below.

1. <u>Summary of Economic Impacts</u>

Table 8 compares the baseline with the Constrained Capacity and the Reduced Capacity Scenario results. The impacts can be summarized as follows:

a. <u>Impact on Prices</u>

Compared to the baseline, real prices in 1983 are 13.5 percent higher under Constrained Capacity and 17.2 percent higher under Reduced Capacity. By 1985, real prices are 24.4 percent higher under Reduced Capacity but 10.3 percent higher under Constrained Capacity.

Clearly, price impacts under both environmental scenarios are severe, but this is more pronounced under the Reduced Capacity Scenario, under which productive capacity is not only constrained but also reduced. The drop in price differential to 10.3 percent from the baseline in 1985 under Constrained Capacity (from the high of 13.5 percent in 1983) is due to capacity expansion coming on-stream in 1984 (about 200,000 annual short tons) and in 1985 (another 200,000 annual short tons). It can be seen, therefore, that the addition of new capacity during this period has a noticeable impact on prices.

b. Impact on Production

The impact of the Constrained Capacity and Reduced Capacity scenarios on domestic primary refined copper production becomes progressively more severe. By 1983, production falls by 17.2 percent under Constrained Capacity and by 22.0 percent under Reduced Capacity from baseline levels. By 1985, the drop in production from the baseline level reaches a staggering 28.6 percent under Reduced Capacity and 12.7 percent under Constrained Capacity, a significant drop even after allowing for capacity expansion (under the Constrained Capacity Scenario) coming on-stream in 1984 and 1985.

c. Impact on International Trade

The overall pattern emerging from the model forecasts under the various scenarios tested is that net imports show a persistent increase over time. Net imports increase 11.3 percent under Constrained Capacity and 18.6 percent under Reduced Capacity in 1981. In 1983 and 1985, however, net imports under Constrained Capacity are only 4.3 percent and 2.9 percent higher, respectively, than the baseline forecasts, while by contrast, they remain 8.4 percent and 10.2 percent higher under Reduced Capacity.

While these international trade impacts, especially under Reduced Capacity, should be considered important enough for policy concern, they nevertheless are less serious than was expected. One explanation is that, with capacity expansion constrained in the United States, world prices would be higher, which in turn would result in a drop in demand for copper from external sources. Since under both Constrained Capacity and Reduced Capacity domestic producer prices overtake LME prices in 1982, a real question is why net imports do not rise much faster over the 1982-1985 period. One answer is the capacity expansion coming on-stream under Constrained Capacity in 1984 and 1985, just when net imports may have shown a significant increase. Another answer, more applicable to Reduced Capacity, could be that the speed of adjustment to lower prices in the rest of the world on the part of the domestic consumers, is perhaps not as fast or automatic as would have been thought. This is consistent with the behavior of the independent fabricators in the past when they continued to purchase copper from the primary producers even where copper at lower prices was available on the "outside market."

d. Impact on Consumption

Consistent with economic theory, consumption falls from baseline levels under both Constrained Capacity and Reduced Capacity due to substantially higher prices. The fall in consumption reaches 4.6 percent in 1983 under Constrained Capacity and 8.1 percent in 1985 under Reduced Capacity.

e. Impact on Employment

The impact of Constrained Capacity and Reduced Capacity on industry-wide employment at all stages of production--mining through refining--is expected to be most serious in terms of curtailing employment growth that would occur under baseline conditions. Basically, Constrained Capacity would prevent about 9,000 jobs (about 5,650 in mining/milling and 3,350 in smelting/refining) and Reduced Capacity nearly 20,300 jobs (about 12,760 in mining/milling and 7,520 in smelting/refining) in 1985, which respectively represent 11.7 percent and 26.3 percent less employment than under baseline conditions (see Table 9 for more detail).[1]

These employment impacts do not reflect layoffs but represent lower potential growth in a few Western states where domestic copper production (mining through refining) is largely concentrated.[2] As noted in Chapter 4, principal copper producing states in 1974 were Arizona (56 percent of total U.S. mine production of recoverable copper), Utah (14 percent), New Mexico (12 percent), Montana (8 percent), Nevada (5 percent), and Michigan (4 percent).

The distribution of copper mining and milling employment by state in 1974 was as follows:

(SIC 1021 -- Copper Ores Mining and Milling)

State	Employment (June 1974)[a]	Percent Breakdown (%)
Arizona	27,372	59.2
Utah	5,899	12.8
New Mexico	2,764	6.0
Montana	4,008	8.7
Nevada	2,094	4.5
Michigan	2,790	6.0
Other[b]	1,279	2.8
TOTAL	46,206	100.0

[a]Number of persons employed (both supervisory and nonsupervisory or production workers) figures refer to June, 1974 -- a peak month in 1974.

[b]Includes the following: Missouri (502), New York (381) and Texas (123).

Source: U.S. Bureau of Labor Statistics, Employment and Wages, Second Quarter 1974, Table C-8 (p.70).

[1]The employment forecasts discussed here reflect labor productivity conditions prevailing in about 1973, which was a peak production ("demand crunch") year. As indicated in Chapter 4, overall labor productivity in the domestic copper industry has at best remained fairly constant in recent years. Employment forecasts reflect no significant improvement in labor productivity over the 1976-1985 period. To the extent that the industry's productivity problem further deteriorates, the employment impacts given here would understate potential impacts.

[2]Possible layoffs would be associated, under this analysis, only in the eventuality that the McGill and Douglas smelters would close down as assumed under the Reduced Capacity scenario.

Further, of the total smelting and refining employment of 17.2 thousand in 1972, more than half of 9.0 thousand was concentrated in the five-state Mountain Region (Montana, New Mexico, Arixona, Utah and Nevada). Arizona alone accounted for 3.0 thousand (17.4 percent). The Northeast Region, basically covering operations in New York (Phelps Dodge-Laurel Hill), New Jersey (Asarco-Perth Amboy, which has since closed down), Maryland (Kennecott-Anne Arundel County, Asarco-Baltimore, which has since closed down), Pennsylvania (Reading Industries, Inc.-Reading), accounted for 6.6 thousand (or 25.6 percent).[1]

If Kennecott-McGill (Nevada) and Phelps Dodge-Douglas (Arizona) smelters actually do close down, as hypothesized under the Reduced Capacity Scenario, the impact on these two isolated communities, which are essentially one-industry towns, would be severe.

2. Related Findings

These main economic impact results are supplemented by the following related findings:

a. Impact on Capacity Growth and Utilization of Capacity

As shown in Table 10, the shortfall in domestic primary smelting/refining capacity compared to the baseline reaches about 400 thousand annual short tons of refined coutput under Constrained Capacity and nearly a million annual short tons under Reduced Capacity (equivalent to nearly 40 percent of 1976 capacity) by 1985.

Capacity utilization is, as expected, higher throughout the period under Constrained Capacity and even higher under Reduced Capacity, compared to the

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[1]The employment data given here are obtained from U.S. Bureau of the Census, Census of Manufactures, 1972, Industry Series: Smelting and Refining of Nonferrous Metals and Alloys, MC72 (2)-33C (Washington, D.C.: U.S. Government Printing Office, 1975), Table 2. It should be noted that employment data at the state level (except for Arizona) are withheld to avoid disclosing figures for individual companies.

baseline forecasts. It can be seen that under the baseline forecasts "demand crunch" conditions are foreseen in the early 1980's, reflecting the relatively "robust" economic growth over this period indicated by the macroeconomic forecasts underlying the baseline results.

Both the capacity shortfall and the utilization rates projected may be less serious under more "moderate" economic growth scenarios. However, the point is that the situation could be as critical as projected here under a more vigorous macroeconomic scenario. Also, the capacity utilization rates (especially under the baseline) are not likely to change significantly. Under the baseline, for example, a "moderate" scenario would probably lower capacity expansion somewhat. This, along with the time-lags associated with smelter/refinery capacity expansion and/or the construction of "greenfield" plants, would still indicate fairly high rates of capacity utilization.

The emphasis here on capacity utilization rates is simply this:[1] (i) the "optimal" capacity utilization rate for the industry, in terms of producing at minimum average total cost is roughly around 86 percent of installed capacity; (ii) beyond this region, the average total cost of production rises rapidly and very steeply near the "practical" capacity limit (at roughly 92 percent of installed capacity, due to irreducible shutdown for repairs, etc.); (iii) consequently, prolonged production along this segment of the industry's average total cost (total unit cost), average variable

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[1] For a detailed discussion of the points made here, pertaining to the cost functions of the primary producers, refer to Technical Appendix to this report, Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry, Section B, "Statement of the Model: Specification and Final Form of the Estimated Equations", especially pp. 26-31.

cost (unit operating and maintenance cost) or marginal cost schedules would occur at higher costs and therefore, higher prices as long as there is no sharp fall in demand (such as in 1975); (iv) therefore, capacity constraints imposed under Constrained Capacity and Reduced Capacity would inevitably lead to higher prices, in a strictly microeconomic sense; these effects are simply quantified, in an internally consistent way, by the model.

b. Impact on Secondary Copper Prices and Production

Impact results for secondary copper prices and production are tabulated in Table 11. The basic conclusion emerging from the model is that prices of both secondary refined copper sold on the "outside" market and scrap prices rise precipitously in response to domestic primary smelting/refinery capacity constraints. In response to these price increases, production of secondary refined copper (produced by secondary smelters/refiners) rises only very slowly, given the fairly inelastic supply function econometrically estimated for secondary smelters/refiners. The situation is different, however, with respect to the supply of scrap that goes directly into the consumption stream: production rises more sharply in response to rising prices.

It should be noted that both prices and production of secondary refined copper and scrap are directionally correct under the various scenarios: results under Constrained Capacity are higher than the baseline forecasts, while results under Reduced Capacity are higher than those under Constrained Capacity.

It should finally be noted that price differences from the baseline become quite serious by 1983 and 1985. In 1985, secondary refined prices are 8.5 percent higher than the baseline under Constrained Capacity and

19.8 percent higher under Reduced Capacity. Scrap prices display a similar pattern (in 1985): they are 10.4 percent higher under Constrained Capacity and 24.7 percent higher under Reduced Capacity.

3. Implications of the Relaxation of Present Environmental Regulations

The expected shortage in U.S. smelting capacity over the period 1976-1983 would result primarily from the fact that the industry can no longer use routes which require a lead time of 2-3 years for expanding capacity. All the permissible routes require about 6-7 years for increasing present capacity. In view of this, it is relevant to examine whether extra capacity might come on stream if environmental regulations governing small expansions (mainly certain provisions in the New Source Performance Standards) as well as emissions from existing loactions were to be changed.

In principle, a series of actions could be identified with the aim of alleviating the apparent domestic smelter capacity bottleneck in the medium-term future. This would mean a "roll-back" of the presently promulgated environmental regulations. We believe certain roll-backs in the present regulations will restore, to some degree, the industry's ability to expand in the short-term. However, major relief would require an increase in emissions. Also, there is major uncertainty as to whether the roll-back expansion routes would be utilized if they are opened, quite apart from what their environmental consequences will be. That is, while the "roll-back" opens up some expansion routes, it does not eliminate uncertainty and it is difficult to define the extent to which such routes will be utilized. Finally, although such roll-backs would provide some relief, we do not believe new incremental capacity can be expected to be avilable before

1980 even if they are defined as early as in 1977. For these reasons, plus the fact that the deviations from baseline capacity growth actually started before 1976 as a result of investment decisions that would have been made then,[1] we believe any roll-back scenario will bring only minor relief to the apparent domestic smelter capacity bottleneck between now and 1983 and will fall far short of returning the industry capacity to baseline capacity levels.

[1]We do not want to leave the impression here that the industry chose to constrain capacity expansion in recent years exclusively because of costs of compliance with environmental regulations. However, pollution control costs were a significant portion of their capital expenditures during that period.

TABLE 8

ECONOMIC IMPACTS UNDER ALTERNATIVE ENVIRONMENTAL SCENARIOS AND CORRESPONDING COMPLIANCE COSTS ON THE U.S. COPPER INDUSTRY, 1976-1985: SUMMARY OF SELECTED RESULTS

(all dollar figures in 1974 prices; thousands of short tons)

Impact Variable	Scenario	1976	1978	1981	1983	1985
Primary refined copper prices (cents per pound)	Baseline	66.3	76.3	77.3	106.3	105.3
	Constrained Capacity	69.2	78.7	84.6	120.6	116.1
	Reduced Capacity	69.2	81.5	88.6	124.6	131.0
	Percent Differences from Baseline (%)					
	Constrained Capacity	4.4	3.1	9.4	13.5	10.3
	Reduced Capacity	4.4	6.8	14.6	17.2	24.4
Primary refined copper production[a]	Baseline	2066.2	2402.3	2549.6	2845.5	3110.9
	Constrained Capacity	1990.7	2315.0	2317.5	2355.1	2715.5
	Reduced Capacity	1990.7	2236.1	2181.5	2218.2	2221.9
	Percent Differences from Baseline (%)					
	Constrained Capacity	- 3.7	- 3.6	- 9.1	- 17.2	- 12.7
	Reduced Capacity	- 3.7	- 6.9	- 14.4	- 22.0	- 28.6
Net Imports[b]	Baseline	134.7	221.1	219.1	378.8	377.0
	Constrained Capacity	146.4	225.9	243.8	394.9	387.8
	Reduced Capacity	146.4	236.8	259.8	410.8	415.5
	Percent Differences from Baseline (%)					
	Constrained Capacity	8.7	2.2	11.3	4.3	2.9
	Reduced Capacity	8.7	7.1	18.6	8.4	10.2
Total Consumption[c]	Baseline	3587.5	4022.1	4475.6	5056.2	5350.0
	Constrained Capacity	3549.0	3981.4	4362.3	4821.6	5150.0
	Reduced Capacity	3549.0	3946.8	4291.7	4749.4	4915.0
	Percent Differences from Baseline (%)					
	Constrained Capacity	- 1.1	- 1.0	- 2.5	- 4.6	- 3.7
	Reduced Capacity	- 1.1	- 1.1	- 4.1	- 6.1	- 8.1
Employment[d]	Baseline	51314	59462	63547	70789	77028
	Constrained Capacity	49550	57532	58207	59653	68035
	Reduced Capacity	49550	55734	55069	56485	56750
	Percent Differences from Baseline (%)					
	Constrained Capacity	- 3.4	- 3.2	- 8.4	- 15.7	- 11.7
	Reduced Capacity	- 3.4	- 6.3	- 13.3	- 20.2	- 26.3

NOTES: [a] Domestic production of refined copper by primary producers, from all sources (domestically mined copper, imported ore/concentrate/blister/scrap, domestically generated unalloyed scrap); although it contains some secondary refined copper, it is exclusive of secondary refined output produced by secondary refiners.

[b] Net of exports.

[c] Includes primary and secondary refined copper, directly consumed scrap and imports.

[d] Total full-time equivalent employment (number of persons) including mining and milling, smelting and refining employment at all domestic primary producer facilities, employment by secondary smelters/refiners are excluded.

SOURCE: Arthur D. Little, Inc. (ADL), based on the Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry.

TABLE 9

EMPLOYMENT EFFECTS OF ALTERNATIVE ENVIRONMENTAL OPTIONS ON THE U.S. COPPER INDUSTRY, 1976-1985[a]

	1976	1978	1981	1983	1985
Baseline					
Total	51,314	59,462	63,547	70,789	77,028
Smelting and refining	17,480	20,324	21,570	24,074	26,319
Mining and milling	33,834	39,138	41,977	46,715	50,709
Constrained Capacity					
Total	49,550	57,532	58,207	59,653	68,035
Smelting and refining	16,842	19,585	19,606	19,925	22,974
Mining and milling	32,708	37,947	38,601	39,728	45,061
Reduced Capacity					
Total	49,550	55,734	55,069	56,485	56,750
Smelting and refining	16,842	18,918	18,456	18,767	18,798
Mining and milling	32,708	36,816	36,613	37,718	37,952

NOTES: [a]Total full-time equivalent employment (number of persons); employment by secondary smelters/refiners is excluded.

SOURCE: Arthur D. Little, Inc., based on results of the Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry.

TABLE 10

DOMESTIC PRIMARY SMELTING/REFINING CAPACITY GROWTH AND CAPACITY UTILIZATION UNDER ALTERNATIVE SCENARIOS, 1976-1985

(Capacity in thousands of annual short tons of refined copper)

Scenarios	1976	1978	1981	1983	1985
Baseline					
Capacity	2605	2708	2908	3150	3449
Percent Capacity Utilization	.793	.887	.877	.903	.902
Constrained Capacity					
Capacity	2605	2605	2605	2605	3005
Percent Capacity Utilization	.764	.889	.890	.904	.904
Reduced Capacity					
Capacity	2605	2527	2437	2437	2437
Percent Capacity Utilization	.764	.892	.895	.905	.912

SOURCE: Arthur D. Little, Inc., based on the Econometric Simulation and Impact Analysis Model of the U.S. Copper Industry.

TABLE 11

SUMMARY OF IMPACTS ON SECONDARY COPPER PRICES AND PRODUCTION, 1976-1985
(all dollar figures in 1974 prices; thousands of short tons)

Impact Variable	Scenario	1976	1978	1981	1983	1985
Prices of secondary refined copper[a] (cents per pound)	Baseline	66.2	78.8	86.9	108.9	110.0
	Constrained Capacity	67.6	81.0	92.0	121.4	119.3
	Reduced Capacity	67.6	82.7	94.5	124.0	131.8
Production of refined copper from scrap[b]	Baseline	221.6	250.2	291.4	315.3	319.8
	Constrained Capacity	220.5	250.5	292.3	330.9	331.0
	Reduced Capacity	220.5	252.9	293.9	331.8	334.0
Prices of scrap (cents per pound of refined equivalent)	Baseline	49.7	62.2	68.0	92.9	93.4
	Constrained Capacity	51.2	64.6	74.1	106.0	103.1
	Reduced Capacity	51.2	66.7	77.2	109.1	116.5
Quantity of scrap generated (directly consumed)[c]	Baseline	974.3	1134.5	1209.8	1528.9	1534.7
	Constrained Capacity	993.3	1166.0	1287.3	1696.7	1659.6
	Reduced Capacity	993.3	1193.0	1327.1	1736.5	1832.0

NOTES: [a]Secondary refined copper produced by secondary smelters/refiners and sold on the "outside" market.
[b]Refers to production by secondary smelters/refiners only.
[c]Excludes scrap going into the smelting/refining stream.

SOURCE: Arthur D. Little., based on the Econometric and Impact Analysis Model of the U.S. Copper Industry.

E. UNQUANTIFIED (UNQUANTIFIABLE) IMPLICATIONS OF ENVIRONMENTAL REGULATIONS AND RELATED ISSUES

The environmental regulations and the impact results discussed earlier have broader implications and raise certain issues which deserve emphasis. These pertain to the regulatory environment, growth of the domestic copper industry and international economic implications.

1. Regulatory Environment

Environmental regulations not only lead to increased costs, due to costs of compliance, but also and perhaps more importantly, cause uncertainty because of their evolving "moving target" nature. From a planning standpoint, the problem of uncertainty is bound to make the industry more cautious and increase both the lead times and the costs required for adding new capacity. The uncertainty element, combined with the cumulative and sometimes conflicting nature of environmental regulations, may further be creating unintended consequences, for example by effectively curtailing domestic productive capacity expansion.[1] Moreover, the existence of many regulatory agencies affecting a given industry, with little or no coordination among them (in the apparent absence of any legal requirement for them to coordinate their activities), may well compound the unintended and unforeseen effects of their actions falling upon the industry being regulated. The situation may get even worse in the future if the present pattern of environmental regulation of industry by Federal Government agencies continues.

There are several recent developments which might make the "reduced capacity" scenario of this chapter quite optimistic. To some extent, that

[1] We have discussed in Chapter 8 in considerable technical detail how the present environmental regulations effectively constrain domestic capacity growth. In retrospect, this was clearly unintended.

scenario is already optimistic in the sense that it assumes some degree of roll-back or accomodation between the EPA and the industry. For example, that scenario assumes that RACT guidelines will not be tightened, and that the fugitives problem at existing and new smelters can be resolved without major cost or capacity penalties at an early date. We present below specific examples:

- We understand that EPA is already considering possible ways for tightening the RACT guidelines.
- EPA regional offices are involved in redefining or further defining control requirements that go beyond the RACT guidelines. From a statutory viewpoint, the states can require standards that are "tougher" than Federal standards. In more than one case, the EPA regional offices appear to have taken the lead in this regard, and provide many of the policy inputs to the state agencies.
- Several proposed OSHA regulations will affect productivity in the copper industry. In some instances, EPA and OSHA requirements are in conflict (e.g., OSHA will permit control of ambient concentrations via dilution while EPA will not). For example, if gases from a multiple-hearth roaster are to be used in an acid plant to reduce SO_2 emissions, such roasters would have to operate at a low draft to reduce dilution air. OSHA requirements might require operation of such roasters under higher draft. In general, while OSHA requires the use of engineering controls to reduce ambient concentrations, such controls

achieve little to meet EPA requirements. In other words, except for fugitives, there is little synergism between EPA and OSHA control costs and such costs are additive. OSHA regulations which would affect the copper industry are those for inorganic arsenic, handling of explosives in open pit mines, SO_2, etc.

2. Issues Pertaining to the Growth of the Domestic Copper Industry

a. Uncertainty in Regulations and Planning Difficulties

As noted before, the uncertainty of new regulations and the way in which they will be enforced will extend the planning horizon. It is instructive to consider how other countries with strong environmental requirements deal with this problem. In Sweden, the pollution control at any new plant is defined via negotiation between the industry and the regulatory body. Once this is over, the owner of the plant has an "environmental license" to operate for ten years. During this period, the plant is not required to add incremental controls. A similar approach could be used in the U.S. where construction of new plants and the phasing-out of old plants could be negotiated between industry and regulatory bodies in the context of regulations which remain unchanged over a predefined time span.

b. New Resource Development

The smelter capacity bottleneck will definitely constrain new mine development in the United States. As discussed later, the U.S. copper industry believes that political risks abroad are greater than environmental risks within the U.S. However, the constraints on planning capacity expansions in the U.S. would suggest that capacity will be exported abroad to areas which are considered less risky politically. The recent growth in copper production capacity in Canada takes on new significance when viewed in this light. It appears that Canadian copper industry will be a major beneficiary of the capacity constraints in the

United States. It also appears that this industry will gear up to export copper to the U.S., probably selling such copper on the basis of producers' prices rather than at "outside market" prices.

In view of the general macro-economic scenario which shows a worldwide recovery, the export of new U.S. concentrates to Japan for toll smelting could not occur to the degree sufficient to eliminate the deviations from baseline conditions. This is because Japanese smelters do not have excess uncommitted capacity of this magnitude.

c. Technological and Energy Implications

EPA regulations affecting the copper industry are unique in the sense that they are more complex than regulations affecting even larger industries (e.g., iron and steel or steam-electric power plants). One reason for this complexity in EPA's apparent desire to force a technological change away from reverb-based technology towards less polluting new smelting technology which is more amenable to control via the use of sulfuric acid plants.

Most reverb-based smelters use natural gas or fuel oil. As soon as natural gas prices rise to the level of fuel oil prices or cheaper natural gas is not available because of shortages or allocations to other classes of consumers, the reverb-based smelters will have to either switch to coal or look into less energy-intensive processes. The fuel prices in the U.S. are rapidly approaching this point. In the long term, the industry would have probably at any rate selected new technology in order to minimize energy costs.

d. Substitution from Aluminum

In the past, the process of substitution has been a gradual one, limited in its pace by the fixity of the machinery and equipment in the short run, the need for process-design changes requiring virtually irrevocable, heavy investments in new machinery and equipment and a desire to avoid risks associated with high degree of maintenance costs in new applications. However, in the future, substitution is likely to continue, even though at a slow pace.

In forecasting relative aluminum and copper prices in the future, it has often been remarked that the higher energy content of aluminum, together with stronger threats of a bauxite cartel,[1] would tend to virtually bring to a halt further substitution of aluminum for copper.

Recent activities by several important producers of bauxite, the major ore used to produce aluminum, have led to a doubling of price.[2] However, because the cost of ore is only a small portion of the total cost of producing aluminum (10 percent), larger price movements would be required to significantly influence aluminum prices.

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[1] The reference here is to the International Bauxite Association (IBA), established in a meeting in Conakry, Guinea, March 5-8, 1974; seven founding members include Australia, Guinea, Guyana, Jamaica, Sierra Leone, Surinam and Yugoslavia; headquartered in Kingston, Jamaica. In a Council of Ministers Meeting of the organization held in Georgetown, Jamaica (November, 1974), three new members (Dominican Republic, Ghana and Haiti) were admitted; three other countries (Greece, India and Trinidad and Tobago) were accepted as official observers. It was also decided that Indonesia and Malaysia would qualify as observers if they should apply. IBA controls about 80 percent of world bauxite production.

[2] Jamaica unilaterally proceeded to institute a new levy of 7.5 percent of the realized price on sale of primary aluminum and increase royalties to 50 cents per ton of bauxite mined. The Government also purchased a 51-percent equity in Kaiser Bauxite Co. and has presumably the same ownership in Revere Jamaica Aluminum, Ltd. Surinam has signed a letter of intent with Alcoa, according to which levies on one ton of bauxite (estimated at $2.50) would be increased to $9. In Haiti, Reynolds agreed to pay increased levies similar to those in Jamaica. See, L. Nachai [U.S. Bureau of Mines], "Investment for Mineral Exploration and Development in Foreign Countries--Problems and Positive Factors," paper presented at the AIME Annual Meeting, Las Vegas, Nevada (February 22-26, 1976), pp. 6, 7.

Compared to copper, which has been estimated to require between 86 and 112 million BTU/ton product,[1] aluminum ingot production is estimated to require twice as much energy per net ton product (i.e., 244 x 10^6 BTU's per ton product).[2]

Consequently, further increases in aluminum prices, whether or not induced by higher energy costs, could slow down but would not necessarily put a stop to substitution from aluminum.

An important end-use market where further substitution could take place is power transmission and distribution cables. Aluminum has already claimed the majority of the market for overhead transmission cable and for distribution cable. Further, it has made considerable inroads into the distribution wire market. While house wiring poses a real question for the future,[3] telephone conductor cable and automobile radiators pose perhaps the most serious threat of substitution from aluminum.

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[1]Cement copper (86); refined copper (112), with the following breakdown: mining (21.6), at 0.2 percent grade with 157 tons of ore per ton metal; concentration (42.3) smelting (38.2); refining (10.2). This high energy consumption stems from problems associated with the relatively low grade of the ore. See, Earl T. Hayes, "Energy Implications of Materials Processing," Science [Materials] Vol. 191, No. 4228 (20 February 1976), 661-665.

[2]Ibid.

[3]Certain practical difficulties stand in the way of significant substitution of aluminum for copper. For example, with copper wire it is very easy to make connections, while with aluminum considerable care is needed. Also, since aluminum "creeps" more than copper, slack can develop in connections, which can lead to a build-up in resistance in the circuit. This poses a subsequent fire risk by promoting oxidization of the metal and, unlike copper, causing a rise in the temperature. Difficulties with installation and with fire risks have led to outright bans of aluminum wire in several areas, notably in California and Washington, D.C.

3. International Economic Implications[1]

Both the capacity constraints imposed domestically by recent EPA regulations and costs of compliance with these regulations may have significant international economic implications beyond those noted above pertaining to international trade effects. A series of basic questions arise in this context:

(a) What will be the effects of domestic environmental regulations on the long-run competitive position of the U.S. copper industry?

(b) What are likely to be the effects of domestic environmental regulations on the domestic as well as international investment behavior of U.S. primary copper producers?

(c) What effect, if any, would domestic environmental regulations have on the future structure of the world copper market?

(d) What are the prospects for the cartelization of the world copper market (outside the United States) and/or for the emergence of commodity access agreements for controlling the world price of copper? What are the potential implications of such developments for U.S. dependence on external sources of copper?

We have investigated these and similar questions in some depth as part of this study. Summarized below are our major findings.

[1]The discussion presented here draws upon working papers and unpublished material provided by Professor Raymond F. Mikesell, W. E. Miner Professor of Economics, University of Oregon (Eugene, Oregon); he remains, however, blameless of the interpretation of his inputs and the conclusions drawn by ADL.

a. Effects on the International Competitive Position of the U.S. Copper Industry

Assessment of the potential effects of domestic environmental regulations on the international competitive position of the U.S. copper industry requires (a) comparative costs of production internationally, (b) information on foreign environmental regulations and estimates of compliance costs on a basis comparable with similar information for the U.S., and (c) consideration of pollution acceptance as a resource in international trade.

First, comparable data on costs in the copper industry in various countries of the world are very difficult to obtain and to interpret in terms of relative competitive advantage. For new large mines, capital costs tend to be somewhat similar because the technical conditions of production are much the same. On the other hand, infrastructure costs incurred by the copper producing firm may differ substantially. Interest costs may differ, depending upon how the financing has been arranged. Labor costs may account for one-third to one-half of operating costs, depending upon whether the mine is an open-pit or underground operation, since the latter type operation is more labor intensive. Wages and labor productivity are important determinants of cost. Rapid increases in wages (such as have occured in Peru and Central Africa) which are not offset by exchange rate depreciation may shift a low-cost mine into a high-cost category within a few years. Differences in the quality of the ore may be offset by the existence of co-products such as gold, the price of which has increased several-fold in recent years.[1]

[1]When the Bougainville mine in Papua New Guinea went into operation in 1972, the high gold content of the ore helped to make that mine a relatively low-cost producer.

The five-fold rise in international oil prices has changed relative costs substantially throughout the world, depending upon the source of energy used in the production and transportation of copper. For example, the rise in oil prices was largely responsible for shifting the Philippine mines from relatively low-cost producers to a high-cost category. Capital and operating costs are also affected by environmental regulations, a subject that will be examined later on. Finally, royalties, excise taxes (which are usually included in production costs), and corporate income taxes introduce complexities in determining comparative costs since these charges have a different impact on government-owned mining enterprises as contrasted with privately-owned mines.

In his recent book, Copper: The Anatomy of an Industry, Sir Ronald Prain ranks the US as a medium-cost producer and Canada and South Africa and some of the new high-volume mine operations in Southeast Asia as low-cost producers. He classified the former low-cost producing countries of Chile, Zambia, and Zaire as currently high-cost producers (pp. 192-3). On the other hand, a 1974 report of the Commodities Research Unit (CRU) entitled "The Current Costs of Producing Primary Copper and Future Trends" ranks the US and Canada as the highest cost producers (although there is a wide range of costs among mines). The CRU report (only a summary of which has been available) ranks the Asian-Australian mines as the least cost, followed by African mines and South American mines in that order. However, these relative positions are expected to change over the next five years, with differential rates of domestic inflation not offset by exchange rate adjustments, and by differential energy costs (e.g., the development of cheap hydro-electric power in Zaire and exploitation of

South African coal reserves). Despite the low grade of US copper ore, the CRU report foresees a narrowing of the cost differential between the United States and Canada on the one hand and other regions of the world on the other hand over the next five years. The reasons given for this trend are: (1) labor costs in North America are expected to rise at a slower rate than elsewhere; (2) most antipollution costs have already been absorbed by North American producers; (3) all the major by-products of North American copper mines are likely to show an increase in value relative to by-products in other mines; and (4) the US and (especially) Canada are likely to be less adversely affected by the future rise in energy prices. Some of these reasons given by the CRU report are clearly subject to question and further examination.

Second, comprehensive and comparable information on foreign pollution abatement standards and compliance costs are lacking to permit quantitative cost comparisons. Information on European countries with smelters--principally Belgium, West Germany, Norway and Sweden--indicates that their pollution abatement standards are comparable to those in the US, but that there is more flexibility in their administration, particularly as related to existing local ambient conditions, so that costs may be lower in some cases than for the United States. Japan may have even higher standards but again with greater administrative flexibility. Even before the imposition of strict SO_2 emission standards, Europe and Japan found it profitable to employ smelting techniques that captured a high proportion of SO_2 for production of sulphuric acid.[1]

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[1]This was in contrast to smelters in the western United States which until recently at least, did not have any outlet for the acid.

Pollution abatement standards in developing countries vary but are generally lower than in the developed countries. This is in part because most of the smelters in Africa and Latin America are located far from populated areas. Despite the desire of the developing countries to process their own ores by building smelters or encouraging foreign investors to do so, it seems likely that most developing countries will over time insist on pollution abatement standards but perhaps with allowance for the ambient conditions and population. Some of the new mine development agreements between host government and foreign companies provide for observance by the foreign companies of environmental regulations, but without providing details regarding those regulations. Anaconda is building a pyro-type smelter in Brazil under contract with a Brazilian government enterprise, which calls for the same pollution abatement standards as apply in the United States. Consideration was given to the use of the Arbiter process, but, because of the heavy demand and high price of sulphuric acid in Brazil and the high price of ammonia (used in the Arbiter process), it was decided to use a pyro-metallurgical process. Finally, the World Bank Group has been encouraging its members to adopt environmental standards in the formulation of the projects for Bank financing, and in some cases has insisted on the incorporation of pollution abatement facilities in such projects.[1]

Finally, we should consider the implications, for the competitive position of the U.S. copper industry, of the willingness elsewhere in the world to accept pollution (or to tolerate lower standards of pollution abatement) as a national resource which will affect the country's comparative

[1] See Environment and Development, World Bank, Washington, D.C., June 1975.

advantage in international trade. It is argued that if certain countries are willing to accept more pollution than others, they will gain a relative advantage in producing those commodities which involve pollution in their production and whose costs of pollution abatement tends to be high.[1] This advantage may also occur because of the profitability of locating high-polluting production in certain countries in areas far from populated centers (e.g., the location of copper smelters in the deserts of northern Chile). One possible mitigating factor would be the possibility of changing the technical conditions of production for any particular commodity toward the use of non-polluting processes, so that over time nonpolluting technology becomes competitive with polluting technology. New nonpolluting processes in copper smelting, such as the hydrometallurgical processes for smelting and refining, may become comparable in cost with the pyro-type. Moreover, over time pollution abatement standards are likely to become more important in the developing countries, thereby reducing their relative advantage.

In conclusion, we do not, on balance, expect the international competitive position of the U.S. copper industry will be significantly affected by domestic costs of compliance per se, given the mitigating factors in the rest of the world having a substantial influence on costs of production.

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[1]See Ingo Walter, "Environmental Control and Patterns of International Trade and Invesment: An Emerging Policy Issue," Banca Nazionale del Lavoro Quarterly Review, (March 1972); Anthony Y. C. Koo, "Environmental Repercussions and Trade Theory," The Review of Economics and Statistics. (May 1974); and W. Leontief, "Environmental Repercussions and the Economic Structure: An Input-Output Approach," The Review of Economics and Statistics, (August 1970).

b. Effects on the Investment Behavior of U.S. Primary Copper Producers

On the basis of operating and capital costs, and without regard to taxes and political risk, foreign investment would appear to be more attractive than investment in the U.S. before any consideration of differences in pollution abatement costs or the capacity constraining influence of EPA regulations domestically. There is virtual concensus in the industry that differences in pollution abatement costs *per se* are likely to be too small in relation to the large number of uncertain factors associated with foreign investment to make an appreciable difference in their decision regarding a foreign investment in most developing countries.

In a perfectly competitive world economy with no constraints on foreign investment, a decline in the profitability of an industry in the United States arising from increased total unit costs alone would tend to shift investment in that industry to other countries where costs have not risen. Capital might be attracted from the United States as well as from other countries, including the countries where the investment opportunities exist. Lower rates of profit in the U.S. industry would reduce the amount of domestic capital available for reinvestment in the industry, while higher rates of profitability abroad would increase foreign capital available for investment in other countries. Higher costs in the United States, accompanied by a slowing down in the rate of capacity growth, would in the long-run tend to bring about upward pressure on world prices, and expected profitability in foreign areas would tend to rise. Even if U.S. mining firms did not increase their investments abroad relative to those in the United States as a consequence of lower relative profitability in the U.S. industry, U.S. firms might shift their investments into other domestic industries, while less U.S. capital would be attracted to the domestic mining industry.

In the absence of constraints on foreign investment in the copper industry, and given a fully competitive world market for copper, foreign copper-producing capacity should grow relative to U.S. capacity.

c. Implications for the Future Structure of the World Copper Industry

In reviewing broadly the possible implications of domestic environmental regulations for the future structure of the world copper industry, it might be well to start with the observation that the long-run supply factors, rather than demand factors, are likely to be the more crucial, given the relative inelasticity of demand for copper and even after allowing for continued long-run substitution from aluminum.

On the supply side, we might begin by dwelling briefly on known world reserves. Reserves are not static but change with the amount of exploration activity and with the price of copper, since the lower the grade of the ore and the higher the cost of extraction, the higher must be the price for its recovery to be profitable. It has been estimated by the U.S. Department of the Interior that at a price of 52 U.S. cents per pound, recoverable world reserves are 340 million short tons while at a price of 75 U.S. cents, recoverable world reserves are 457 million tons, or 34 percent larger. A recent study shows that U.S. recoverable reserves increase from about 70 million short tons at 50 cents per pound (calculated for a 12 percent rate of return on DCF), to over 125 million tons at $1.00 per pound.[1] In addition

[1] U.S. Bureau of Mines, An Economic Appraisal of the Supply of Copper from Primary Domestic Sources, Bureau of Mines Information Circular 8598 (1973), p. 44. It may be noted that recoverable copper is a function of both the price of copper and the rate of return on investment necessary to attract mining companies to produce the copper.

to identified world copper reserves, reserves now unknown but suspected to be present near known deposits provide another 400 million tons of potentially recoverable copper. Undiscovered mineral deposits that may exist in unknown districts are estimated at 320 million tons. In addition, substantial amounts of copper may be found in the seabeds. Thus, identified and potential copper world reserves are in excess of a billion tons of copper content, more than three times the estimated cumulative world consumption of copper between now and the year 2000. Hence, it is most unlikely that aggregate world reserves will constitute a constraint on output in the foreseeable future. On the other hand, reserves could constitute a constraint on output in particular producing areas over the next several decades and this is more likely to be the case in the absence of adequate exploration activity for identifying additional reserves.

Next, nearly two-thirds of known world reserves are located outside the United States, mostly in the less developed countries (LDCS). In virtually all foreign copper exporting countries, except Canada, the copper content of the ores is substantially higher than in this country, and it is likely that the differential in metal content will increase over time. There are, of course, a large number of other factors which have a bearing on cost and, perhaps more important, the rate at which copper resources can be developed. The shift in ownership and control patterns in the mining industries of the developing countries and the declining role of the international mining companies in exploration and development in these countries have made it difficult to assess the reasons for relative rates of increase in copper producing capacity abroad.

The LDCs are anxious to develop their mineral resources in order to expand their export earnings, and they recognize the need for the technical knowledge, venture and debt capital, and managerial ability of the international mining firms. A case can be made that for some countries at least exploration and new investment have been curtailed by the nationalization movement. However, it would be rash to predict that the growth of copper mining capacity will be substantially retarded in the developing countries as consequence of the nationalization movement and of the emergence of new relationships between the host countries and the foreign investor. In fact, most of the governments of the copper exporting countries have ambitious plans for expanding their copper producing capacity and these plans may be pushed without regard for the outlook for profitability as ordinarily perceived by private enterprise, provided the capital can be obtained. Moreover, governments are not subject to the kinds of constraints on investment in new capacity imposed by high taxes, government regulations, and political instability that deter private investors.

However, there are serious difficulties facing many foreign countries in obtaining the necessary technology, management and capital from abroad for realizing their national plans for resource development. Some important questions still remain basically unresolved. First, will there be an adequate expansion of exploration in the developing countries?[1] Will host governments be able to raise the billions of dollars required to develop their mineral reserves as majority or 100 percent owners and managers?

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[1]It might be pointed out that virtually all of the properties that Minero Peru is planning to develop were originally concessions held by foreign companies on which considerable sums had been spent for exploration.

Will the host governments be able to maintain or attract the technical and managerial personnel needed for the efficient operation of existing mines and the expansion of their productive capacity? The answers to these and other questions, such as those relating to the effects of nationalization on world markets, will have an important bearing on the long-run supply of copper. However, in this context, it seems quite likely that for the present and for some years to come, the development of new mining capacity, particularly in the developing areas, will depend upon management and technology provided by the large international mining companies and upon the ability of these companies to raise large amounts of capital, running into many billions of dollars, from outside sources.

d. Prospects for Cartelization and Commodity Access Agreements

In recent years there has been a great deal of discussion and theorizing regarding the international control of copper prices. The purpose of control arrangements might be simply to avoid sharp fluctuations in world copper prices that prove uneconomic and harmful to producers and consumers alike. The objective of such an effort would be to maintain the price of copper close to its long-term equilibrium level as determined by long-run cost and demand factors. Alternatively, the purpose might be to maximize the copper earnings of the developing countries, since the developing countries account for the vast bulk of the primary copper produced outside the United States and nearly all of this copper is exported. Recently serious concern has been expressed that the present members of CIPEC, or an organization involving all of the major copper exporting countries, might act in concert to double or triple the world price of copper--much in the same way that OPEC has tripled the price of petroleum over the past two years. We shall explore briefly the possibility of achieving market price control for copper later on in this section.

CIPEC has not yet evolved a mechanism to stabilize prices, although it hopes to promote a buffer stock arrangement for copper involving both producing and consuming countries. In March, 1976 representatives of 76 producing and consuming countries (including the U.S., which does both) met in Geneva at the invitation of the U.N. Conference on Trade and Development (UNCTAD) to work towards a buffer stock arrangement. UNCTAD suggested the creation of an internationally financed buffer stock to buy up more than half a million tons of surplus copper that would be sold when prices exceeded a stipulated maximum, along the lines of the existing tin agreement.[1] Meanwhile, CIPEC apparently intends to maintain a 15 percent cutback in production by its members during the rest of 1976 and perhaps beyond. The CIPEC Secretariat does not foresee a balance between world demand and supply of copper that would permit a substantial price rise before 1978.[2]

The history of efforts at collusive control of copper prices shows that while it has been possible to maintain or raise prices over relatively short periods, disequilibrium prices soon invite increased primary copper production, increased supplies of secondary copper, and the substitution of other metals for copper in important uses. Thus any rational undertaking

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[1] Robert Prinshy, "Copper Parley Isn't Likely to Make Much Progress Toward a Price Pact," The Wall Street Journal (March 25, 1976).

[2] Based on information from private sources.

by CIPEC to control copper prices must take into account the intermediate and long-term effects on their foreign exchange earnings, and not simply their ability to influence prices in the short-run. In the short-run, the non-CIPEC world supply of primary copper is probably fairly inelastic, but account must be taken of the supply of scrap which can be increased rather readily in the short-run.

CIPEC's world market power in copper differs from that of OPEC's in petroleum in several important respects. First, world petroleum reserves are heavily concentrated in the Middle East, and at the rate of growth of world petroleum demand in 1970-1972, nearly half of the required annual increase in output over the next decade would have to come from one country, namely Saudi Arabia. Copper resources on the other hand are more widely distributed throughout the world, and the CIPEC countries account for a much smaller share of world copper exports than do the OPEC countries of the world petroleum exports. Second, substitutes for primary copper, including scrap and other metals, are more readily available in the short and intermediate-run than are substitutes for petroleum for meeting the world's energy requirements. Withholding the oil output of two or three Arab states could substantially impair the economies of Western Europe and Japan. Withholding all of CIPEC's copper output would inconvenience the world economy but not seriously reduce the world's industrial and agricultural production. Third, several of the Arab oil states have producing capacity that substantially exceeds their need for foreign exchange over the next few years, and at current levels of production they are accumulating reserves on a massive scale. This is not true for any of the CIPEC countries, all of which desire to expand output and to develop their copper reserves for meeting their foreign exchange requirements. This factor is important for attempts to control output and productive capacity of copper over the longer-run. Some of these factors would operate to limit CIPEC's market power even if the organization were expanded to include all of the major copper countries in the developing world and if they were able to unite on a common program for market control.

In conclusion, nevertheless, in the face of constraints on domestic capacity growth the likelihood that an expanded CIPEC will be able to exercise some control over the world price of copper in the medium-term future should not be ruled out. In the longer-run, all copper producing countries would probably want to obtain a larger share of the world market; hence, it is most unlikely that there will be any agreement on sharing the growth in copper producing capacity over the long-run. At any rate, even if CIPEC were able to achieve somewhat greater price stability in the medium-term through the operation of a buffer stock, or otherwise, the long-run average price of copper might not be greatly affected. Moreover, if the average price of copper were raised, revenues might not rise because of competition from substitutes for primary copper, including scrap copper, aluminum and plastics.

APPENDIX A

BASELINE MODEL FORECASTS (1976-1985)

APPENDIX A--BASELINE MODEL FORECASTS

Presented in this appendix are the following:

1. Historical and projected values of all independent (exogenous) variables, along with historical values of all dependent (endogenous) variables;

2. Summary of year-by-year model solutions for the nonlinear version of the model; and,

3. Summary of year-by-year subsidiary calculations (e.g. sales, production, employment, capacity, capacity utlization, etc.).

General Notes:

(1) Listing of variables/values: refer to Appendix D for a "dictionary" of the variables;

(2) Three "parametric" model solutions have been obtained for each year:

one: AVC = AR (Average variable cost = net demand schedule for primary producers)

two: ATC = AR (Average total cost = net demand schedule for primary producers)

three: AVC = MC = MR (Implicit monopolistic solution).

The solution used in our analysis (and also listed here) refers to Solution Two (ATC = AR). Refer to the technical Appendix for more detail.

EXOGENOUS AND ENDOGENOUS VARIABLES LISTED BELOW

YEAR	CONST	RPAL	YUD	RPLME	YUD/YGR	DUMST2	DIGOV	IRR(-1)	QFAB	DSTE2
1954	1.0000	24.555	43.082	58.525	1.3548	.50000	199.30	87.700	2113.0	1.5000
1955	1.0000	32.411	49.296	79.356	1.3469	1.5000	23.600	47.100	2565.0	.00000
1956	1.0000	28.855	50.453	69.752	1.2867	.00000	49.500	61.600	2435.5	.00000
1957	1.0000	23.002	51.284	44.777	1.2298	.00000	79.000	120.60	2214.0	.00000
1958	1.0000	20.745	44.905	39.699	1.0395	.00000	124.70	181.00	2021.5	4.6700
1959	1.0000	22.763	51.533	47.139	1.1130	4.6700	4.5000	80.700	2383.0	.75000
1960	1.0000	21.320	52.444	48.689	1.0144	.75000	6.0000	64.800	2119.5	.00000
1961	1.0000	18.924	51.450	45.642	.93716	.00000	-5.0000	139.30	2213.0	.00000
1962	1.0000	17.562	57.166	46.631	.99767	.00000	-7.4000	79.800	2423.0	.00000
1963	1.0000	18.372	60.895	46.646	1.0321	.00000	-11.400	117.40	2540.5	2.0000
1964	1.0000	19.306	65.451	69.101	1.0132	2.0000	-27.300	76.900	2863.0	.00000
1965	1.0000	22.770	73.322	90.972	1.0751	.00000	-122.50	45.600	3052.5	.00000
1966	1.0000	19.369	82.021	104.93	1.1853	.00000	-445.00	60.800	3396.5	5.5000
1967	1.0000	15.589	82.850	76.148	1.2311	5.5000	-177.20	65.700	2903.0	3.0000
1968	1.0000	14.472	87.407	80.416	1.1623	3.0000	-13.600	55.400	2911.0	.00000
1969	1.0000	17.991	91.135	91.460	1.0659	.00000	-8.0000	56.600	3274.0	.00000
1970	1.0000	14.515	84.093	84.768	.93333	.00000	.00000	45.900	2820.0	1.0000
1971	1.0000	10.593	82.353	62.581	.89709	1.0000	-1.8000	160.60	2909.5	.00000
1972	1.0000	9.2281	89.809	59.578	.94140	.00000	.00000	103.00	3234.0	.00000
1973	1.0000	13.018	101.08	94.261	.99387	.00000	-33.800	157.40	3596.5	2.2500
1974	1.0000	16.180	100.00	93.000	1.0000	2.2500	-182.50	49.100	3097.0	.00000
1975	1.0000	22.442	78.000	50.340	.97400	.00000	.00000	194.90	2315.0	.00000
1976	1.0000	30.093	98.524	56.640	1.0360	.00000	.00000	264.90	2602.1	1.5000
1977	1.0000	29.329	107.88	73.000	1.0250	1.5000	50.000	274.90	2649.3	.00000
1978	1.0000	29.051	106.85	71.800	1.0258	.00000	100.00	221.40	2822.1	.00000
1979	1.0000	28.874	104.39	65.080	1.0287	.00000	100.00	167.90	2757.2	.75000
1980	1.0000	28.352	111.53	76.000	1.0208	.75000	50.000	219.90	2945.6	.00000
1981	1.0000	28.528	123.35	91.000	1.0101	.00000	.00000	271.90	3256.0	.00000
1982	1.0000	28.737	132.71	96.000	1.0030	.00000	.00000	216.40	3505.3	1.5000
1983	1.0000	28.918	140.25	99.800	.99810	1.5000	.00000	164.90	3704.4	.00000
1984	1.0000	28.918	144.74	101.90	.99550	.00000	.00000	200.00	3822.9	.00000
1985	1.0000	28.918	149.37	104.00	.99289	.00000	.00000	200.00	3945.3	1.5000
1986	1.0000	28.918	154.15	106.00	.99036	1.5000	.00000	200.00	4071.5	.00000
1987	1.0000	28.918	159.08	108.40	.98800	.00000	.00000	200.00	4201.8	.00000
1988	1.0000	28.918	164.17	110.70	.98570	.00000	.00000	200.00	4336.3	.75000
1989	1.0000	28.918	169.43	113.10	.98346	.75000	.00000	200.00	4475.0	.00000
1990	1.0000	28.918	174.85	115.60	.97895	.00000	.00000	200.00	4618.2	.00000
1991	1.0000	28.918	-.00000	115.60	-.00000	.00000	.00000	200.00	-.00000	1.5000
1992	1.0000	28.918	-.00000	115.60	-.00000	1.5000	.00000	200.00	-.00000	.00000
1993	1.0000	28.918	-.00000	115.60	-.00000	.00000	.00000	200.00	-.00000	.00000

YEAR	IF(-1)	IRS(-1)	QD(-1)	IPOLLM+M	IPRODM+M	IPOLLS+R	KAPSR	KAPPR	DOLKAP	CAPAC
1954	172.00	60.000	2287.0	.00000	.00000	.00000	200.00	1696.0	535.76	.00000
1955	146.00	35.000	1916.5	.00000	.00000	.00000	206.00	1656.0	540.64	.00000
1956	170.00	56.000	2418.7	.00000	.00000	.00000	271.00	1799.0	545.35	.00000
1957	177.00	59.000	2365.0	.00000	.00000	.00000	271.00	1793.0	550.11	.00000
1958	175.00	43.000	2106.4	.00000	.00000	.00000	271.00	1810.5	554.90	.00000
1959	179.00	49.000	1974.6	.00000	.00000	.00000	296.00	1812.5	559.74	.00000
1960	140.00	71.000	2318.6	.00000	.00000	.00000	296.00	2013.0	564.62	.00000
1961	148.00	62.000	2079.3	.00000	.00000	.00000	313.50	2017.5	569.54	.00000
1962	152.00	43.000	2170.0	.00000	.00000	.00000	313.50	2027.5	574.51	.00000
1963	157.00	59.000	2361.1	.00000	.00000	.00000	317.50	2016.5	579.52	.00000
1964	149.00	47.000	2565.7	.00000	.14600+09	.00000	317.50	2016.5	584.57	.24292+10
1965	159.00	53.000	2775.0	.00000	.15800+09	.00000	317.50	2016.5	589.67	.00000
1966	168.00	49.000	2995.4	.00000	.17100+09	.00000	317.50	2102.5	594.81	.00000
1967	231.00	52.000	3368.6	.00000	.18400+09	.00000	314.00	2112.5	600.00	.00000
1968	182.00	48.000	2850.4	.00000	.19700+09	.00000	319.00	2208.0	645.42	.00000
1969	168.00	42.000	2813.5	.00000	.21100+09	.00000	304.00	2339.0	694.28	.00000
1970	178.00	57.000	3164.2	.00000	.22500+09	.40000+08	304.00	2372.0	746.84	.00000
1971	242.00	68.000	2930.5	.00000	.24000+09	.40000+08	304.00	2372.0	803.38	.00000
1972	229.00	51.000	2956.0	.00000	.25700+09	.40000+08	304.00	2489.0	864.20	.00000
1973	167.00	46.000	3266.2	.00000	.45450+09	.40000+08	304.00	2419.0	929.62	.00000
1974	167.00	42.000	3481.7	.00000	.46500+09	.22600+09	304.00	2546.0	1600.0	.43000+10
1975	242.00	43.000	3106.2	.00000	.37100+09	.24080+09	304.00	-.00000	1600.0	.00000
1976	272.00	63.000	-.00000	.00000	.39330+09	.00000	350.00	-.00000	1600.0	.00000
1977	281.00	63.000	-.00000	.00000	.40000+09	.00000	350.00	-.00000	1600.0	.00000
1978	255.00	52.000	-.00000	.00000	.40000+09	.00000	350.00	-.00000	1600.0	.00000
1979	229.00	41.000	-.00000	.00000	.40000+09	.00000	350.00	-.00000	1600.0	.00000
1980	252.50	51.400	-.00000	.00000	.40000+09	.00000	350.00	-.00000	1600.0	.00000
1981	276.00	61.000	-.00000	.00000	.40000+09	.00000	350.00	-.00000	1600.0	.00000
1982	250.00	50.800	-.00000	.00000	.40000+09	.00000	350.00	-.00000	1600.0	.00000
1983	224.00	39.800	-.00000	.00000	.40000+09	.00000	350.00	-.00000	1600.0	.00000
1984	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000
1985	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000
1986	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000
1987	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000
1988	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000
1989	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000
1990	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000
1991	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000
1992	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000
1993	250.00	50.000	-.00000	.00000	.50000+09	.00000	350.00	-.00000	1600.0	.00000

YEAR	FCCOEF1	FCCOEF2	FCCOEF3	FCCOEF4	FCCOEF5	FCCOEF6	DEP1	DEP2	REP	QCU
1954	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	835.50
1955	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	998.60
1956	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1104.2
1957	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1086.9
1958	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	979.30
1959	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	824.80
1960	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1080.2
1961	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1165.2
1962	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1228.4
1963	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1213.2
1964	.19460	.19460	.19460	.19460	.19460	.19460	.15700-01	.15700-01	.26600-01	1246.8
1965	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1351.7
1966	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.15700-01	.15700-01	.26600-01	1429.2
1967	.25000-01	.25000-01	.25000-01	.25000-01	.25000-01	.25000-01	.15700-01	.15700-01	.26600-01	954.10
1968	.17460	.17460	.17460	.17460	.17460	.17460	.15700-01	.15700-01	.26600-01	1204.6
1969	.25690	.25690	.25690	.25690	.25690	.25690	.15700-01	.15700-01	.26600-01	1544.6
1970	.27310	.27310	.27310	.27310	.27310	.27310	.15700-01	.15700-01	.26600-01	1719.7
1971	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.15700-01	.15700-01	.26600-01	1522.2
1972	.16850	.16850	.16850	.16850	.16850	.16850	.15700-01	.15700-01	.26600-01	1664.8
1973	.20380	.20380	.20380	.20380	.20380	.20380	.15700-01	.15700-01	.26600-01	1717.9
1974	.23280	.17000	.26280	.23280	.23280	.23280	.30950-01	.15700-01	.53200-01	1593.6
1975	.16280	.17000	.16650	.16280	.16280	.16280	.19100-02	.15700-01	.53200-01	-.00000
1976	.16280	.17000	.17650	.16280	.16280	.16280	.30000-01	.15700-01	.53200-01	-.00000
1977	.16280	.17000	.18650	.16280	.16280	.16280	.30000-01	.15700-01	.53200-01	-.00000
1978	.18280	.17000	.21280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1979	.18280	.17000	.21280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1980	.20280	.17000	.23280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1981	.20280	.17000	.23280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1982	.23280	.17000	.26280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1983	.23280	.17000	.26280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1984	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1985	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1986	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1987	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1988	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1989	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1990	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1991	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1992	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1993	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000

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YEAR	NETY	CCAPI	FIPDE	VARCOS1	VARCOS2	VARCOS3	VARCOS4	QD	RPEMJ	NE
1954	.18549+06	.19620	84.000	-.00000	-.00000	-.00000	-.00000	1916.5	55.568	124.70
1955	.33379+06	.46990	85.900	-.00000	-.00000	-.00000	-.00000	2418.7	67.769	40.800
1956	.42300+06	.23100	91.800	-.00000	-.00000	-.00000	-.00000	2365.0	71.026	83.300
1957	.22613+06	-.88800-01	97.500	-.00000	-.00000	-.00000	-.00000	2106.4	48.357	274.00
1958	.17079+06	.45500-01	100.00	-.00000	-.00000	-.00000	-.00000	1974.6	41.203	287.40
1959	.20223+06	.17250	102.00	-.00000	-.00000	-.00000	-.00000	2318.6	49.289	-32.900
1960	.22508+06	-.22700-01	102.20	-.00000	-.00000	-.00000	-.00000	2079.3	50.616	438.00
1961	.20393+06	.11540	102.10	-.00000	-.00000	-.00000	-.00000	2170.0	47.500	480.50
1962	.21782+06	.62000-01	102.30	-.00000	-.00000	-.00000	-.00000	2361.1	48.633	269.80
1963	.22045+06	.15450	102.30	-.00000	-.00000	-.00000	-.00000	2565.7	48.633	228.40
1964	.27626+06	.19830	103.00	36.000	-.00000	-.00000	-.00000	2775.0	50.204	267.70
1965	.37756+06	.12170	103.90	37.000	-.00000	-.00000	-.00000	2995.4	54.329	256.10
1966	.49100+06	.90400-01	106.00	38.000	-.00000	-.00000	-.00000	3368.6	54.903	135.10
1967	.33791+06	.63000-01	109.30	39.000	-.00000	-.00000	-.00000	2850.4	56.814	-123.60
1968	.42022+06	.16590	112.00	40.000	-.00000	-.00000	-.00000	2813.5	60.086	-72.700
1969	.55193+06	.17490	115.20	41.000	-.00000	-.00000	-.00000	3164.2	65.577	130.70
1970	.51607+06	.11750	120.30	42.000	-.00000	-.00000	-.00000	2930.5	76.556	168.90
1971	.61506+06	-.49500-01	124.50	43.000	-.00000	-.00000	-.00000	2956.0	65.324	74.400
1972	.38322+06	.61700-01	126.50	44.000	-.00000	-.00000	-.00000	3266.2	62.118	29.500
1973	.59883+06	.91100-01	130.00	45.000	-.00000	-.00000	-.00000	3461.7	68.669	72.600
1974	.88136+06	.76400-01	143.50	43.000	-.00000	-.00000	-.00000	3106.2	-.00000	-106.50
1975	-.00000	.13180	150.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1976	-.00000	.14360	155.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1977	-.00000	.14440	160.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1978	-.00000	.15600	165.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1979	-.00000	.15870	170.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1980	-.00000	.14890	175.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1981	-.00000	.13810	180.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1982	-.00000	.13280	185.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1983	-.00000	.13410	190.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1984	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1985	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1986	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1987	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1988	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1989	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1990	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1991	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1992	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1993	-.00000	.13410	-.00000	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000

YEAR	QR	DELIF	DELIRR	DELIRS	QPR	RPSR	QSR	RPS	QSNR	RPFUT1
1954	1418.4	-26.000	-40.600	-25.000	1220.1	64.645	198.30	45.929	742.00	46.753
1955	1562.8	24.000	14.500	21.000	1320.7	77.043	242.10	60.774	938.80	57.375
1956	1687.8	7.0000	59.000	3.0000	1467.2	68.903	220.60	53.617	855.40	76.868
1957	1676.1	-2.0000	60.400	-16.000	1422.1	54.095	254.00	32.843	808.70	52.575
1958	1579.5	4.0000	-100.30	6.0000	1373.1	48.912	206.40	28.119	735.30	38.420
1959	1331.5	-39.000	-75.900	22.000	1071.6	53.035	259.90	35.646	883.10	45.210
1960	1794.6	8.0000	74.500	-9.0000	1559.6	50.790	235.00	33.417	831.60	49.021
1961	1613.9	4.0000	-59.500	-19.000	1609.2	52.040	204.70	34.577	778.40	43.943
1962	1884.5	5.0000	37.600	16.007	1677.6	52.575	206.90	34.297	804.10	48.061
1963	1884.4	-8.0000	-40.500	-12.000	1639.7	53.544	244.70	35.267	849.00	45.343
1964	1990.4	10.000	-31.300	6.0000	1740.7	56.519	249.70	40.810	989.70	48.272
1965	2214.8	9.0000	15.200	-4.0000	1864.0	73.662	276.80	53.498	1025.6	55.669
1966	2183.3	63.000	4.9000	3.0000	1896.5	87.523	286.80	67.790	1013.1	82.559
1967	1526.6	-49.000	-10.300	-4.0000	1251.4	69.584	275.20	49.264	932.10	77.441
1968	1839.0	-14.000	1.2000	-6.0000	1546.3	67.136	292.70	47.035	982.60	73.855
1969	2214.9	10.000	-10.700	15.000	1937.0	78.477	277.90	59.161	1082.9	67.260
1970	2202.7	64.000	114.70	11.000	1975.1	70.917	267.60	52.342	978.50	69.935
1971	1962.4	-13.000	-57.600	-17.000	1733.3	60.422	229.10	35.018	971.90	60.485
1972	2258.5	-62.000	54.400	-5.0000	2011.4	72.426	247.10	47.883	1062.2	60.486
1973	2312.6	.00000	-108.30	-4.0000	2027.2	84.241	265.40	58.579	1119.5	60.329
1974	2130.5	75.000	145.80	1.0000	1838.8	79.880	297.70	54.880	1025.1	61.640
1975	-.00000	30.000	70.000	20.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1976	-.00000	9.0000	10.000	.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1977	-.00000	-26.000	-53.500	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1978	-.00000	-26.000	-53.500	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1979	-.00000	23.500	52.000	10.400	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1980	-.00000	23.500	52.000	10.400	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1981	-.00000	-26.000	-53.000	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1982	-.00000	-26.000	-53.000	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1983	-.00000	23.500	52.000	10.400	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1984	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1985	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1986	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1987	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1988	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1989	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1990	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1991	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1992	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1993	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1974	1975	1976	1977	1978
QD - TOTAL CONSUMPTION IN US	3598.477	2982.701	3587.493	3969.063	4022.147
RPEMJ - DEFL. AVE REF. PRICE	68.740	59.177	66.289	66.651	76.325
NE - NET EXPORTS SCRAP + REF.	-28.582	43.134	-134.681	-195.115	-221.098
QR - TOTAL PRODUCTION REFINED	2314.769	2044.503	2287.408	2543.530	2646.060
DELTF - STOCK CHANGE FABRICAT.	-.380	-40.166	-37.371	-51.430	-31.817
DELTRR - STOCK CHANGE REFINER.	36.756	-77.148	-151.740	-179.521	-90.827
DELTRS - STOCK CHANGE SCRAP	13.658	5.282	-5.044	-4.888	5.943
QPR - TOTAL PROD. PRIMARY REF.	2015.238	1824.807	2066.154	2307.573	2402.259
RPSR - PRICE SECONDARY REFINED	81.794	58.591	66.005	73.214	78.979
QSR - PROD REFINED FROM SCRAP	299.532	219.697	221.254	235.958	243.801
RPS - REAL PRICE OF SCRAP	61.243	41.497	49.442	55.157	62.461
QSNR - SCRAP RECEIPTS NOT SEC.	1122.661	869.299	971.249	1044.579	1138.287
RPFUT1 - DEFL FUT PRICE (JAN)	70.665	48.689	51.553	60.711	58.447

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1979	1980	1981	1982	1983
QD - TOTAL CONSUMPTION IN US	4070.518	4193.489	4475.554	4771.943	5056.210
RPEMJ - DEFL. AVE REF. PRICE	76.058	75.255	77.341	93.505	106.337
NE - NET EXPORTS SCRAP + REF.	-274.153	-277.732	-219.131	-285.838	-378.830
QR - TOTAL PRODUCTION REFINED	2758.242	2705.697	2837.973	3014.099	3158.277
DELTF - STOCK CHANGE FABRICAT.	-19.894	-31.958	-28.851	-3.147	-3.526
DELTRR - STOCK CHANGE REFINER.	-2.703	-96.223	-179.943	-97.471	-21.137
DELTRS - STOCK CHANGE SCRAP	6.659	7.759	2.537	16.639	31.059
QPR - TOTAL PROD. PRIMARY REF.	2595.629	2445.513	2549.571	2711.966	2845.512
RPSR - PRICE SECONDARY REFINED	77.716	79.819	86.989	99.125	108.623
QSR - PROD REFINED FROM SCRAP	196.130	260.184	288.402	302.133	312.764
RPS - REAL PRICE OF SCRAP	61.206	62.566	68.221	81.924	92.638
USNR - SCRAP RECEIPTS NOT SEC.	1122.183	1139.638	1212.194	1388.026	1525.500
RPFUT1 - DEFL FUT PRICE (JAN)	55.697	61.216	67.177	69.451	72.897

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1984	1985
QD - TOTAL CONSUMPTION IN US	5181.898	5350.026
RPCMJ - DEFL. AVE REF. PRICE	104.255	105.338
NE - NET EXPORTS SCRAP + REF.	-354.480	-376.999
QR - TOTAL PRODUCTION REFINED	3278.792	3428.308
DELIF - STOCK CHANGE FABRICAT.	-2.200	8.931
DELIRR - STOCK CHANGE REFINER.	-56.362	-46.556
DELIRS - STOCK CHANGE SCRAP	22.196	22.625
QPR - TOTAL PROD. PRIMARY REF.	2964.351	3110.868
RPSR - PRICE SECONDARY REFINED	108.126	109.607
QSR - PROD REFINED FROM SCRAP	314.441	317.440
RPS - REAL PRICE OF SCRAP	91.606	92.967
QSNR - SCRAP RECEIPTS NOT SEC.	1512.260	1529.720
RPFUT1 - DEFL FUT PRICE (JAN)	72.133	73.088

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1974	1975	1976	1977	1978
PRODUCTION					
**********					
PRIMARY REFINED	2770550.300	2159718.100	2739279.200	3076050.700	3667066.500
SECONDARY REFINED	489994.850	257445.590	292079.360	345506.210	385105.290
NON-REFINED SCRAP	1375096.700	721463.680	960417.860	1152323.600	1421961.000
SALES					
*****					
PRIMARY REFINED	2720017.900	2251025.100	2940453.600	3315356.600	3805714.700
SECONDARY REFINED	467651.560	251256.600	298738.550	352663.520	375718.470
NON-REFINED SCRAP	1375096.700	721463.680	960417.860	1152323.600	1421961.000
EMPLOYMENT(MAN-YEARS)					
**********					
PRIMARY REFINED	17049.387	15438.296	17480.154	19522.611	20323.682
SECONDARY REFINED	2534.108	1858.687	1871.841	1996.259	2062.615
MINING AND MILLING	34238.214	30240.659	33833.509	37621.867	39138.405
POLL. ABATEMENT INVESTMENT					
***** ********* **********					
MINING AND MILLING	.000	.000	.000	.000	.000
SMELTING AND REFINING	226000.000	207801.170	.000	.000	.000
PHYSICAL REFINERY CAPACITY					
******** ******** ********					
BEGINNING OF YEAR	2546.000	2546.000	2605.000	2665.725	2707.611
NET CHANGE	-.000	59.000	60.725	41.886	38.539
CAPACITY UTILIZATION					
******** ***********					
PRIMARY REFINED	.792	.717	.793	.866	.887
SECONDARY REFINED	.985	.723	.632	.674	.697

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
MONETARY ESTIMATES IN 1000'S OF DOLLARS

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1979	1980	1981	1982	1983
PRODUCTION					
**********					
PRIMARY REFINED	3948384.300	3680724.700	3943752.100	5071624.100	6051677.700
SECONDARY REFINED	304849.670	415352.110	501756.150	598978.740	679470.840
NON-REFINED SCRAP	1373676.300	1426048.900	1653931.400	2274257.300	2826390.200
SALES					
*****					
PRIMARY REFINED	3952496.600	3825549.600	4222093.200	5253904.500	6096630.500
SECONDARY REFINED	294500.160	402965.850	497341.540	565991.900	611996.620
NON-REFINED SCRAP	1373676.300	1426048.900	1653931.400	2274257.300	2826390.200
EMPLOYMENT(MAN-YEARS)					
**********					
PRIMARY REFINED	21959.636	20689.621	21569.977	22943.872	24073.710
SECONDARY REFINED	1659.305	2201.221	2439.949	2556.118	2646.059
MINING AND MILLING	40797.711	40020.513	41977.028	44582.138	46714.702
POLL. ABATEMENT INVESTMENT					
***** ********* **********					
MINING AND MILLING	.000	.000	.000	.000	.000
SMELTING AND REFINING	.000	.000	.000	.000	.000
PHYSICAL REFINERY CAPACITY					
******** ******** ********					
BEGINNING OF YEAR	2746.150	2810.084	2907.807	3027.909	3149.782
NET CHANGE	63.934	97.723	120.101	121.874	137.150
CAPACITY UTILIZATION					
******** ***********					
PRIMARY REFINED	.945	.870	.877	.896	.905
SECONDARY REFINED	.560	.743	.824	.863	.894

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
MONETARY ESTIMATES IN 1000'S OF DOLLARS

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SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1984	1985
PRODUCTION		
**********		
PRIMARY REFINED	6180960.200	6553838.300
SECONDARY REFINED	679983.700	695874.150
NON-REFINED SCRAP	2770653.400	2844273.000
SALES		
*****		
PRIMARY REFINED	6298480.000	6651920.700
SECONDARY REFINED	631984.080	646276.940
NON-REFINED SCRAP	2770653.400	2844273.000
EMPLOYMENT(MAN-YEARS)		
**********		
PRIMARY REFINED	25079.113	26318.680
SECONDARY REFINED	2660.245	2685.616
MINING AND MILLING	48497.269	50708.765
POLL. ABATEMENT INVESTMENT		
***** ********* **********		
MINING AND MILLING	.000	.000
SMELTING AND REFINING	.000	.000
PHYSICAL REFINERY CAPACITY		
******** ******** ********		
BEGINNING OF YEAR	3286.933	3448.563
NET CHANGE	161.630	181.711
CAPACITY UTILIZATION		
******** ***********		
PRIMARY REFINED	.902	.902
SECONDARY REFINED	.898	.907

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
MONETARY ESTIMATES IN 1000'S OF DOLLARS

APPENDIX B

"CONSTRAINED CAPACITY" ENVIRONMENTAL POLICY SCENARIO MODEL RESULTS (1976-1985)

APPENDIX B--"CONSTRAINED CAPACITY" ENVIRONMENTAL POLICY SCENARIO MODEL RESULTS

Presented in this appendix are the following:

1. Historical and projected values of all independent (exogenous) variables, along with historical values of all dependent (endogenous) variables;

2. Summary of year-by-year model solutions for the nonlinear version of the model; and,

3. Summary of year-by-year subsidiary calculations (e.g. sales, production, employment, capacity, capacity utilization, etc.).

General Notes:

(1) Listing of variables/values: refer to Appendix D for a "dictionary" of the variables;

(2) Three "parametric" model solutions have been obtained for each year:

one: AVC = AR (Average variable cost = net demand schedule for primary producers)

two: ATC = AR (Average total cost = net demand schedule for primary producers)

three: AVC = MC = MR (Implicit monopolistic solution).

The solution used in our analysis (and also listed here) refers to Solution Two (ATC = AR). Refer to the technical Appendix for more detail.

EXOGENOUS AND ENDOGENOUS VARIABLES LISTED BELOW

YEAR	CONST	RPAL	YUD	RPLME	YUD/YGR	DUMST2	DIGOV	IRR(-1)	QFAB	DSTE2
1954	1.0000	24.555	43.082	38.525	1.3548	.50000	199.30	87.700	2113.0	1.5000
1955	1.0000	32.411	49.296	79.356	1.3469	1.5000	23.600	47.100	2565.0	.00000
1956	1.0000	28.855	50.953	69.752	1.2867	.00000	49.500	61.600	2435.5	.00000
1957	1.0000	23.002	51.284	44.777	1.2298	.00000	79.000	120.60	2214.0	.00000
1958	1.0000	20.745	44.905	39.699	1.0395	.00000	124.70	181.00	2021.5	4.6700
1959	1.0000	22.763	51.533	47.139	1.1130	4.6700	4.5000	80.700	2383.0	.75000
1960	1.0000	21.320	52.444	48.689	1.0144	.75000	6.0000	64.800	2119.5	.00000
1961	1.0000	18.924	51.450	43.642	.93716	.00000	-5.0000	139.30	2213.0	.00000
1962	1.0000	17.562	57.166	46.631	.99767	.00000	-7.4000	79.800	2423.0	.00000
1963	1.0000	18.372	60.895	46.646	1.0321	.00000	-11.400	117.40	2540.5	2.0000
1964	1.0000	19.306	65.451	69.101	1.0132	2.0000	-27.300	76.900	2863.0	.00000
1965	1.0000	22.770	73.322	90.972	1.0751	.00000	-122.50	45.600	3052.5	.00000
1966	1.0000	19.369	82.021	104.93	1.1853	.00000	-445.00	60.800	3398.5	5.5000
1967	1.0000	15.589	82.850	76.148	1.2311	5.5000	-177.20	65.700	2903.0	3.0000
1968	1.0000	14.472	87.407	80.416	1.1623	3.0000	-13.800	55.400	2911.0	.00000
1969	1.0000	17.991	91.135	91.460	1.0659	.00000	-8.0000	56.600	3274.0	.00000
1970	1.0000	14.515	84.093	84.768	.93333	.00000	.00000	45.900	2820.0	1.0000
1971	1.0000	10.593	82.353	62.581	.89709	1.0000	-1.8000	160.60	2909.5	.00000
1972	1.0000	9.2281	89.809	59.378	.94140	.00000	.00000	103.00	3234.0	.00000
1973	1.0000	13.018	101.08	94.261	.99387	.00000	-33.800	157.40	3596.5	2.2500
1974	1.0000	16.180	100.00	93.000	1.0000	2.2500	-182.50	49.100	3097.0	.00000
1975	1.0000	22.442	78.000	50.340	.97400	.00000	.00000	194.90	2315.0	.00000
1976	1.0000	30.093	98.524	56.640	1.0360	.00000	.00000	264.90	2602.1	1.5000
1977	1.0000	29.329	107.88	73.000	1.0250	1.5000	50.000	274.90	2849.3	.00000
1978	1.0000	29.051	106.85	73.000	1.0258	.00000	100.00	221.40	2822.1	.00000
1979	1.0000	28.874	104.39	75.000	1.0287	.00000	100.00	167.90	2757.2	.75000
1980	1.0000	28.352	111.53	80.000	1.0208	.75000	50.000	219.90	2945.8	.00000
1981	1.0000	28.528	123.35	92.000	1.0101	.00000	.00000	271.90	3258.0	.00000
1982	1.0000	28.737	132.71	100.00	1.0030	.00000	.00000	218.40	3505.3	1.5000
1983	1.0000	28.918	140.25	110.00	.99810	1.5000	.00000	164.90	3704.4	.00000
1984	1.0000	28.918	144.74	108.45	.99550	.00000	.00000	200.00	3822.9	.00000
1985	1.0000	28.918	149.37	112.00	.99289	.00000	.00000	200.00	3945.3	1.5000
1986	1.0000	28.918	154.15	-.00000	.99036	1.5000	.00000	200.00	4071.5	.00000
1987	1.0000	28.918	159.08	-.00000	.98800	.00000	.00000	200.00	4201.8	.00000
1988	1.0000	28.918	164.17	-.00000	.98570	.00000	.00000	200.00	4336.3	.75000
1989	1.0000	28.918	169.43	-.00000	.98346	.75000	.00000	200.00	4475.0	.00000
1990	1.0000	28.918	174.85	-.00000	.97895	.00000	.00000	200.00	4618.2	.00000
1991	1.0000	28.918	-.00000	-.00000	-.00000	.00000	.00000	200.00	-.00000	1.5000
1992	1.0000	28.918	-.00000	-.00000	-.00000	1.5000	.00000	200.00	-.00000	.00000
1993	1.0000	28.918	-.00000	-.00000	-.00000	.00000	.00000	200.00	-.00000	.00000

YEAR	IF(-1)	IRS(-1)	QD(-1)	IPOLLM+M	IPRODM+M	IPOLLS+R	KAPSR	KAPPR	DOLKAP	CAPAC
1954	172.00	60.000	2287.0	.00000	.00000	.00000	200.00	1696.0	535.76	.00000
1955	146.00	35.000	1916.5	.00000	.00000	.00000	206.00	1656.0	540.64	.00000
1956	170.00	56.000	2418.7	.00000	.00000	.00000	271.00	1799.0	545.35	.00000
1957	177.00	59.000	2365.0	.00000	.00000	.00000	271.00	1793.0	550.11	.00000
1958	175.00	43.000	2106.4	.00000	.00000	.00000	271.00	1810.5	554.90	.00000
1959	179.00	49.000	1974.6	.00000	.00000	.00000	296.00	1812.5	559.74	.00000
1960	140.00	71.000	2318.6	.00000	.00000	.00000	296.00	2013.0	564.62	.00000
1961	148.00	62.000	2079.3	.00000	.00000	.00000	313.50	2017.5	569.54	.00000
1962	152.00	43.000	2170.0	.00000	.00000	.00000	313.50	2027.5	574.51	.00000
1963	157.00	59.000	2361.1	.00000	.00000	.00000	317.50	2016.5	579.52	.00000
1964	149.00	47.000	2565.7	.00000	.14600+09	.00000	317.50	2016.5	584.57	.24292+10
1965	159.00	53.000	2775.0	.00000	.15800+09	.00000	317.50	2016.5	589.67	.00000
1966	168.00	49.000	2995.4	.00000	.17100+09	.00000	317.50	2102.5	594.81	.00000
1967	231.00	52.000	3368.6	.00000	.18400+09	.00000	314.00	2112.5	600.00	.00000
1968	182.00	48.000	2850.4	.00000	.19700+09	.00000	319.00	2208.0	645.42	.00000
1969	168.00	42.000	2813.5	.00000	.21100+09	.00000	304.00	2339.0	694.28	.00000
1970	178.00	57.000	3164.2	.00000	.22500+09	.20900+08	304.00	2372.0	746.84	.00000
1971	242.00	68.000	2930.5	.00000	.24000+09	.30000+08	304.00	2372.0	803.38	.00000
1972	229.00	51.000	2956.0	.00000	.25700+09	.14640+09	304.00	2489.0	864.20	.00000
1973	167.00	46.000	3266.2	.00000	.45450+09	.20460+09	304.00	2419.0	929.62	.00000
1974	167.00	42.000	3481.7	.00000	.46500+09	.22600+09	304.00	2546.0	1600.0	.43000+10
1975	242.00	43.000	3106.2	.00000	.37100+09	.24080+09	304.00	-.00000	1600.0	.00000
1976	272.00	63.000	-.00000	.00000	.25000+09	.15600+09	350.00	-.00000	1600.0	.00000
1977	281.00	63.000	-.00000	.00000	.25000+09	.90000+08	350.00	-.00000	1600.0	.00000
1978	255.00	52.000	-.00000	.00000	.25000+09	.60000+08	350.00	-.00000	1600.0	.00000
1979	229.00	41.000	-.00000	.00000	.25000+09	.40000+08	350.00	-.00000	1600.0	.00000
1980	252.50	51.400	-.00000	.00000	.25000+09	.40000+08	350.00	-.00000	1600.0	.00000
1981	276.00	61.000	-.00000	.00000	.42000+09	.60000+08	350.00	-.00000	1600.0	.00000
1982	250.00	50.800	-.00000	.00000	.76000+09	.10000+09	350.00	-.00000	1600.0	.00000
1983	224.00	39.800	-.00000	.00000	.76000+09	.10000+09	350.00	-.00000	1600.0	.00000
1984	250.00	50.000	-.00000	.00000	.44500+09	.60000+08	350.00	-.00000	1600.0	.00000
1985	250.00	50.000	-.00000	.00000	.30000+09	.40000+08	350.00	-.00000	1600.0	.00000
1986	250.00	50.000	-.00000	.00000	.00000	.00000	350.00	-.00000	1600.0	.00000
1987	250.00	50.000	-.00000	.00000	.00000	.00000	350.00	-.00000	1600.0	.00000
1988	250.00	50.000	-.00000	.00000	.00000	.00000	350.00	-.00000	1600.0	.00000
1989	250.00	50.000	-.00000	.00000	.00000	.00000	350.00	-.00000	1600.0	.00000
1990	250.00	50.000	-.00000	.00000	.00000	.00000	350.00	-.00000	1600.0	.00000
1991	250.00	50.000	-.00000	.00000	.00000	.00000	350.00	-.00000	1600.0	.00000
1992	250.00	50.000	-.00000	.00000	.00000	.00000	350.00	-.00000	1600.0	.00000
1993	250.00	50.000	-.00000	.00000	.00000	.00000	350.00	-.00000	1600.0	.00000

YEAR	FCCOEF1	FCCOEF2	FCCOEF3	FCCOEF4	FCCOEF5	FCCOEF6	DFP1	DFP2	REP	QCU
1954	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	835.50
1955	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	998.60
1956	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1104.2
1957	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1086.9
1958	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	979.30
1959	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	824.80
1960	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1080.2
1961	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1165.2
1962	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1228.4
1963	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1213.2
1964	.19460	.19460	.19460	.19460	.19460	.19460	.15700-01	.15700-01	.26600-01	1246.8
1965	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1351.7
1966	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.15700-01	.15700-01	.26600-01	1429.2
1967	.25000-01	.25000-01	.25000-01	.25000-01	.25000-01	.25000-01	.15700-01	.15700-01	.26600-01	954.10
1968	.17460	.17460	.17460	.17460	.17460	.17460	.15700-01	.15700-01	.26600-01	1204.6
1969	.25690	.25690	.25690	.25690	.25690	.25690	.15700-01	.15700-01	.26600-01	1544.6
1970	.27310	.27310	.27310	.27310	.27310	.27310	.15700-01	.15700-01	.26600-01	1719.7
1971	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.15700-01	.15700-01	.26600-01	1522.2
1972	.16850	.16850	.16850	.16850	.16850	.16850	.15700-01	.15700-01	.26600-01	1664.8
1973	.20380	.20380	.20380	.20380	.20380	.20380	.15700-01	.15700-01	.26600-01	1717.9
1974	.23280	.17000	.26280	.23280	.23280	.23280	.30930-01	.15700-01	.53200-01	1593.6
1975	.16280	.17000	.16650	.16280	.16280	.16280	.19100-02	.15700-01	.53200-01	-.00000
1976	.16280	.17000	.17650	.16280	.16280	.16280	.30000-01	.15700-01	.53200-01	-.00000
1977	.16280	.17000	.18650	.16280	.16280	.16280	.30000-01	.15700-01	.53200-01	-.00000
1978	.18280	.17000	.21280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1979	.18280	.17000	.21280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1980	.20280	.17000	.23280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1981	.20280	.17000	.23280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1982	.23280	.17000	.26280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1983	.23280	.17000	.26280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1984	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1985	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1986	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1987	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1988	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1989	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1990	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1991	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1992	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1993	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000

YEAR	NETY	CCAP1	FIPDE	VARCOS1	VARCOS2	VARCOS3	VARCOS4	QD	RPEMJ	NE
1954	.18549+06	.19620	84.000	-.00000	-.00000	-.00000	-.00000	1916.5	55.568	124.70
1955	.33379+06	.46990	85.900	-.00000	-.00000	-.00000	-.00000	2418.7	67.769	40.800
1956	.42300+06	.23100	91.800	-.00000	-.00000	-.00000	-.00000	2365.0	71.026	83.300
1957	.22613+06	-.88800-01	97.500	-.00000	-.00000	-.00000	-.00000	2106.4	48.357	274.00
1958	.17079+06	.45500-01	100.00	-.00000	-.00000	-.00000	-.00000	1974.6	41.203	287.40
1959	.20223+06	.17250	102.00	-.00000	-.00000	-.00000	-.00000	2318.6	49.289	-32.900
1960	.22508+06	-.22700-01	102.20	-.00000	-.00000	-.00000	-.00000	2079.5	50.616	438.00
1961	.20393+06	.11540	102.10	-.00000	-.00000	-.00000	-.00000	2170.0	47.500	480.50
1962	.21782+06	.62000-01	102.30	-.00000	-.00000	-.00000	-.00000	2361.1	48.633	269.80
1963	.22045+06	.15450	102.30	-.00000	-.00000	-.00000	-.00000	2565.7	48.633	228.40
1964	.27626+06	.19830	103.00	36.000	-.00000	-.00000	-.00000	2775.0	50.204	267.70
1965	.37756+06	.12170	103.90	37.000	-.00000	-.00000	-.00000	2995.4	54.320	256.10
1966	.49100+06	.90400-01	106.00	38.000	-.00000	-.00000	-.00000	3368.6	54.903	135.10
1967	.33791+06	.63000-01	109.30	39.000	-.00000	-.00000	-.00000	2850.4	56.814	-123.60
1968	.42022+06	.16590	112.00	40.000	-.00000	-.00000	-.00000	2813.5	60.086	-72.700
1969	.55193+06	.17490	115.20	41.000	-.00000	-.00000	-.00000	3164.2	65.577	130.70
1970	.51607+06	.11750	120.30	42.000	-.00000	-.00000	-.00000	2930.5	76.556	168.90
1971	.61506+06	-.49500-01	124.50	43.000	-.00000	-.00000	-.00000	2956.0	65.324	74.400
1972	.38322+06	.61700-01	126.50	44.000	-.00000	-.00000	-.00000	3266.2	62.118	29.500
1973	.59883+06	.91100-01	130.00	45.000	-.00000	-.00000	-.00000	3481.7	68.669	72.600
1974	.88136+06	.76400-01	143.50	43.000	-.00000	-.00000	-.00000	3106.2	-.00000	-108.50
1975	-.00000	.15180	150.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1976	-.00000	.16360	155.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1977	-.00000	.16440	160.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1978	-.00000	.17600	165.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1979	-.00000	.17870	170.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1980	-.00000	.16890	175.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1981	-.00000	.15810.	180.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1982	-.00000	.15280	185.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1983	-.00000	.15410	190.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1984	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1985	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1986	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1987	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1988	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1989	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1990	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1991	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1992	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1993	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000

YEAR	QH	DELIF	DELIRR	DELIRS	QPR	RPSR	QSR	RPS	QSNR	RPFUT1
1954	1418.4	-26.000	-40.600	-25.000	1220.1	64.645	198.30	45.929	742.00	46.753
1955	1562.8	24.000	14.500	21.000	1320.7	77.043	242.10	60.774	958.80	57.375
1956	1687.8	7.0000	59.000	3.0000	1467.2	68.903	220.60	53.617	855.40	76.868
1957	1676.1	-2.0000	60.400	-16.000	1422.1	54.095	254.00	32.843	808.70	52.575
1958	1579.5	4.0000	-100.30	6.0000	1373.1	48.912	206.40	28.119	735.30	38.420
1959	1331.5	-39.000	-75.400	22.000	1071.6	53.035	259.90	35.646	883.10	45.210
1960	1794.6	8.0000	74.500	-9.0000	1559.6	50.790	235.00	33.417	831.60	49.021
1961	1813.9	4.0000	-59.500	-19.000	1609.2	52.040	204.70	34.577	778.40	43.943
1962	1884.5	5.0000	37.600	16.007	1677.6	52.575	206.90	34.297	804.10	48.061
1963	1884.4	-8.0000	-40.500	-12.000	1639.7	53.544	244.70	35.267	849.00	45.343
1964	1990.4	10.000	-31.300	6.0000	1740.7	56.519	249.70	40.810	989.70	48.272
1965	2214.8	9.0000	15.200	-4.0000	1864.0	73.662	276.80	53.498	1025.6	55.669
1966	2183.3	63.000	4.9000	3.0000	1896.5	87.523	286.80	67.790	1013.1	82.559
1967	1526.6	-49.000	-10.300	-4.0000	1251.4	68.580	275.20	49.264	932.10	77.041
1968	1839.0	-14.000	1.2000	-6.0000	1546.3	67.136	292.70	47.055	982.60	73.855
1969	2214.9	10.000	-10.700	15.000	1937.0	78.477	277.90	59.161	1082.9	67.260
1970	2242.7	64.000	114.70	11.000	1975.1	70.917	267.60	52.342	978.50	69.935
1971	1962.4	-13.000	-57.600	-17.000	1733.3	60.422	229.10	35.018	971.90	60.485
1972	2258.5	-62.000	54.400	-5.0000	2011.4	72.426	247.10	47.883	1062.2	60.486
1973	2312.6	.00000	-108.30	-4.0000	2027.2	84.241	285.40	58.579	1119.5	60.329
1974	2136.5	75.000	145.80	1.0000	1838.8	79.880	297.70	54.880	1025.1	81.640
1975	-.00000	30.000	70.000	20.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1976	-.00000	9.0000	10.000	.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1977	-.00000	-26.000	-53.500	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1978	-.00000	-26.000	-53.500	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1979	-.00000	23.500	52.000	10.400	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1980	-.00000	23.500	52.000	10.400	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1981	-.00000	-26.000	-53.000	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1982	-.00000	-26.000	-53.000	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1983	-.00000	23.500	52.000	10.400	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1984	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1985	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1986	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1987	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1988	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1989	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1990	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1991	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1992	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1993	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1974	1975	1976	1977	1978
QD - TOTAL CONSUMPTION IN US	3598.477	2982.701	3548.958	3935.761	3981.446
RPEMJ - DEFL. AVE REF. PRICE	68.740	59.177	69.235	68.400	78.748
NE - NET EXPORTS SCRAP + REF.	-28.582	43.134	-146.355	-202.047	-225.944
QR - TOTAL PRODUCTION REFINED	2314.769	2044.503	2211.288	2483.667	2565.515
DELTF - STOCK CHANGE FABRICAT.	-.380	-40.166	-37.371	-51.430	-31.817
DELINR - STOCK CHANGE REFINER.	36.756	-77.148	-156.764	-183.880	-99.746
DELTRS - STOCK CHANGE SCRAP	13.658	5.282	-3.843	-4.132	7.598
QPR - TOTAL PROD. PRIMARY REF.	2015.238	1824.807	1990.742	2247.789	2315.001
RPSR - PRICE SECONDARY REFINED	81.794	58.591	67.550	74.264	80.966
QSR - PROD REFINED FROM SCRAP	299.532	219.697	220.547	235.878	250.512
RPS - REAL PRICE OF SCRAP	61.243	41.497	51.164	56.406	64.622
QSNR - SCRAP RECEIPTS NOT SEC.	1122.661	869.299	993.337	1060.604	1166.025
RPFUT1 - DEFL FUT PRICE (JAN)	70.665	48.689	51.553	60.711	58.992

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1979	1980	1981	1982	1983
QD - TOTAL CONSUMPTION IN US	3986.998	4124.006	4362.317	4594.132	4821.554
RPCMJ - DEFL. AVE REF. PRICE	81.982	78.839	84.560	104.754	120.596
NE - NET EXPORTS SCRAP + REF.	-264.323	-276.084	-243.780	-314.573	-394.920
QR - TOTAL PRODUCTION REFINED	2582.211	2570.004	2609.722	2656.026	2685.944
DELTF - STOCK CHANGE FABRICAT.	-18.570	-31.958	-28.851	-3.147	-5.526
DELTRR - STOCK CHANGE REFINER.	-33.475	-115.404	-198.654	-132.307	-77.975
DELTRS - STOCK CHANGE SCRAP	16.390	9.609	5.979	22.097	37.521
QPR - TOTAL PROD. PRIMARY REF.	2323.929	2301.150	2317.457	2343.202	2355.080
RPSR - PRICE SECONDARY REFINED	83.790	83.707	91.967	107.681	121.406
QSR - PROD REFINED FROM SCRAP	258.282	268.854	292.265	312.824	330.864
RPS - REAL PRICE OF SCRAP	67.645	66.504	74.073	91.444	105.982
QSNR - SCRAP RECEIPTS NOT SEC.	1204.810	1190.166	1287.290	1510.175	1696.711
RPFUT1 - DEFL FUT PRICE (JAN)	59.902	63.035	67.632	71.269	77.535

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1984	1985
DD - TOTAL CONSUMPTION IN US	4960.707	5149.982
RPEMJ - DEFL. AVE REF. PRICE	116.310	116.055
NE - NET EXPORTS SCRAP + REF.	-376.301	-387.769
QR - TOTAL PRODUCTION REFINED	2858.160	3046.500
DELTF - STOCK CHANGE FABRICAT.	-2.200	8.931
DELTRR - STOCK CHANGE REFINER.	-101.900	-92.420
DELTNS - STOCK CHANGE SCRAP	27.807	27.413
QPR - TOTAL PROD. PRIMARY REF.	2530.553	2715.472
RPSR - PRICE SECONDARY REFINED	118.130	119.348
QSR - PROD REFINED FROM SCRAP	327.607	331.028
RPS - REAL PRICE OF SCRAP	102.338	103.092
QSUR - SCRAP RECEIPTS NOT SEC.	1649.953	1659.638
RPFUT4 - DEFL FUT PRICE (JAN)	75.112	76.726

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

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SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1974	1975	1976	1977	1978
PRODUCTION					
PRIMARY REFINED	2770550.300	2159718.100	2756562.400	3074974.400	3646021.300
SECONDARY REFINED	489994.850	257445.590	297959.480	350344.680	405658.600
NON-REFINED SCRAP	1375096.700	721463.680	1016458.080	1196495.400	1507023.900
SALES					
PRIMARY REFINED	2720017.900	2251025.100	2973631.700	3326522.700	3803117.300
SECONDARY REFINED	467651.560	251256.600	303151.100	356482.280	393354.480
NON-REFINED SCRAP	1375096.700	721463.680	1016458.080	1196495.400	1507023.900
EMPLOYMENT(MAN-YEARS)					
PRIMARY REFINED	17049.387	15438.296	16842.148	19016.831	19585.460
SECONDARY REFINED	2534.108	1858.687	1865.877	1995.580	2119.391
MINING AND MILLING	34238.214	30240.659	32707.609	36736.412	37947.021
POLL. ABATEMENT INVESTMENT					
MINING AND MILLING	.000	.000	.000	.000	.000
SMELTING AND REFINING	226000.000	207801.170	126315.787	66914.497	40863.583
PHYSICAL REFINERY CAPACITY					
BEGINNING OF YEAR	2546.000	2546.000	2605.000	2605.000	2605.000
NET CHANGE	-.000	59.000	-.000	-.000	-.000
CAPACITY UTILIZATION					
PRIMARY REFINED	.792	.717	.764	.863	.889
SECONDARY REFINED	.985	.723	.630	.674	.716

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
MONETARY ESTIMATES IN 1000'S OF DOLLARS

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1979	1980	1981	1982	1983
PRODUCTION					
PRIMARY REFINED	3810387.100	3628399.300	3919278.400	4909191.800	5680284.100
SECONDARY REFINED	432830.330	450100.110	537572.260	673704.420	803375.650
NON-REFINED SCRAP	1629987.700	1583011.000	1907073.100	2761923.400	3596401.100
SALES					
PRIMARY REFINED	3865273.100	3810365.000	4255241.500	5186386.200	5868353.400
SECONDARY REFINED	405363.110	434012.480	526574.880	626116.280	712270.650
NON-REFINED SCRAP	1629987.700	1583011.000	1907073.100	2761923.400	3596401.100
EMPLOYMENT(MAN-YEARS)					
PRIMARY REFINED	19660.992	19468.275	19606.234	19824.047	19924.536
SECONDARY REFINED	2185.125	2274.570	2472.630	2646.562	2799.188
MINING AND MILLING	38193.999	38013.449	38600.915	39285.810	39728.338
POLL. ABATEMENT INVESTMENT					
MINING AND MILLING	.000	.000	.000	.000	.000
SMELTING AND REFINING	25730.091	23923.445	33774.275	53199.978	50243.682
PHYSICAL REFINERY CAPACITY					
BEGINNING OF YEAR	2605.000	2605.000	2605.000	2605.000	2605.000
NET CHANGE	-.000	-.000	-.000	-.000	200.000
CAPACITY UTILIZATION					
PRIMARY REFINED	.892	.883	.890	.900	.904
SECONDARY REFINED	.738	.768	.835	.894	.945

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
MONETARY ESTIMATES IN 1000'S OF DOLLARS

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SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1984	1985
PRODUCTION		
PRIMARY REFINED	5886566.300	6302876.300
SECONDARY REFINED	774001.730	790151.420
NON-REFINED SCRAP	3377041.300	3421917.900
SALES		
PRIMARY REFINED	6123605.600	6517391.900
SECONDARY REFINED	708305.790	724716.460
NON-REFINED SCRAP	3377041.300	3421917.900
EMPLOYMENT(MAN-YEARS)		
PRIMARY REFINED	21409.076	22973.540
SECONDARY REFINED	2771.632	2800.576
MINING AND MILLING	42275.612	45061.397
POLL. ABATEMENT INVESTMENT		
MINING AND MILLING	.000	.000
SMELTING AND REFINING	28710.882	18229.048
PHYSICAL REFINERY CAPACITY		
BEGINNING OF YEAR	2805.000	3005.000
NET CHANGE	200.000	-.000
CAPACITY UTILIZATION		
PRIMARY REFINED	.902	.904
SECONDARY REFINED	.936	.946

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
MONETARY ESTIMATES IN 1000'S OF DOLLARS

APPENDIX C

"REDUCED CAPACITY" ENVIRONMENTAL POLICY SCENARIO
MODEL RESULTS
(1976-1985)

APPENDIX C--"REDUCED CAPACITY" ENVIRONMENTAL POLICY SCENARIO MODEL RESULTS

Presented in this appendix are the following:

1. Historical and projected values of all independent (exogenous) variables, along with historical values of all dependent (endogenous) variables;

2. Summary of year-by-year model solutions for the nonlinear version of the model; and,

3. Summary of year-by-year subsidiary calculations (e.g. sales, production, employment, capacity, capacity utilization, etc.).

General Notes:

(1) Listing of variables/values: refer to Appendix D for a "dictionary" of the variables;

(2) Three "parametric" model solutions have been obtained for each year:

one: AVE = AR (Average variable cost = net demand schedule for primary producers)

two: ATC = AR (Average total cost = net demand schedule for primary producers)

three: AVE = MC = MR (Implicit monopolistic solution).

The solution used in our analysis (and also listed here) refers to Solution Two (ATC = AR). Refer to the technical Appendix for more detail.

EXOGENOUS AND ENDOGENOUS VARIABLES LISTED BELOW

YEAR	CONST	RPAL	YUD	RPLME	YUD/YGR	DUMST2	DIGOV	IRR(-1)	QFAB	DSTE2
1954	1.0000	24.559	43.082	58.525	1.3548	.50000	199.30	87.700	2113.0	1.5000
1955	1.0000	32.411	49.296	79.356	1.3469	1.5000	23.600	47.100	2565.0	.00000
1956	1.0000	28.855	50.953	69.752	1.2867	.00000	49.500	61.600	2435.5	.00000
1957	1.0000	23.002	51.284	44.777	1.2298	.00000	79.000	120.60	2214.0	.00000
1958	1.0000	20.745	44.905	39.699	1.0395	.00000	124.70	181.00	2021.5	4.6700
1959	1.0000	22.763	51.533	47.139	1.1130	4.6700	4.5000	80.700	2583.0	.75000
1960	1.0000	21.320	52.444	48.689	1.0144	.75000	6.0000	64.800	2119.5	.00000
1961	1.0000	18.924	51.450	45.642	.93716	.00000	-5.0000	139.30	2213.0	.00000
1962	1.0000	17.562	57.166	46.631	.99767	.00000	-7.4000	79.800	2423.0	.00000
1963	1.0000	18.372	60.895	46.646	1.0321	.00000	-11.400	117.40	2540.5	2.0000
1964	1.0000	19.306	65.451	69.101	1.0132	2.0000	-27.500	76.900	2863.0	.00000
1965	1.0000	22.770	73.322	90.972	1.0751	.00000	-122.50	45.600	3052.5	.00000
1966	1.0000	19.369	82.021	104.93	1.1853	.00000	-445.00	60.800	3398.5	5.5000
1967	1.0000	15.589	82.850	76.148	1.2311	5.5000	-177.20	65.700	2903.0	3.0000
1968	1.0000	14.472	87.407	80.416	1.1673	3.0000	-13.800	55.400	2911.0	.00000
1969	1.0000	17.991	91.135	91.460	1.0659	.00000	-8.0000	56.600	3274.0	.00000
1970	1.0000	14.515	84.093	84.768	.93335	.00000	.00000	45.900	2820.0	1.0000
1971	1.0000	10.593	82.353	62.581	.89709	1.0000	-1.8000	160.60	2909.5	.00000
1972	1.0000	9.2281	89.809	59.578	.94140	.00000	.00000	103.00	3234.0	.00000
1973	1.0000	13.018	101.08	94.261	.99387	.00000	-33.800	157.40	3596.5	2.2500
1974	1.0000	16.180	100.00	93.000	1.0000	2.2500	-182.50	49.100	3097.0	.00000
1975	1.0000	22.442	78.000	50.340	.97400	.00000	.00000	194.90	2315.0	.00000
1976	1.0000	30.093	98.524	56.640	1.0360	.00000	.00000	264.90	2602.1	1.5000
1977	1.0000	29.329	107.88	73.000	1.0250	1.5000	50.000	274.90	2849.3	.00000
1978	1.0000	29.051	106.85	73.000	1.0258	.00000	100.00	221.40	2822.1	.00000
1979	1.0000	28.874	104.39	75.000	1.0287	.00000	100.00	167.90	2757.2	.75000
1980	1.0000	28.352	111.53	80.000	1.0208	.75000	50.000	219.90	2745.6	.00000
1981	1.0000	28.528	123.35	92.000	1.0101	.00000	.00000	271.90	3258.0	.00000
1982	1.0000	28.737	132.71	100.00	1.0030	.00000	.00000	218.40	3505.3	1.5000
1983	1.0000	28.918	140.25	110.00	.99810	1.5000	.00000	164.90	3704.4	.00000
1984	1.0000	28.918	144.74	115.00	.99550	.00000	.00000	200.00	3822.9	.00000
1985	1.0000	28.918	149.37	120.00	.99289	.00000	.00000	200.00	3945.3	1.5000
1986	1.0000	28.918	154.15	125.00	.99036	1.5000	.00000	200.00	4071.5	.00000
1987	1.0000	28.918	159.08	130.00	.98800	.00000	.00000	200.00	4201.8	.00000
1988	1.0000	28.918	164.17	130.00	.98570	.00000	.00000	200.00	4336.3	.75000
1989	1.0000	28.918	169.43	130.00	.98346	.75000	.00000	200.00	4475.0	.00000
1990	1.0000	28.918	174.85	130.00	.97895	.00000	.00000	200.00	4618.2	.00000
1991	1.0000	28.918	-.00000	130.00	-.00000	.00000	.00000	200.00	-.00000	1.5000
1992	1.0000	28.918	-.00000	130.00	-.00000	1.5000	.00000	200.00	-.00000	.00000
1993	1.0000	28.918	-.00000	130.00	-.00000	.00000	.00000	200.00	-.00000	.00000

YEAR	IF(-1)	IRS(-1)	QD(-1)	IPOLLM+M	IPRODM+M	IPOLLS+R	KAPSR	KAPPR	DOLKAP	CAPAC
1954	172.00	60.000	2287.0	.00000	.00000	.00000	200.00	1696.0	535.76	.00000
1955	146.00	35.000	1916.5	.00000	.00000	.00000	206.00	1656.0	540.64	.00000
1956	170.00	56.000	2418.7	.00000	.00000	.00000	271.00	1799.0	545.35	.00000
1957	177.00	59.000	2365.0	.00000	.00000	.00000	271.00	1793.0	550.11	.00000
1958	175.00	43.000	2106.4	.00000	.00000	.00000	271.00	1810.5	554.90	.00000
1959	179.00	49.000	1974.6	.00000	.00000	.00000	296.00	1812.5	559.74	.00000
1960	140.00	71.000	2318.6	.00000	.00000	.00000	296.00	2013.0	564.62	.00000
1961	148.00	62.000	2079.3	.00000	.00000	.00000	313.50	2017.5	569.54	.00000
1962	152.00	43.000	2170.0	.00000	.00000	.00000	313.50	2027.5	574.51	.00000
1963	157.00	59.000	2361.1	.00000	.00000	.00000	317.50	2016.5	579.52	.00000
1964	149.00	47.000	2565.7	.00000	.14600+09	.00000	317.50	2016.5	584.57	.24292+10
1965	159.00	53.000	2775.0	.00000	.15800+09	.00000	317.50	2016.5	589.67	.00000
1966	168.00	49.000	2995.4	.00000	.17100+09	.00000	317.50	2102.5	594.81	.00000
1967	231.00	52.000	3368.6	.00000	.18400+09	.00000	314.00	2112.5	600.00	.00000
1968	182.00	48.000	2850.4	.00000	.19700+09	.00000	319.00	2208.0	645.42	.00000
1969	168.00	42.000	2813.5	.00000	.21100+09	.00000	304.00	2339.0	694.28	.00000
1970	178.00	57.000	3164.2	.00000	.22500+09	.20900+08	304.00	2372.0	746.84	.00000
1971	242.00	68.000	2930.5	.00000	.24000+09	.30000+08	304.00	2372.0	803.38	.00000
1972	229.00	51.000	2956.0	.00000	.25700+09	.14640+09	304.00	2489.0	864.20	.00000
1973	167.00	46.000	3266.2	.00000	.45450+09	.20460+09	304.00	2419.0	929.62	.00000
1974	167.00	42.000	3481.7	.00000	.46500+09	.22600+09	304.00	2546.0	1600.0	.43000+10
1975	242.00	43.000	3106.2	.00000	.37100+09	.24080+09	304.00	-.00000	1600.0	.00000
1976	272.00	63.000	-.00000	.00000	.25000+09	.15600+09	350.00	-.00000	1600.0	.00000
1977	281.00	63.000	-.00000	.00000	.25000+09	.90000+08	350.00	-.00000	1600.0	.00000
1978	255.00	52.000	-.00000	.00000	.25000+09	.60000+08	350.00	-.00000	1600.0	.00000
1979	229.00	41.000	-.00000	.00000	.25000+09	.40000+08	350.00	-.00000	1600.0	.00000
1980	252.50	51.400	-.00000	.00000	.25000+09	.40000+08	350.00	-.00000	1600.0	.00000
1981	276.00	61.000	-.00000	.00000	.25000+09	.40000+08	350.00	-.00000	1600.0	.00000
1982	250.00	50.800	-.00000	.00000	.25000+09	.40000+08	350.00	-.00000	1600.0	.00000
1983	224.00	39.800	-.00000	.00000	.25000+09	.40000+08	350.00	-.00000	1600.0	.00000
1984	250.00	50.000	-.00000	.00000	.25000+09	.40000+08	350.00	-.00000	1600.0	.00000
1985	250.00	50.000	-.00000	.00000	.25000+09	.40000+08	350.00	-.00000	1600.0	.00000
1986	250.00	50.000	-.00000	.00000	.25000+09	.00000	350.00	-.00000	1600.0	.00000
1987	250.00	50.000	-.00000	.00000	.25000+09	.00000	350.00	-.00000	1600.0	.00000
1988	250.00	50.000	-.00000	.00000	.25000+09	.00000	350.00	-.00000	1600.0	.00000
1989	250.00	50.000	-.00000	.00000	.25000+09	.00000	350.00	-.00000	1600.0	.00000
1990	250.00	50.000	-.00000	.00000	.25000+09	.00000	350.00	-.00000	1600.0	.00000
1991	250.00	50.000	-.00000	.00000	.25000+09	.00000	350.00	-.00000	1600.0	.00000
1992	250.00	50.000	-.00000	.00000	.25000+09	.00000	350.00	-.00000	1600.0	.00000
1993	250.00	50.000	-.00000	.00000	.25000+09	.00000	350.00	-.00000	1600.0	.00000

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YEAR	FCCOEF1	FCCOEF2	FCCOEF3	FCCOEF4	FCCOEF5	FCCOEF6	DFP1	DEP2	REP	QCU
1954	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	835.50
1955	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	998.60
1956	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1104.2
1957	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1086.9
1958	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	979.30
1959	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	824.80
1960	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1080.2
1961	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1165.2
1962	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1228.4
1963	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1213.2
1964	.19460	.19460	.19460	.19460	.19460	.19460	.15700-01	.15700-01	.26600-01	1246.8
1965	.22120	.22120	.22120	.22120	.22120	.22120	.15700-01	.15700-01	.26600-01	1351.7
1966	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.15700-01	.15700-01	.26600-01	1429.2
1967	.25000-01	.25000-01	.25000-01	.25000-01	.25000-01	.25000-01	.15700-01	.15700-01	.26600-01	954.10
1968	.17460	.17460	.17460	.17460	.17460	.17460	.15700-01	.15700-01	.26600-01	1204.6
1969	.25690	.25690	.25690	.25690	.25690	.25690	.15700-01	.15700-01	.26600-01	1544.6
1970	.27310	.27310	.27310	.27310	.27310	.27310	.15700-01	.15700-01	.26600-01	1719.7
1971	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.10000+00	.15700-01	.15700-01	.26600-01	1522.2
1972	.16850	.16850	.16850	.16850	.16850	.16850	.15700-01	.15700-01	.26600-01	1664.8
1973	.20380	.20380	.20380	.20380	.20380	.20380	.15700-01	.15700-01	.26600-01	1717.9
1974	.23280	.17000	.26280	.23280	.23280	.23280	.30930-01	.15700-01	.53200-01	1593.6
1975	.16280	.17000	.16650	.16280	.16280	.16280	.19100-02	.15700-01	.53200-01	-.00000
1976	.16280	.17000	.17650	.16280	.16280	.16280	.30000-01	.15700-01	.53200-01	-.00000
1977	.16280	.17000	.18650	.16280	.16280	.16280	.30000-01	.15700-01	.53200-01	-.00000
1978	.18280	.17000	.21280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1979	.18280	.17000	.21280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1980	.20280	.17000	.23280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1981	.20280	.17000	.23280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1982	.23280	.17000	.26280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1983	.23280	.17000	.26280	.23280	.23280	.23280	.30000-01	.15700-01	.53200-01	-.00000
1984	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1985	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1986	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1987	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1988	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1989	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1990	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1991	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1992	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000
1993	.23280	.17000	.26280	-.00000	-.00000	-.00000	.30000-01	.15700-01	.53200-01	-.00000

YEAR	NETY	CCAP1	FIPDE	VARCOS1	VARCOS2	VARCOS3	VARCOS4	QD	RPEMJ	NE
1954	.18549+06	.19620	84.000	-.00000	-.00000	-.00000	-.00000	1916.5	55.568	124.70
1955	.33379+06	.46990	85.900	-.00000	-.00000	-.00000	-.00000	2418.7	67.769	40.800
1956	.42300+06	.23100	91.800	-.00000	-.00000	-.00000	-.00000	2365.0	71.026	83.300
1957	.22613+06	-.88800-01	97.500	-.00000	-.00000	-.00000	-.00000	2106.4	48.357	274.00
1958	.17079+06	.45500-01	100.00	-.00000	-.00000	-.00000	-.00000	1974.6	41.203	287.40
1959	.20223+06	.17250	102.00	-.00000	-.00000	-.00000	-.00000	2318.6	49.289	-32.900
1960	.22508+06	-.22700-01	102.20	-.00000	-.00000	-.00000	-.00000	2079.3	50.616	438.00
1961	.20593+06	.11540	102.10	-.00000	-.00000	-.00000	-.00000	2170.0	47.500	480.50
1962	.21782+06	.62000-01	102.30	-.00000	-.00000	-.00000	-.00000	2361.1	48.633	269.80
1963	.22045+06	.15450	102.30	-.00000	-.00000	-.00000	-.00000	2565.7	48.633	228.40
1964	.27626+06	.19830	103.00	36.000	-.00000	-.00000	-.00000	2775.0	50.204	267.70
1965	.37756+06	.12170	103.90	37.000	-.00000	-.00000	-.00000	2995.4	54.320	256.10
1966	.49100+06	.90400-01	106.00	38.000	-.00000	-.00000	-.00000	3368.6	54.903	135.10
1967	.33791+06	.63000-01	109.30	39.000	-.00000	-.00000	-.00000	2850.4	56.814	-123.60
1968	.42022+06	.16590	112.00	40.000	-.00000	-.00000	-.00000	2813.5	60.086	-72.700
1969	.55193+06	.17490	115.20	41.000	-.00000	-.00000	-.00000	3164.2	65.577	130.70
1970	.51607+06	.11750	120.30	42.000	-.00000	-.00000	-.00000	2930.5	76.556	168.90
1971	.61506+06	-.49500-01	124.50	43.000	-.00000	-.00000	-.00000	2956.0	65.324	74.400
1972	.58322+06	.61700-01	126.50	44.000	-.00000	-.00000	-.00000	3266.2	62.118	29.500
1973	.59883+06	.71100-01	130.00	45.000	-.00000	-.00000	-.00000	3481.7	68.669	72.600
1974	.88136+06	.76400-01	143.50	43.000	-.00000	-.00000	-.00000	3106.2	-.00000	-108.50
1975	-.00000	.15180	150.00	43.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1976	-.00000	.16360	155.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1977	-.00000	.16440	160.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1978	-.00000	.17600	165.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1979	-.00000	.17870	170.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1980	-.00000	.16890	175.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1981	-.00000	.15810	180.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1982	-.00000	.15280	185.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1983	-.00000	.15410	190.00	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1984	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1985	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1986	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1987	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1988	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1989	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1990	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1991	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1992	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1993	-.00000	.15410	-.00000	45.500	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000

YEAR	QH	DELIF	DELIRR	DELIRS	QPR	RPSR	QSR	RPS	QSNR	RPFUT1
1954	1418.4	-26.000	-40.600	-25.000	1220.1	64.645	198.30	45.929	742.00	46.753
1955	1562.8	24.000	14.500	21.000	1320.7	77.043	242.10	60.774	938.80	57.375
1956	1687.8	7.0000	59.000	3.0000	1467.2	68.903	220.60	53.617	855.40	76.868
1957	1676.1	-2.0000	60.400	-16.000	1422.1	54.095	254.00	32.843	808.70	52.575
1958	1579.5	4.0000	-100.30	6.0000	1373.1	48.912	206.40	28.119	735.30	58.420
1959	1331.5	-39.000	-75.900	22.000	1071.6	53.035	259.90	35.646	883.10	45.210
1960	1794.6	8.0000	74.500	-9.0000	1559.6	50.790	235.00	33.417	851.60	49.021
1961	1813.9	4.0000	-59.500	-19.000	1609.2	52.040	204.70	34.577	778.40	43.943
1962	1884.5	5.0000	37.600	16.007	1677.6	52.575	206.90	34.297	804.10	48.061
1963	1884.4	-8.0000	-40.500	-12.000	1639.7	53.544	244.70	35.267	849.00	45.343
1964	1990.4	10.000	-31.300	6.0000	1740.7	56.519	249.70	40.810	989.70	48.272
1965	2214.8	9.0000	15.200	-4.0000	1864.0	73.662	276.80	53.498	1025.6	55.669
1966	2183.3	63.000	4.9000	3.0000	1896.5	87.523	286.80	67.790	1013.1	82.559
1967	1526.6	-49.000	-10.300	-4.0000	1251.4	68.584	275.20	49.264	932.10	77.441
1968	1839.0	-14.000	1.2000	-6.0000	1546.3	67.136	292.70	47.035	982.60	73.855
1969	2214.9	10.000	-10.700	15.000	1937.0	78.477	277.90	59.161	1082.9	67.260
1970	2242.7	64.000	114.70	11.000	1975.1	70.917	267.60	52.342	978.50	69.935
1971	1962.4	-13.000	-57.600	-17.000	1733.3	60.422	229.10	35.018	971.90	60.485
1972	2258.5	-62.000	54.400	-5.0000	2011.4	72.426	247.10	47.883	1062.2	60.486
1973	2312.6	.00000	-108.30	-4.0000	2027.2	84.241	285.40	58.579	1119.5	60.329
1974	2136.5	75.000	145.80	1.0000	1836.8	79.880	297.70	54.860	1025.1	81.640
1975	-.00000	30.000	70.000	20.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1976	-.00000	9.0000	10.000	.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1977	-.00000	-26.000	-53.500	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1978	-.00000	-26.000	-53.500	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1979	-.00000	23.500	52.000	10.400	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1980	-.00000	23.500	52.000	10.400	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1981	-.00000	-26.000	-53.000	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1982	-.00000	-26.000	-53.000	-11.000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1983	-.00000	23.500	52.000	10.400	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1984	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1985	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1986	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1987	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1988	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1989	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1990	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1991	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1992	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000
1993	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000	-.00000

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1974	1975	1976	1977	1978
QD - TOTAL CONSUMPTION IN US	3598.477	2982.701	3548.958	3940.675	3946.806
RPLMJ - DEFL. AVE RLF. PRICE	68.740	59.177	69.235	68.024	81.497
NE - NET EXPORTS SCRAP + REF.	-28.582	43.134	-146.355	-200.558	-236.841
QR - TOTAL PRODUCTION REFINED	2314.769	2044.503	2211.288	2093.374	2489.026
DELTF - STOCK CHANGE FABRICAT.	-.380	-40.166	-37.371	-51.430	-31.817
DELTRR - STOCK CHANGE REFINER.	36.756	-77.148	-156.764	-183.240	-105.217
DELTRS - STOCK CHANGE SCRAP	13.658	5.282	-3.843	-4.286	9.103
QPR - TOTAL PROD. PRIMARY REF.	2015.238	1824.807	1990.742	2257.406	2236.090
RPSR - PRICE SECONDARY REFINED	81.794	58.591	67.550	74.067	82.700
QSR - PROD REFINED FROM SCRAP	299.532	219.697	220.547	235.968	252.936
RPS - REAL PRICE OF SCRAP	61.243	41.497	51.164	56.187	66.725
QSNR - SCRAP RECEIPTS NOT SEC.	1122.661	869.299	993.337	1057.787	1193.008
RPFUT1 - DEFL FUT PRICE (JAN)	70.665	48.689	51.553	60.711	58.992

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1979	1980	1981	1982	1983
QD - TOTAL CONSUMPTION IN US	3946.109	4058.380	4291.672	4521.751	4749.437
RPEMJ - DEFL. AVE REF. PRICE	84.391	83.009	88.603	108.826	124.612
NE - NET EXPORTS SCRAP + REF.	-273.873	-292.619	-259.805	-330.713	-410.837
QR - TOTAL PRODUCTION REFINED	2503.622	2439.274	2475.326	2519.284	2550.014
DELIP - STOCK CHANGE FABRICAT.	-18.570	-31.958	-28.851	-3.147	-3.526
DELTRR - STOCK CHANGE REFINER.	-39.305	-124.916	-208.530	-142.350	-87.946
DELTRS - STOCK CHANGE SCRAP	17.676	11.710	7.949	24.039	39.394
QPR - TOTAL PROD. PRIMARY REF.	2243.483	2168.213	2181.450	2205.176	2218.229
RPSR - PRICE SECONDARY REFINED	85.308	86.347	94.522	110.256	123.955
QSR - PROD REFINED FROM SCRAP	260.139	271.061	293.875	314.107	331.784
RPS - REAL PRICE OF SCRAP	69.485	69.712	77.177	94.571	109.083
QSNR - SCRAP RECEIPTS NOT SEC.	1228.416	1231.327	1327.110	1550.296	1736.508
RPFUT1 - DEFL FUT PRICE (JAN)	59.902	63.035	67.632	71.269	77.535

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1984	1985
QD - TOTAL CONSUMPTION IN US	4816.960	4915.009
RPEMJ - DEFL. AVE REF. PRICE	125.806	131.042
NE - NET EXPORTS SCRAP + REF.	-387.978	-415.466
QR - TOTAL PRODUCTION REFINED	2555.958	2565.883
DELTF - STOCK CHANGE FABRICAT.	-2.200	8.931
DELTRR - STOCK CHANGE REFINER.	-137.897	-144.546
DELTRS - STOCK CHANGE SCRAP	31.859	33.996
QPR - TOTAL PROD. PRIMARY REF.	2218.710	2221.879
RPSR - PRICE SECONDARY REFINED	126.623	131.808
QSR - PROD REFINED FROM SCRAP	337.248	344.004
RPS - REAL PRICE OF SCRAP	111.287	116.529
QSNR - SCRAP RECEIPTS NOT SEC.	1764.785	1832.041
RPFUT1 - DEFL FUT PRICE (JAN)	78.090	80.364

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
PRICE ESTIMATES IN CENTS PER POUND

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1974	1975	1976	1977	1978
PRODUCTION					
PRIMARY REFINED	2770550.300	2159718.100	2756562.400	3071173.100	3644686.200
SECONDARY REFINED	489994.850	257445.590	297959.480	349548.960	418353.180
NON-REFINED SCRAP	1375096.700	721463.680	1016458.080	1188673.500	1592076.600
SALES					
PRIMARY REFINED	2720017.900	2251025.100	2973631.700	3320468.500	3816183.700
SECONDARY REFINED	467651.560	251256.600	303151.100	355897.290	403296.470
NON-REFINED SCRAP	1375096.700	721463.680	1016458.080	1188673.500	1592076.600
EMPLOYMENT(MAN-YEARS)					
PRIMARY REFINED	17049.387	15438.296	16842.148	19098.193	18917.856
SECONDARY REFINED	2534.108	1858.687	1865.877	1996.343	2159.896
MINING AND MILLING	34238.214	30240.659	32707.609	36879.994	36815.684
POLL. ABATEMENT INVESTMENT					
MINING AND MILLING	.000	.000	.000	.000	.000
SMELTING AND REFINING	226000.000	207801.170	126315.787	66914.497	40863.585
PHYSICAL REFINERY CAPACITY					
BEGINNING OF YEAR	2546.000	2546.000	2605.000	2605.000	2507.000
NET CHANGE	-.000	59.000	-.000	-98.000	-.000
CAPACITY UTILIZATION					
PRIMARY REFINED	.792	.717	.764	.867	.892
SECONDARY REFINED	.985	.723	.630	.674	.723

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
MONETARY ESTIMATES IN 1000'S OF DOLLARS

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1979	1980	1981	1982	1983
PRODUCTION					
PRIMARY REFINED	3786579.700	3599640.700	3865647.900	4799595.200	5528364.500
SECONDARY REFINED	443837.250	468108.380	555555.840	692644.460	822529.700
NON-REFINED SCRAP	1707124.200	1716756.000	2048437.200	2932252.000	3788478.700
SALES					
PRIMARY REFINED	3852918.700	3807024.800	4235174.400	5109422.100	5747546.300
SECONDARY REFINED	413679.130	447886.110	540528.150	639655.520	724868.860
NON-REFINED SCRAP	1707124.200	1716756.000	2048437.200	2932252.000	3788478.700
EMPLOYMENT(MAN-YEARS)					
PRIMARY REFINED	18980.398	18343.595	18455.588	18656.515	18766.745
SECONDARY REFINED	2200.839	2293.243	2486.255	2657.424	2806.974
MINING AND MILLING	37031.575	36079.793	36613.038	37263.229	37717.760
POLL. ABATEMENT INVESTMENT					
MINING AND MILLING	.000	.000	.000	.000	.000
SMELTING AND REFINING	25730.091	23923.445	22516.184	21279.991	20097.473
PHYSICAL REFINERY CAPACITY					
BEGINNING OF YEAR	2507.000	2437.000	2437.000	2437.000	2437.000
NET CHANGE	-70.000	-.000	-.000	-.000	-.000
CAPACITY UTILIZATION					
PRIMARY REFINED	.895	.890	.895	.905	.910
SECONDARY REFINED	.743	.774	.840	.897	.948

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
MONETARY ESTIMATES IN 1000'S OF DOLLARS

SUMMARY FOR YEARS: 1974 - 1985
MOST PROBABLE
PARAMETRIC SOLUTIONS FOR THE ENDOGENOUS VARIABLES

	1984	1985
PRODUCTION		
**********		
PRIMARY REFINED	5582529.500	5823207.300
SECONDARY REFINED	854067.090	906850.360
NON-REFINED SCRAP	3927953.200	4269704.100
SALES		
*****		
PRIMARY REFINED	5929494.500	6202040.200
SECONDARY REFINED	773386.460	817232.210
NON-REFINED SCRAP	3927953.200	4269704.100
EMPLOYMENT(MAN-YEARS)		
**********		
PRIMARY REFINED	18770.815	18797.623
SECONDARY REFINED	2853.196	2910.359
MINING AND MILLING	37805.686	37952.495
POLL. ABATEMENT INVESTMENT		
***** ********* **********		
MINING AND MILLING	.000	.000
SMELTING AND REFINING	19140.588	18229.048
PHYSICAL REFINERY CAPACITY		
******** ******** ********		
BEGINNING OF YEAR	2437.000	2437.000
NET CHANGE	-.000	-.000
CAPACITY UTILIZATION		
******** ***********		
PRIMARY REFINED	.910	.912
SECONDARY REFINED	.964	.983

QUANTITY ESTIMATES IN 1000'S OF SHORT TONS
MONETARY ESTIMATES IN 1000'S OF DOLLARS

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APPENDIX D

THE ECONOMETRIC SIMULATION AND IMPACT ANALYSIS MODEL OF THE U.S. COPPER INDUSTRY: DEFINITION OF VARIABLES[1]

MARKET CLEARING MODULE

ENDOGENOUS VARIABLES

No.		
1.	ATC*	Average total cost, primary producers
2.	AVC*	Average variable cost, primary producers
3.	CAPP*	Capacity utilization rate for all refining, primary and secondary. (CAPP = QR/(KAPPR + KAPSR)).
4.	DIFF	Difference between the deflated LME price of copper and the EMJ price (RPLME - RPEMJ = DIFF) in ¢/lb.
5.	ER	U.S. exports of refined copper. Source: CDA, Table 1.
6.	FIXCOS*	Total fixed charges on fixed costs incurred by the primary producers as a whole in a given year.
7.	IF*	Fabricators stocks of copper, both scrap and refined (IF = IFS + IFR). ΔIF = IF(t) - IF9t-1) = DELIF
8.	IFR	Refined copper stocks held by wire mills, brass mills and other fabricators and semi-fabricators, end of year. Source: CDA, Table 1, item 16.
9.	IFS	Scrap stocks held by brass mills, foundries and other fabricators and semi-fabricators, end of year. Source: CDA, Table 2, item 3.
10.	IR	U.S. imports of refined copper. Source: CDA, Table 1.

[1] All quantity series in 1,000 short-tons.
-Variables in alphabetical order; variable form has (*) if it appears explicitly in the ADL Model.
-Endogenous variable list includes those variables utilized in developing final variable for example, net exports comes from imports and exports of refined copper and copper scrap.

APPENDIX D
(continued)

No.		
11.	IRR*	Refined copper stocks held at refineries, end of year. Source: CDA, Table 1, item 6. $\Delta IRR = IRR(t) - IRR(t-1) = DELIRR$
12.	IRS	Scrap stocks held by smelters and refineries, end of year. Source: CDA, Table 2, item 3. $\Delta IRS = IRS(t) - IRS(t-1) = DELIRS$
13.	MRPEMJ*	Marginal revenue, primary producers.
14.	NE*	Net exports of copper, scrap and refined) (NE = NES + NER)
15.	NER	Net exports of refined copper from the U.S. (ER-IR).
16.	NES	Net export of scrap. Source: CDA, Table 2.
17.	PEMJ	Metals Week (formerly E&MJ Metal and Mining Markets) average domestic refinery price of electrolytic copper wire bars and ingot bars, FOB refinery; also tabulated in the Yearbook of the American Bureau of Metal Statistics (ABMS) as monthly average prices of copper, domestic refinery--New York--¢/lb.
18.	PFUT1	Simple average of Closing Future Price (¢/lb) of copper for all of the next 12 months reported starting in January of the year. Source: Wall Street Journal.
19.	PS	From 1956 on, dealers' buying price for #2 heavy copper scrap; before 1956, dealer's buying price for #1 heavy copper scrap. ¢/lb--Metal Statistics.

APPENDIX D
(continued)

20.	QD*	Total consumption of refined and scrap copper in the U.S. by ingot makers, brass mills, wire mills, foundries, powder plants and other industries. Source: CDA, Table 3.
21.	QPR*	Total production of refined copper from Primary Sources. Source: Copper Development Association (CDA), Table 1, item 13. Series is adjusted to include refined copper produced from scrap and sold at the primary producers price and to exclude copper produced from ore yet sold in the secondary market.
22.	QR = QSR + QPR*	Total production of refined copper in the U.S. in 1,000 short tons. Source: CDA, Table 1.
23.	QSNR*	Receipts of domestic scrap that are not sent to secondary smelters and refiners. Source: CDA (QS-QSR).
24.	QSR*	Production of refined copper in the United States produced from scrap. Source: CDA, Table 1, item 13. Series is adjusted to include copper produced from ore and sold in the outside market and to exclude copper produced from scrap and sold at the primary producers' price.
25.	RPEMJ*	Deflated PEMJ. Deflator is alternatively PUWD or PUWD74.
26.	RPFUT1*	PFUT1 deflated by PUWD or PUWD74.
27.	RPS*	The real price of scrap, PS, deflated by PUWD or PUWD74.

APPENDIX D
(continued)

No.		
28.	RPSR*	A recorded price series for secondary refined copper is not available in the literature. Our series has been built up using the price of scrap, PS, and the margins characterizing the secondary sector over the historical period, SPRED: PSR = PS + SPRED. RPSR is the real secondary price, deflated by PUWD or PUWD74.
29.	SPRED	Average difference between the scrap price (PS) and the price of secondary refined copper (PSR) reflecting commercial costs, operating costs and gross profits. (Arthur D. Little, Inc. estimates).
		EXOGENOUS AND PREDETERMINED VARIABLES
1.	ACRO*	Relative activity variable determining net exports of copper. It is defined as the ratio of indices of manufacturing production in the U.S. and the Federal Republic of Germany (ACRO = YUD/YGR). Alternative ratios have been investigated involving the indices of manufacturing production in Japan, France, the U.K., EEC and the OECD.
2.	DSTE2*	Dummy variable indicating whether a strike is expected next year and how many months it is expected to last. For example, if a 2-1/2 month strike is expected to affect between 75-100% of production next year, DSTE2 = 2.5. DSTE2 = 0 if no strike is espected. (DSTE2(t) = DUMST2(T+1)).

APPENDIX D

(continued)

3.	DUMST2*	Dummy variable for strikes affecting the smelting and refining stages of copper production. Dummy estimates number of months a major strike affected more than 75% of the production workers in the industry; 0.0 when no strike. Source: Interviews with Asarco, Phelps Dodge, Kennecott and Anaconda.
4.	IGOV*	Refined copper stocks held in government stockpile, end of year. Source: CDA, Table 1, item 16. ΔIGOV = IGOV(t) - IGOV(t-1) = DIGOV
5.	KAPP*	KAPPR + KAPSR
6.	KAPPR*	Copper refining capacity of the primary producers beginning of the year in 1,000 short-tons per year. Source: ABMS Yearbook. KAPPR is endogenous in the investment module.
7.	KAPSR*	Copper refinery capacity, secondary producers at beginning of year in 1,000 short-tons per year. Both primary and secondary capacity definitions are aimed at estimating capacity utilized for producing copper for sale at the primary producers' price or the outside market price. Capacity in the secondary market has therefore been that of AMAX and Cerro, since production of the two companies has been predominantly sold at competitive outside market prices.
8.	PAUSC	Scrap aluminum clipping prices, monthly averages of dealers' buying prices of new aluminum clippings in New York, American Metal Market, ¢/lb.

APPENDIX D

(continued)

9.	PLME	The London Metals Exchange Price of Copper: electrolytic, delivered for 1946 to 1953; electrolytic wire bars monthly average settlement price for 1953 to 1974. Asked quotation for spot is converted to ¢/lb by the annual average exchange rate for sterling. Both series found in ABMS Yearbook--"Average Prices of Principal Metals," (p. 147 in the 1973 Yearbook).
10.	QFAB*	Supply of mill, foundry and power products to domestic market-total. Source: CDA, Table 4.
11.	RPAL*	Deflated price of scrap aluminum clippings (PAUSC deflated by PUWD or PUWD74) in ¢/lb.
12.	RPLME*	Deflated LME price of copper (PLME deflated by PUWD or PUWD74) in ¢/lb.
13.	VARCOS*	Unit average variable cost of operating cost of the primary producers.
14.	YGR	Index of manufacturing production, Federal Republic of West Germany, 1963 base year converted to 1974 = 100. Source: IMF, International Financial Statistics, Washington.
15.	YUD	Federal Reserve Board Index of Durable Manufacturers Production, 1967 base year converted to 1974 = 100.

APPENDIX D
(Continued)

INVESTMENT MODULE

ENDOGENOUS VARIABLES

No.		
1.	QCU*	The supply primary copper in the United States from mine production. Source: CDA, Table 1.
2.	NETY*	Net income, the calculation of earnings after deductions for costs and taxes, often called earnings to surplus. The seven companies included in the compilation of net income are: Phelps Dodge, Kennecott, Anaconda, AMAX, Asarco, Inspiration, Consolidated Copper and Copper Range. Source: Moody's.

EXOGENOUS AND PREDETERMINED VARIABLES

1.	CCAP*	Weighted average cost of debt and equity capital to the primary producers, the weights being the levels of debt and equity capitalzation. Many alternative definitions of this cost of capital are possible. The alternatives developed for our analysis are discussed fully in Appendix F.
2.	DGNP74	Implicit deflator of GNP for the U.S. converted to 1974 base year from 1958 base year. Source: U.S. Department of Commerce, Survey of Current Business.
3.	PDGNP	Implicit price deflator, gross national product. Source: Department of Commerce, Bureau of Economic Analysis. 1972 = 100, updated to 1974 = 100.
4.	PDPDE	Implicit price deflator, fixed investment, non-residential producers' durable equipment. Source: Department of Commerce, Bureau of Economic Analysis. 1972 = 100, updated to 1974 = 100.
5.	PUWD74	Wholesale price index of durable manufacturing, 1974 = 100. Source: BLS.

APPENDIX D
(Continued)

6. KAPP* KAPPR + KAPSR

7. KAPPR* Copper refining capacity of the primary producers beginning of the year in 1,000 short-tons per year. Source: ABMS Yearbook. KAPPR is endogenous in the investment module.

8. KAPSR* Copper refinery capacity, secondary producers at beginning of year in 1,000 short-tons per year. Both primary and secondary capacity definitions are aimed at estimating capacity utilized for producing copper for sale at the primary producers' price or the outside market price. Capacity in the secondary market has therefore been that of AMAX and Cerro, since production of the two companies has been predominantly sold at competitive outside market prices.