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THE U.S. SMELTING AND REFINING INDUSTRY: STATUS AND IMPLICATIONS FOR COPPER, LEAD, AND ZINC

by

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ABSTRACT

The purpose of this study is to assess the implications of the current decline in the U.S. smelting and refining capacity for copper, lead, and zinc. To accomplish this, the supply and demand relationships, trends in the industry, and participating firms are evaluated. The study develops an assessment of the decline in capacity and a series of recommendations for government and industry.

A detailed survey of the supply and demand characteristics for copper, lead, and zinc is presented. The survey includes aspects of resources, production, and processing, as well as capacity, demand, substitution, and prices.

The trends in the supply and demand characteristics, as well as processing characteristics, costs, and international trade are evaluated for possible synergies and structural changes. The firms which participate in these industries are also evaluated and trends and structural changes are noted. The trends are examined within the framework of a hypothesis of metal industry development proposed by D. F. Hewett.

The conclusion of this study is that the declining trend in smelting and refining capacity for copper, lead, and zinc may not be a temporary phenomenon. While the decline in U.S. smelting capacity has serious ramifications, the trend may be altered by government and industry action. A continued large smelting industry in the United States may depend on the success of these combined efforts.

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INTRODUCTION

STATEMENT OF THE PROBLEM

There have been two recent closures of smelters in the United States which have stimulated concern in the mining industry and some controversy in government and financial circles. These closures affected the domestic capacity to process copper, lead, and zinc, metals which are basic to an industrialized economy.

The recent closures removed 15% of the domestic smelting capacity for copper and 20% of the smelting capacity for lead and zinc. Industry representatives have maintained that these declines are indications of a broader trend in the industry that will seriously affect the national interest. This study attempts to answer three questions:

1. Does the recent loss of smelting capacity represent a long-term decline?
2. What are the implications of this decline?
3. What can (or should) be done?

SCOPE

Smelting capacity is a function of many factors. This study examines some of the primary considerations, which include the sources of concentrates, the metal price, production and government policies such as taxation and regulation. The study involves a detailed examination of the supply and demand characteristics for copper, lead, and zinc as well as a survey of the trends in the overall industry and participating firms. This survey is needed to develop a perspective of the three industries. The industry trends are evaluated within the framework of a model of industry development to assess the impact and possible ramifications of the recent smelter closures.

To develop an overall assessment of copper, lead, and zinc industries a broad range of sources is required, including U.S. Bureau of Mines publications and statistical data sources as well as books, journals, and newspapers. The industry plans and perspectives are developed through various publications and interviews. The government position and concerns are defined through various reports by the Environmental Protection Agency and the Department of Commerce.

The trends are evaluated for significance in the framework of a hypothesis of primary metal industry development proposed by D. F. Hewett. Conclusions are based upon the examination of the overall industry trends as they relate to the Hewett model and other projected impacts on the industry.

PROCEDURE

An overall understanding of the industry is required in order to assess the status of the domestic smelting and refining capacity and the implications of the current decline. This study is organized to develop this understanding as follows:

- Chapter 1 examines the supply and demand aspects of copper, lead, and zinc.
- Chapter 2 assesses the trends in supply and demand relationships, including prices and changes in consumption, production, and international trade. These relationships are examined with respect to processing, environmental, and labor costs.
- Chapter 3 examines the trends of the participants in the industry. As a primary competitor, the Japanese smelting industry is also described.
- Chapter 4 evaluates and discusses the overall industry trends and the implications of these trends.
- Chapter 5 concludes the study with a summary of the industry perspective and conclusions of the author. Recommendations for industry and government are also submitted.

CHAPTER 1: MARKET REVIEW OF COPPER, LEAD, AND ZINC

An understanding of the market components for copper, lead, and zinc is necessary for a complete appreciation of the trends in smelting and refining capacity in the United States. The supply and demand relationships for each of the metals are summarized in the following sections. The period from 1960 to 1979 has been used as the basis period for determining trends and market behavior.

1.1 SUPPLY RELATIONSHIPS

The components of supply include where the metal is found, how it is recovered and the reserves and resources for each metal. These are summarized for copper, lead, and zinc in the following sections.

Copper Mines

Copper is a metal which has been known to man for at least 6,000 years, and reserves and resources are distributed worldwide. World production has climbed steadily and the United States has been the world's largest producer for the past 30 years. The Soviet Union has become a major producer, alternating from year to year with Chile as the world's second largest producer. Some industry representatives believe Chile will surpass both the United States and the Soviet Union in 1982. Notable other producing countries are Peru and Poland.

The copper produced in the United States is mined in 12 states (Schroeder, 1980). Arizona is the leading producer, yielding 65% of the nation's supply in 1980 (Schroeder and Jolly, 1980). In 1980, Utah and New Mexico were nearly equal, each producing roughly 13%. Michigan and Montana produced smaller amounts and only minor quantities were produced in Missouri and Tennessee. The production data are compiled in Appendix A, Table A-1-1.

The top four primary producing mines in the copper industry in 1980 were the Utah Copper Mine, the Morenci Mine, Sierrita Mine, and the Tyrone Mine. Other major producers were the Twin Buttes Mine, the Ray Pit, and Magma Copper's San Manuel Mine (Schroeder, 1980). In 1979, the four primary mines accounted for 63% of U.S. mine production (Schroeder, 1979). A total of 25 mines accounted for 94% of the U.S. production. A list of the major producing mines and their order of production for 1978 and 1980 is included in Appendix A, Table A-1-2.

Copper Smelting and Refining

The domestic smelting capacity, located in nine states, consists of 16 smelters. Table 1.1-1 lists these smelters and their capacities. Smelters are typically located close to the mines to reduce transportation costs. The two exceptions to this are the ASARCO smelters in El Paso, Texas and Tacoma, Washington. These two smelters are remote from the mine and receive copper concentrate from the United States and abroad.

In accordance with being the leading copper producer, the United States is also the world leader in smelter production. The Soviet Union is currently the second largest and Chile, third. Japan was in a distant fourth place until 1970, when it surpassed Chile. Since then, Japan and Chile have been close for third largest producer. The world's smelter production since 1960 is summarized in Appendix A, Table A-1-3.

Refineries are required for the final step in copper processing. They are usually located to reduce transportation costs for the purchaser of the refined product. There were 14 refineries operating in 12 states in 1980. Table 1.1-2 lists the refineries and their production capacities. Two refineries were closed in 1980. The temporary closure of the ASARCO refinery in Tacoma, Washington, and the permanent closure of the Anaconda refinery in Great Falls, Montana, reduced cur-

TABLE 1.1-1: Domestic Primary Copper Smelters[1] and Capacities, 1978

LOCATION	OPERATOR	CAPACITY[2]
Anaconda, Montana	Anaconda	180
Tacoma, Washington	ASARCO	91
Garfield, Utah	Kennecott	254
El Paso, Texas	ASARCO	104
McGill, Nevada	Kennecott	45
Hidalgo, New Mexico	Phelps Dodge	127
Hurley, New Mexico	Kennecott	73
Hayden, Arizona	ASARCO	163
Miami, Arizona	Inspiration	136
Morenci, Arizona	Phelps Dodge	181
Ajo, Arizona	Phelps Dodge	64
Douglas, Arizona	Phelps Dodge	115
San Manuel, Arizona	Magma Copper Company	182
Copper Hill, Tennessee	Cities Service	20
White Pine, Michigan	Copper Range	82

(1)Blister copper production.
(2)Thousand metric tons of copper content.

(Source: Schroeder, 1980 - Mineral Facts and Problems)

TABLE 1.1-2: Electrolytic Copper Refinery Capacities of the United States, 1980 (In Tons of 2000 Pounds)

WORKS	LOCATION	CAPACITY/1980
ASARCO	Amarillo, TX	420,000
ASARCO	Perth Amboy, NJ	168,000
ASARCO	Tacoma, WA	156,000
The Anaconda Co.	Great Falls, MT	252,000
Inspiration Cons. Copper Co.	Inspiration, AZ	70,000
Kennecott Copper Corp.	Garfield, UT	191,000
Kennecott Refining Corp	Anne Arundel Cty., MD	276,000
Cerro Copper & Brass Co., Div. of Cerro Corp.	St. Louis, MO	44,000
Chemetco, Inc.	Alton, IL	40,000
Newmont Mining Corp. (Magma Copper Co.)	San Manuel, AZ	200,000
Phelps Dodge Refining Corp.	El Paso, TX	420,000
Phelps Dodge Refining Corp.	Laurel Hill, NY	72,000
U.S. Metals Refining Division, AMAX, Inc.	Carteret, NJ	105,200
Reading Metals Refining Corp. (Reading Tube Corp. subsidiary)	Reading, PA	40,000
Southwire Co. Copper Div.	Carrollton, GA	100,000
TOTAL		2,500,000

(Compiled from Metal Statistics, 1981, page 271) rent domestic refining capacity by 15%, or 370,000 tonnes per year (Schroeder, 1980).

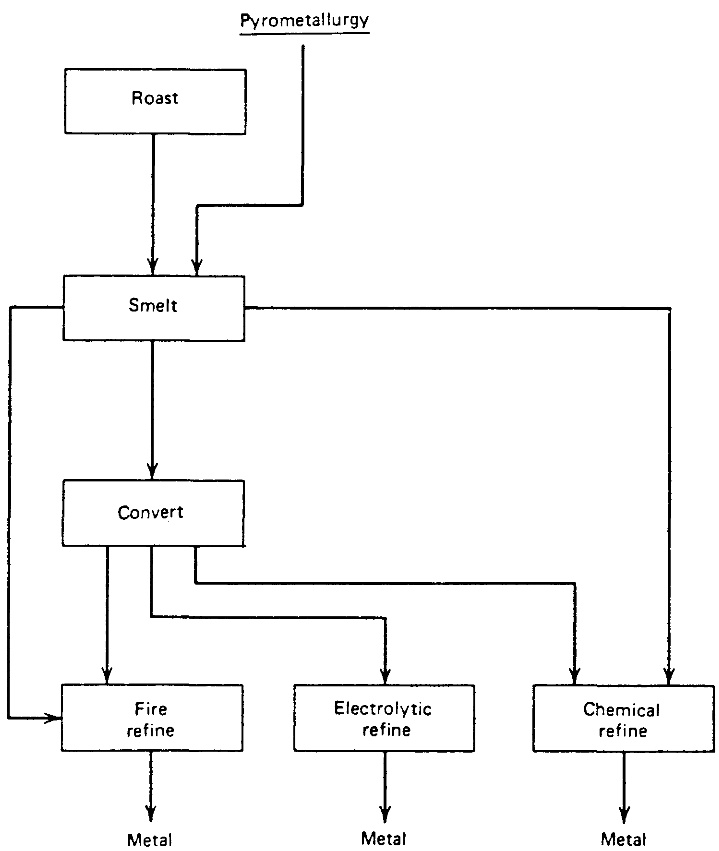
Copper Recovery

Copper mineralization is mostly porphyry copper and native copper. The metal is also recovered in conjunction with lead, zinc, and/or silver. Porphyry copper ore currently averages 0.49% copper and significant beneficiation is required. After crushing, the ore receives additional treatment depending on whether it is oxide or sulfide. Sulfide ores are floated, then fired in a reverberatory furnace, to produce copper matte. New processes have been developed which eliminate the reverberatory furnace in new plants. Additional treatment in a converter furnace produces blister copper, which is 99.4% copper. Shipment of the concentrate can occur after flotation, where the copper content is 15% to 40% or more typically as blister copper (Mikesell, 1979). The blister copper is then refined electrolytically. Two to four weeks is usually required to develop a copper cathode. More rapid rates carry too many impurities into the cathode (Bennett, 1973). Recent advancements in the process include the use of stainless steel cathodes so that the cathodes can be mechanically stripped. Figure 1.1-1 is a flow diagram of the copper concentration and refining process.

If the ore is an oxide rather than a sulfide, an acid leaching step is necessary. The pregnant liquor is then electrorefined. Leaching is being used on mine tailings and low-grade ore. This process requires days to years, depending on the technique selected.

As can be surmised from the concentration process, significant amounts of waste are generated. These include mining tails, particulate emissions, sulfur, slag, and fumes. In recent years process waste has increased because the current average stripping ratio is 2.5:1 (Schroeder, 1979). Recently developed lower grade mines have ratios as high as 3:1 (Everest Associates, 1982). As more waste rock is required per ton of ore, greater amounts of waste are also generated.

Figure 1.1-1 Flow Diagram of Copper Concentration and Refining Process



Source: Gill, 1980

Steps have been taken to minimize this waste. These include the leaching of the mine tails, recovery of the sulfur for process acid and recovery of the particulates for refining. By-product recovery has also increased and includes gold, silver, and molybdenum. These modifications have reduced the environmental impact and have improved the recovery economics for mines in recent years.

Copper Supply

The United States has 19% of the known world copper reserves and 26% of the copper resources (Rathjen, 1980b). Of this, five states account for 90% of the domestic reserves. They are Arizona, Utah, New Mexico, Montana, and Michigan. The most recent appraisals of U.S. production indicates continued modest growth in production (Appendix A, Table A-1-4). The U.S. Bureau of Mines projects an annual average growth rate for the United States of 3.0% and 3.0% for the world. Known world reserves appear to be adequate for the forecast demand to the year 2000.

Scrap plays an important part in the supply of copper. Total copper scrap has been estimated to be 21% of the market. According to the U.S. Bureau of Mines, scrap is expected to reach 26% of the market by 1990 and 30% of the market by the year 2000 (Rathjen, 1980a). Recent research estimates that scrap and recycled copper actually comprises 40% of the current domestic supply (Everest Associates, 1982).

Lead Mines

Lead has also been used since ancient times. Lead resources are scattered around the world. The United States became the world's largest producer in 1969 and has continued in this position. The Soviet Union, Canada, Australia, and Mexico are also important producers.

The United States produced 15% of the total world production in 1979. Domestic supplies came from roughly 25 mines in seven states with Missouri the leading producer. The eight mines in this state produced 90% of the domestic supply. Idaho contributed 8% and Colorado was the third, producing approximately 1%. The lead production by state is summarized in Appendix A, Table A-1-5. The Buick Mine produced the most lead, followed by the Fletcher, the Magmont, and the Ozark Mine (Rathjen, 1980b). Four companies, AMAX, Cominco, St. Joe, and Kennecott, produces 80% of the domestic lead (Roskills, 1979). A list of primary producing mines from 1978 to 1980 is included in Appendix A, Table A-1-6.

Lead Smelting and Refining

In 1979, there were six lead smelters and four lead refineries. Most of the lead smelters are located close to the mines of the major producing areas, but ASARCO's smelters are located to serve a variety of concentrate suppliers. The six smelters and their rated capacities are shown in Table 1.1-3. Lead is found in concentrations of 4% to 10%; because of this high grade, it is economically feasible to ship the lead ore some distance. Canada and Mexico have taken advantage of this fact. Railroads are used by these two countries to ship ore and concentrate to ASARCO's smelters and, until recently, the Bunker Hill smelter in Idaho.

Lead Producing

Lead is one of the easier metals to recover. All the mines are underground operations and room-and-pillar techniques can be used for much of the U.S. production. Rubber-tired equipment can also be employed, which permits rapid ore extraction. Some Western mines have more complex geology and require timbered stoping methods for more selective mining.

TABLE 1.1-3: Primary Lead Smelters and Refineries

Location	Owner	Process[1]	Capacity[2]
Herculaneum, MO	St. Joe Lead	S & R	204
Boss, MO	AMAX & Homestake	S & R	127
Bradley, ID	Bunker Hill	S & R	119
El Paso, TX	ASARCO	S	82
East Helena, MT	do	S	82
Gover, MO	do	S & R	100
Omaha, NE	do	R	164

(1)S = smelter, R = refining.
(2)Thousand metric tons lead content.

(Source: Rathjen, 1980a - Mineral Facts and Problems)

The ore is crushed, then floated for primary concentration. This step yields a 25% to 75% lead concentrate which is then sintered or roasted and then smelted with additives to produce lead bullion (Roskills, 1979). The Missouri ores have so few impurities that the product can be sold as chemical grade lead without further refining.

If further refining is needed, the lead bullion can then be fired in a blast furnace to remove the final impurities of zinc, copper, and silver or be cast into anodes for electrorefining. The final product is typically 99.9% lead (Roskills, 1979). Figure 1.1-2 illustrates the lead refining process.

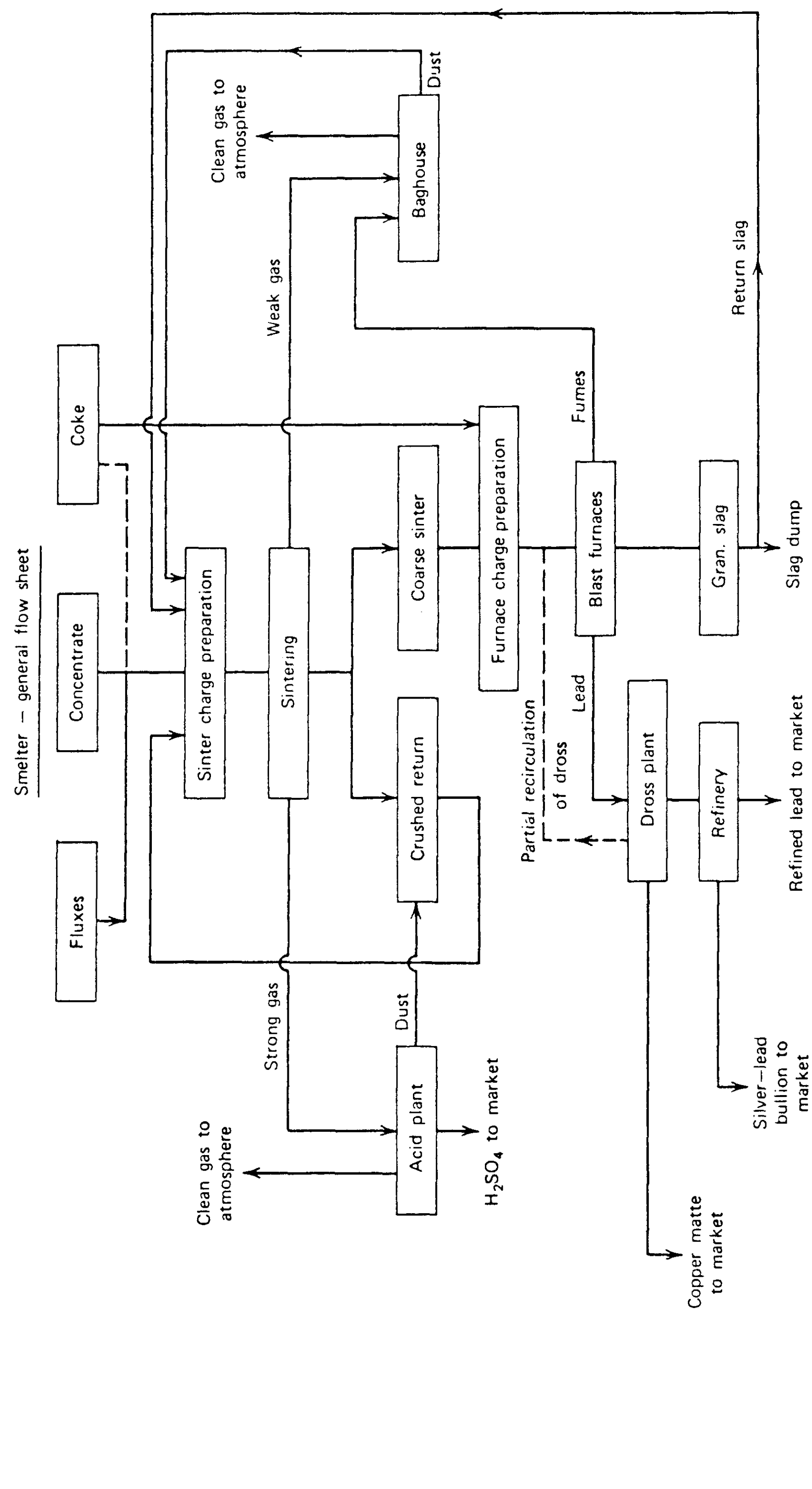
The lead recovery process generates significant by-products. Sulfur emissions, particulate lead, arsenic, and antimony, as well as mine tails and slag, are processing problems. Recent environmental regulations regarding levels of lead and other by-products in the workplace may have important implications for the industry.

Lead Supply

According to the U.S. Bureau of Mines, there are sufficient world reserves to meet projected world demand. The United States has 26% of the total world resources and an estimated 35% of known world reserves. Most of the U.S. reserves lie in the New Lead Belt in Missouri. This area has been undergoing development in the last ten years, and further expansion is possible.

Scrap is a major secondary source of lead in the United States and the world. Lead scrap is readily amenable to secondary recovery because of its primary use in batteries. Batteries contain significant amounts of lead in a readily reusable form and are easily collected. Secondary recovery is a major industry. In 1978 there were 115 plants owned by 15 companies (Roskills, 1979). Two firms, NL Industries and RSR Corporation, owned 18 secondary smelters and accounted for

Figure 1.1-2 Flow Diagram of Lead Refining Process



Source: Gill, 1980.

50% of the total secondary lead output (Roskills, 1979). This industry is changing, however. In 1981, the Lead Industries Association could only identify 56 operating facilities. Also, RSR is being required to divest itself of two refineries to meet U.S. anti-trust regulations (Metals Week, 1980a).

Zinc Mines

Zinc is a widely used metal which has also been known and used by mankind for many centuries. The current world supply of zinc comes primarily from Canada, the Soviet Union, and Australia. Other significant producers are Japan, Peru, and Mexico. The United States was the largest zinc metal producer until 1971. Domestic production has since declined while total world mine production has increased at a gradual rate. The U.S. mine production began declining in 1974. Since then, several states have ceased or have severely curtailed their production. For example, Colorado and New York production dropped by 50% in one year (see Appendix A, Table A-1-7). Ten leading mines accounted for 69% of the domestic production in 1979 and 25 mines contributed to 98% of production (Cammaroto, 1980b). Tennessee was the leading producer, followed by Missouri and Idaho. Six companies own most of the U.S. production. In 1979, 91% of the refined or primary slab zinc production and 85% of the mine output came from these companies. The top producing mines are summarized in Appendix A, Table A-1-8.

Zinc Smelting and Refining

World smelting capacity for zinc has exceeded mine production through the 1970s. Domestic smelting capacity has declined, and plans for additional capacity are not forthcoming in the next few years. New smelters have been built or modified, but these did not offset the smelter closures which occurred in 1974 and 1975.

Currently there are seven primary slab zinc smelter/refineries in the United States. The location and capacities of these smelters are listed in Table 1.1-4. Of the listed facilities, Bunker Hill is no longer in operation and New Jersey Zinc has closed the slab zinc facilities in Palmerton, Pennsylvania.

World smelter production has shown a gradual increase. World production of primary slab zinc peaked in 1974, and did not regain those levels until 1978. There has been an increase in smelting and refining capacity in Canada and Asia and a decline in Western Europe and the United States. The Soviet Union is the world's largest producer of slab zinc, followed by Japan and Canada (Roskills, 1979). (See Appendix A, Table A-1-9.)

Zinc Processing

Zinc occurs primarily as the mineral sphalerite. It frequently occurs with lead, silver, or copper. For example, the Boss Mine in Idaho has an 8.6% lead grade and 3.4% zinc (Wise, 1979). The Bunker Hill Mine in Idaho has grades of 2.9% lead, 3.1% zinc, 2 oz./ton silver (Roskills, 1979).

The zinc ore is usually mined using a variety of underground techniques. Room-and-pillar, shrinkage stoping, and square set methods are all used. The mined ore must be concentrated before smelting and the techniques used depend on the ore. The simple ores in Tennessee are easily crushed, separated by heavy media, and floated. Western ores require successive treatments to separate and concentrate the ore. The concentrate is then roasted to remove some of the sulfur.

Zinc is refined by one of several methods. Electrolytic deposition is becoming the predominant technique and retorting or furnace distillation is used in older plants. Electrolytic recovery is used in the newer plants and offers the benefits of improved recovery of by-products and reduced environmental pollution. This process also yields a purer product. The recovery of by-products such as copper,

TABLE 1.1-4: Primary Zinc Smelters and Refineries

LOCATION	OPERATOR	CAPACITY[1]
Kellog, Idaho	Bunker Hill	99
Corpus Christi, Texas	ASARCO	98
Bartlesville, Oklahoma	National Zinc	51
Sauget, Illinois	AMAX	76
Clarksville, Indiana	Jersey Miniere	82
Monaca, Pennsylvania	St. Joe	201
Palmerton, Pennsylvania	New Jersey Zinc	109

(1)Thousand metric tons of zinc content.

(Source: Cammaroto, 1980b - Minerals Yearbook) lead, gold, silver, and cadmium significantly improve the economics of the operation.

Zinc Supply

The United States has an estimated 9% of the world reserves (Cammaroto, 1980a). The U.S. Bureau of Mines estimates that there is not sufficient domestic supply to meet U.S. needs. The Bureau also estimates that world reserves are inadequate for the projected demand. It is suggested that additional reserves will be developed to meet the demand, but the domestic sources will be insufficient for U.S. demand.

Scrap is a relatively minor part of zinc supply and is not expected to increase significantly. In 1979, scrap was 6% of the total metal supply (Cammaroto, 1980b). Zinc is primarily used in galvanizing and pigments where recovery is a major obstacle.

1.2 DEMAND RELATIONSHIPS

Demand, the other half of the marketplace, is comprised of the uses for each metal. Substitution and the projected growth in demand are also important aspects which are discussed in the following sections.

Copper Uses

Copper is used in a variety of industrial and residential applications. The primary use for copper is in electrical items where the high electrical conductivity of the metal is needed. Transformers, power generators, electrical motors, and dynamometers are typical uses. Copper is also needed for home and auto wiring, busbars, switches, and lighting as well as numerous other similar uses.

Copper is corrosion resistant and has superior machining characteristics when it is alloyed as brass and bronze. Copper is used in piping, exterior decoration, and roofing. Alloys are used for machined fittings requiring a tight fit. Copper alloys are also used in coinage and ordnance. Pigments and chemical compounds are a minor part of copper demand. Figure 1.2-1 illustrates the components and relative proportions of copper uses in the United States.

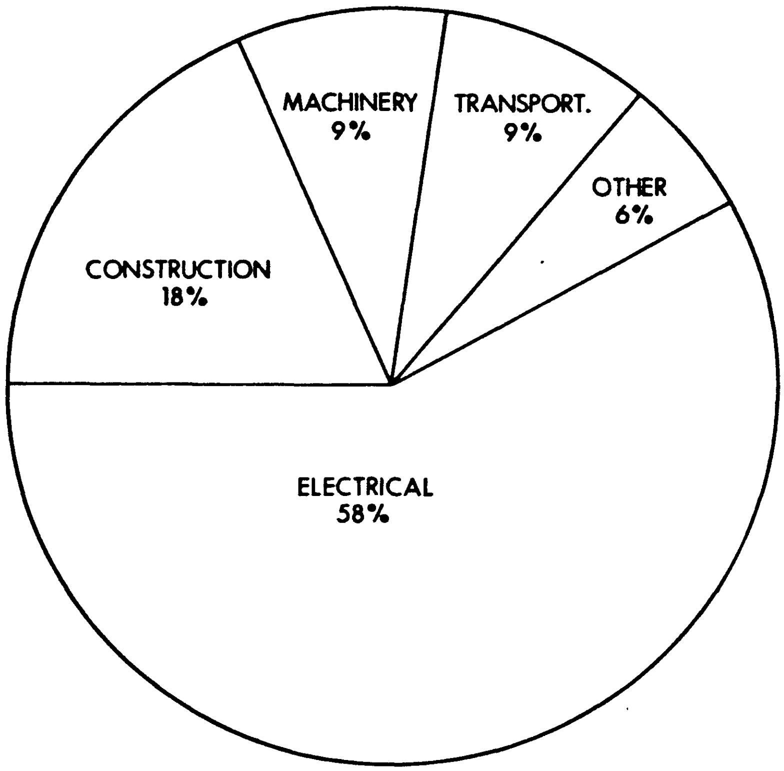
Copper Substitution

Copper faces substitution through increased use of aluminum and plastics. Aluminum has replaced copper in 40% of the market for long-distance cable (Schroeder, 1979). Aluminum can also be a substitute for copper in other electrical applications, but it is limited to some degree by its physical characteristics. For example, the shift to aluminum wiring in housing proved to be a poor choice. The coefficient of expansion of aluminum wiring created electrical shorts which caused numerous house fires and that use has largely been discontinued. Copper has also been replaced by plastics. Plastic pipes are cheaper and easier to work with. Plastic tubing, bushings, and nylon bearings have also displaced the metal. Fiberoptics pose a potential threat in communications, but additonal research is required before fiberoptics is economically feasible.

Copper Demand

Substitution, while remaining a part of the market, does not pose a threat to continued copper demand. A more significant threat to demand will be the world economic condition. Copper applications are closely linked to a growing industrial world. As the rate and degree of the world economy fluctuates, so will the

Figure 1.2-1 <u>Components of Copper Uses in the United States</u>



Source: Lead Industries Association, 1980.

demand for the metal. An examination of demand by the United Nations indicates that per capita consumption in the more developed countries has achieved saturation (Gluschke, 1979). This is because many of the end uses of copper are long-lived items such as plumbing, wiring, and generators. Only lesser developed countries represent major, growing markets. The projected demand, as determined by the U.S. Bureau of Mines, is summarized in Table 1.2-1.

Lead Uses

Lead, like copper, can be used as the pure metal with trace impurities as hardeners or alloyed in bronze and solders. The major use for lead is as alloys in batteries. There are two primary types of batteries. One is the type used in passenger cars which is lead-antimony or lead-calcium alloy and is referred to as an SLI battery (Starting, Lighting, Ignition). The second type is the lead-zinc-carbon alloy dry battery used in flashlights, radios, etc. (Roskills, 1979). These two types of batteries comprise almost 60% of the annual U.S. lead consumption (Lead Institute, 1980).

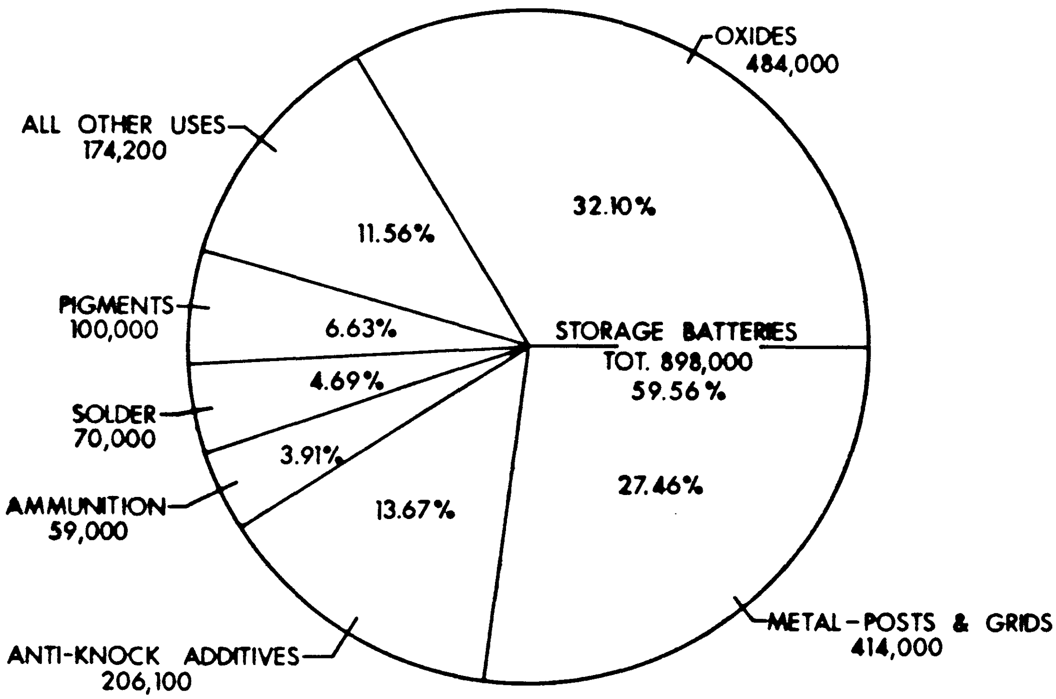
The second greatest use for lead is an anti-knock additive in gasoline known as tetraethyl lead. Demand for this application is declining with the recent air pollution requirements instituted in the United States. The combination of no-lead fuels and a decline in gasoline consumption has reduced this market significantly. The U.S. consumption and relative components are illustrated in Figure 1.2-2 and summarized in Appendix A, Table A-1-10. Other major uses of lead include solders, ammunition, and pigments. Minor uses are in pipes, as a cable covering, in brass and bronze, sheets, and as type metal.

TABLE 1.2-1: Summary of Forecasts of U.S. and Rest-of-World Copper Demand (Thousand Metric Tons)

	1978	Forecast Range		Probable		Probable Average Annual Growth Rate 1978-2000 (Percentage)
		Low	High	1990	2000	
United States:						
Primary	1,879	2,400	4,200	2,500	3,200	2.4
Secondary	501	1,100	1,800	900	1,400	4.8
Total	2,300	3,500	6,000	3,400	4,600	3.0
Cumulative (primary)	---	47,000	64,000	26,000	55,000	---
Rest-of-World:						
Primary	6,221	11,000	18,100	9,900	14,500	3.9
Secondary	1,499	3,600	6,400	2,700	4,500	5.1
Total	7,720	14,600	24,500	12,600	19,000	4.2
Cumulative (primary)	---	186,000	251,000	97,000	219,000	---
World:						
Primary	8,100	13,400	22,300	12,400	17,700	3.6
Secondary	2,000	4,700	8,200	3,600	5,900	5.0
Total	10,100	18,100	30,500	16,000	23,600	3.9
Cumulative (primary)	---	233,000	315,000	123,000	274,000	---

(Mineral Facts and Problems, Bulletin 671, Page 241)

Figure 1.2-2 Components of Lead Uses in the United States



Source: Lead Industries Association, 1980.

Lead Demand

Lead demand has sustained numerous substitution impacts in recent years, as the detrimental effects of lead on living things has gained understanding. In addition, many minor uses for lead, such as type metal, have become obsolete. The major market in storage batteries is expected to remain the primary source of demand in the future. The U.S. Bureau of Mines projects a very modest growth of primary demand in the United States of 1.2% because of the relative maturity of battery demand. As Table 1.2-2 indicates, primary demand for the world is estimated to grow at an average rate of 3.9%. This is attributed to the increased automobile demand in the developing countries.

Zinc Uses

Whereas copper and lead are corrosion resistant, zinc provides corrosion protection to other metals. As Figure 1.2-3 illustrates, primarily zinc is used to galvanize sheet metal for automobiles, tubes and piping, fencing, and structural shapes. The second major use of zinc is in die castings, largely for the automobile industry. The characteristics of ease of forming and light weight have made zinc extremely useful for automobile parts. Brass is the third major use of zinc, representing approximately 14% of demand in 1979 (Cammaroto, 1980b). The current zinc applications and quantities used are summarized in Appendix A, Table A-1-11.

Zinc Substitution

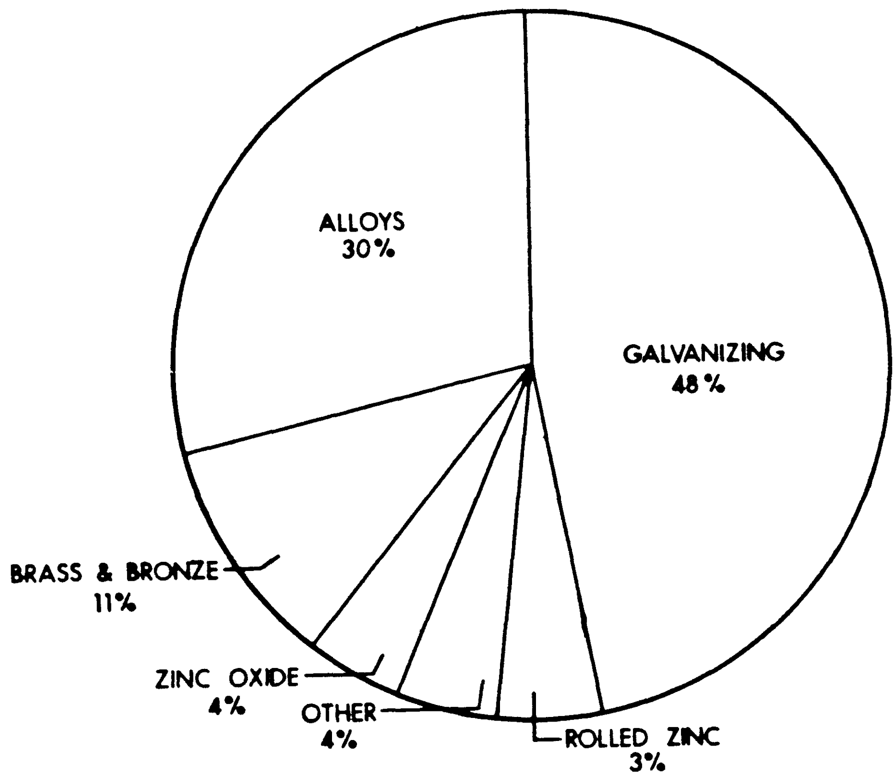
Substitution has played a significant role in zinc demand. Aluminum and magnesium, either alloyed with zinc or alone, compete in die castings. Some plastics have also made in-roads in this area. New zinc-based paints on steel have been developed that provide the corrosion resistance of zinc but use less of the metal.

TABLE 1.2-2: Summary of Forecasts of U.S. and Rest-of-World Lead Demand (Thousand Metric Tons)

	1978	Forecast Range		Probable		Probable Average Annual Growth Rate 1978-2000 (Percentage)
		Low	High	1990	2000	
United States:						
Primary	774	860	1,300	900	1,000	1.2
Secondary	650	940	1,700	1,000	1,300	3.2
Total	1,424	1,800	3,000	1,900	2,300	2.2
Cumulative (primary)	---	18,000	22,600	10,100	19,600	---
Rest-of-World:						
Primary	6,221	11,000	18,100	9,900	14,500	3.9
Secondary	1,499	3,600	6,400	2,700	4,500	5.1
Total	7,720	14,600	24,500	12,600	19,000	4.2
Cumulative (primary)	---	186,000	251,000	97,000	219,000	---
World:						
Primary	8,100	13,400	22,300	12,400	17,700	3.6
Secondary	2,000	4,700	8,200	3,600	5,900	5.0
Total	10,100	18,100	30,500	16,000	23,600	3.9
Cumulative (primary)	---	233,000	315,000	123,000	274,000	---

(Mineral Facts and Problems, Bulletin 671, 1980, Page 507)

Figure 1.2-3 Components of Zinc Uses in the United States



Source: Zinc Industries Association, 1980.

Aluminum, steels, and plastics have also replaced brass in many applications. Paints and chemicals, aluminum, magnesium, and titanium have also made significant in-roads.

Zinc Demand

Zinc has been subjected to an onslaught of substitution in many areas. Because of environmental considerations, lighter automobiles have required less of the metal. The high prices of zinc in the early 1970s resulted in industry substitution, and the metal has not been completely successful in recapturing these markets. The U.S. Bureau of Mines predicts only moderate growth to the year 2000 in both the domestic and world markets, as shown in Table 1.2-3. This demand is further subject to the status of the national and world economies. The modest projections of a 1.7% domestic growth in demand and a 2.1% world growth rate reflects these considerations (Cammaroto, 1980a).

1.3 METAL PRICES

The juncture of supply and demand is defined in economic terms as the sales price. The sales price of metals is affected by numerous factors. Speculators can play a major role in manipulating metals prices. Protective associations perform various market operations in an attempt to stabilize the prices. The increased national ownership has also affected prices. The imperative of cash flow by developing countries has affected the market periodically by developing an oversupply. Environmental requirements and the concomitant costs can effect the price. Transportation charges, stockpiles, scrap, and other considerations can effect near- and long-term metal prices. The metals under consideration, copper, lead, and zinc, are sold under at least two price structures: the producer price and the commodity exchange price.

TABLE 1.2-3: Summary of Forecasts of U.S. and Rest-of-World Zinc Demand (Thousand Metric Tons)

	1978	Forecast Range		Probable		Probable Average Annual Growth Rate 1978-2000 (Percentage)
		Low	High	1990	2000	
United States Metal:						
Primary	952	800	1,400	1,000	1,150	0.9
Secondary	77	100	200	100	150	3.1
Non-Metal: Primary	200	300	900	300	500	4.3
Total United States:						
Primary	1,152	1,100	2,300	1,300	1,650	1.6
Secondary	77	100	200	100	150	3.1
Total	1,229	1,200	2,500	1,400	1,800	1.7
Cumulative (primary)	---	24,800	37,100	14,800	30,600	---
Total Rest-of-World:						
Metal:						
Primary	4,900	6,000	9,000	6,300	7,650	2.0
Secondary	300	400	700	420	550	2.8
Non-Metal: Primary	350	500	800	470	600	2.5
Total Rest-of-World:						
Primary	5,250	6,500	9,800	6,700	8,250	2.1
Secondary	300	400	700	420	550	2.8
Total	5,550	6,900	10,500	7,190	8,800	2.1
Cumulative (primary)	---	129,800	163,100	72,300	148,000	---
World Metal:						
Primary	5,852	6,800	10,000	7,300	8,800	1.9
Secondary	377	500	900	520	700	2.9
Non-Metal: Primary	550	800	1,700	800	1,100	3.2
World Total:						
Primary	6,402	7,600	12,100	8,070	9,900	2.0
Secondary	377	500	900	520	700	2.9
Total	6,779	8,100	13,000	8,590	10,600	2.1
Cumulative (primary)	---	154,600	200,200	87,100	178,600	---

(Mineral Facts and Problems, U.S. Bureau of Mines, 1980, page 15)

Price Establishment

Copper is traded on two commodity exchanges, the London Metal Exchange (LME) and the New York Commodities Exchange (Comex). Lead and zinc, which have a lower sales volume are traded only on the LME. Commodity exchanges serve the marginal producer and are frequently referred to as "the market of last resort". Very little metal physically trades hands in this market, although this can and does occur. The exchanges are used by buyers and sellers to sell surplus stock, purchase stocks, fulfill near-term agreements, and for speculation. Prices on these exchanges are established literally on the market floor and fluctuate daily.

Producer prices, on the other hand, are established by the metal producers. These prices frequently are established with LME or Comex quotes as a guide, but they are not necessarily the same as the posted exchange prices. The majority of the metal that actually trades hands in the United States is sold on the basis of producer prices under long-term contracts. Long-term contracts frequently include terms to make the long-term commitment attractive.

The pricing of copper in the United States has had a variable history. In 1978, Kennecott announced plans to sell on the basis of the posted Comex price instead of the producer price. Later that year, Anaconda followed this step. With two major producers abandoning producer pricing, the remaining producers altered but did not abandon the producer price system. This action has tended to increase the volatility of copper prices. Prices change more rapidly and frequently because exchanges are used for speculation. Since then, Anaconda has had less copper to sell and in early 1982 Kennecott reverted to the producer price system.

As previously mentioned, lead and zinc are traded on only one exchange, the LME. As with copper, the major producing countries have established producer prices for long-term contract sales. While LME prices are used as a guide, producer prices are fixed separately by each company. The U.S. producer price is the primary price for lead. Zinc prices are quoted by U.S., European, and Canadian producer prices.

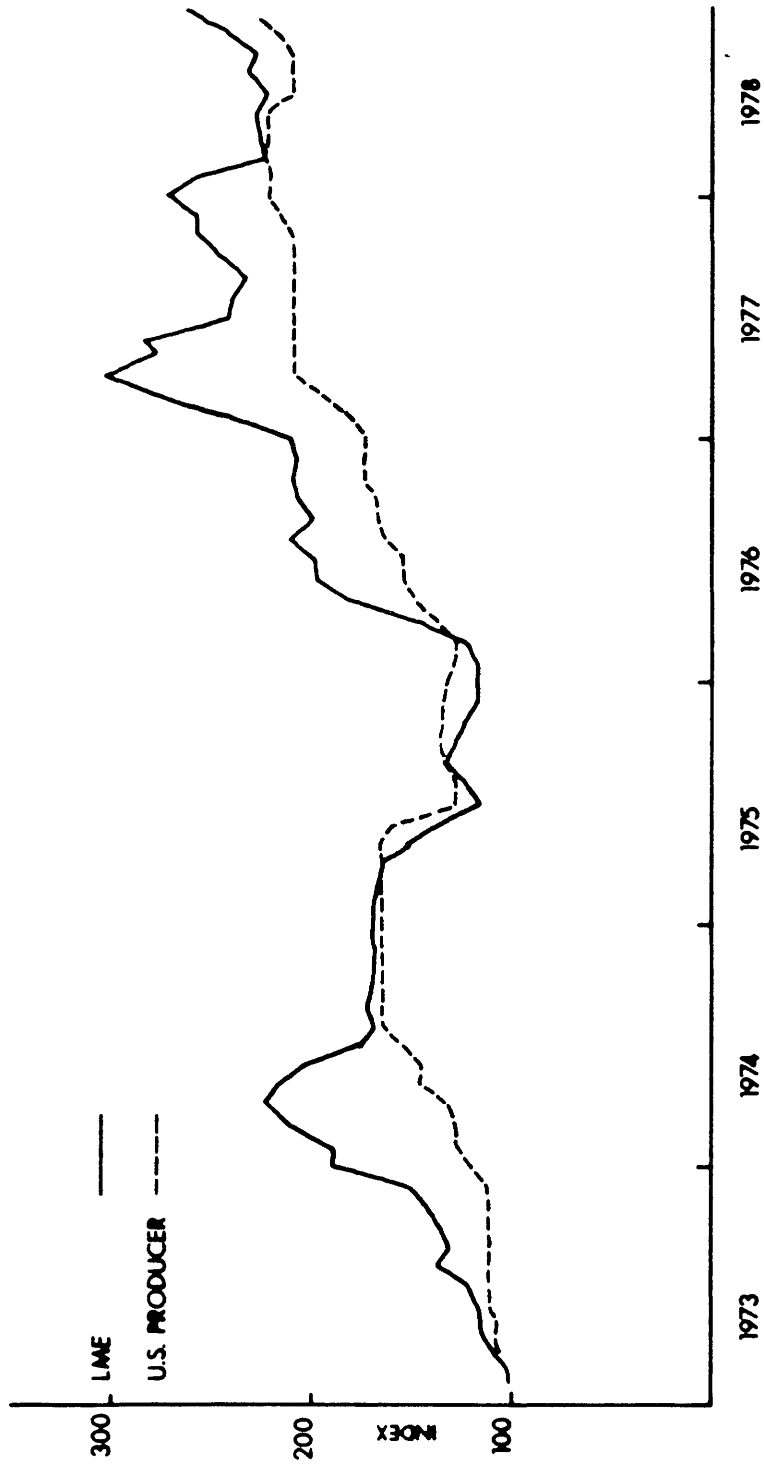
Lead and zinc prices generally tend to be more stable than copper prices for several reasons. First, lead and zinc do not rely on the commodities exchanges to establish prices for long-term contracts. This removes the volatility of speculation from a major part of the exchanges. Secondly, the major resources for lead tend to be in more developed countries. These companies have a similar outlook, costs are competitive, and the producers are independently owned. Because of this common perspective, producers can exert some control on the price to moderate price swings. A third factor stabilizing lead price is the large secondary market. With scrap forming 40% to 60% of the world market sales, producer prices must be conservative to maintain a market share. Zinc prices have gained stability because of the relative balance of production and demand. Because scrap plays only a small part in the zinc market, it has little influence on the price. A significant factor for zinc has been the recent refinery closures in the United States. These actions have brought world supplies closer to current and projected demand.

As a rule, producer prices are more stable than prices on the commodity exchanges because of the inherent speculation in these institutions. Figure 1.3-1 illustrates this difference. The producer price follows the LME price, but closely parallels it only during periods of extended LME stability. Much of the exchange variability is not experienced.

Price Influences

All three metals have been subjected to price swings for the last 20 years. Copper has seen some especially wide changes. Product organizations have been formed in an effort to protect the industries from the instability. One group, the Intergovernmental Council of Copper Exporting Countries (CIPEC), was formed in 1967

Figure 1.3-1 Index of Average LME Cash Settlement and U.S. Producer Prices for Refined Lead, 1973-1978



by four producing countries (Mikesell, 1980). These four countries, Chile, Peru, Zaire, and Zambia, attempted to control prices by controlling supply in 1974 (Gluschke, 1979). The time selected to attempt control was during weak copper prices, and the effectiveness of the effort cannot be fully determined. Since then, the organization has been a forum for policy coordination and research. Other producers, Indonesia, Australia and Papua-New Guinea, joined the organization in 1975 (Mikesell, 1980). Because copper forms 95% of the exports for five member countries and 50% for another, significant export controls by this group in the future are doubtful (Roskills, 1979).

Lead and zinc have no similar separate organizations. The International Lead and Zinc Research Organization (ILZRO) has been supported by the United Nations. The Lead and Zinc Associations were formed by major producers and marketers. These groups conduct studies, evaluate markets and conduct marketing efforts.

A consortium, referred to as EPC, was formed in 1964 to stabilize zinc prices (Roskills, 1979). The actual membership of the group has not been confirmed, but it consisted of 20 to 50 companies from Europe, Australia, and Canada. This group collaborated to influence zinc prices on the LME as well as their posted producer prices. The EPC functioned until 1976, when the United States initiated anti-trust proceedings. This action caused the break-up of the consortium and collaboration ceased (Roskills, 1979). The European Economic Community is considering a coordinated producer price system but has not yet established one (Robbins, 1980).

These factors all affect the metals prices to varying degrees, but the overriding influence is the general world market. Commodities, as a group, follow a cyclical pattern (Belica, 1981). The degree of price swings will vary, depending on the metal. Copper is a major metal that is used throughout the world. Because it is closely tied to all economies, demand changes as world demand fluctuates. One analyst suggests using copper as the indicator of national and world economic health (Robbins, 1980). Producer prices, stocks, speculators, new supplies, and improved recoveries can exert only a limited influence when compared to world economic vigor. The current softness in metals prices illustrates this relationship.

CHAPTER 2: TRENDS OF THE INDUSTRY

Trends in non ferrous metals processing can be identified by an analysis of certain aspects of the industry. This chapter examines the data from 1960 to 1980 to identify trends and the correlation between certain areas. Smelting and refining capacity trends are considered, as well as several factors that relate to them. These include metals prices, production, consumption, capital and operating costs, and international trade. Defining the interaction of these variables provides a more accurate perspective of the primary metal processing industry.

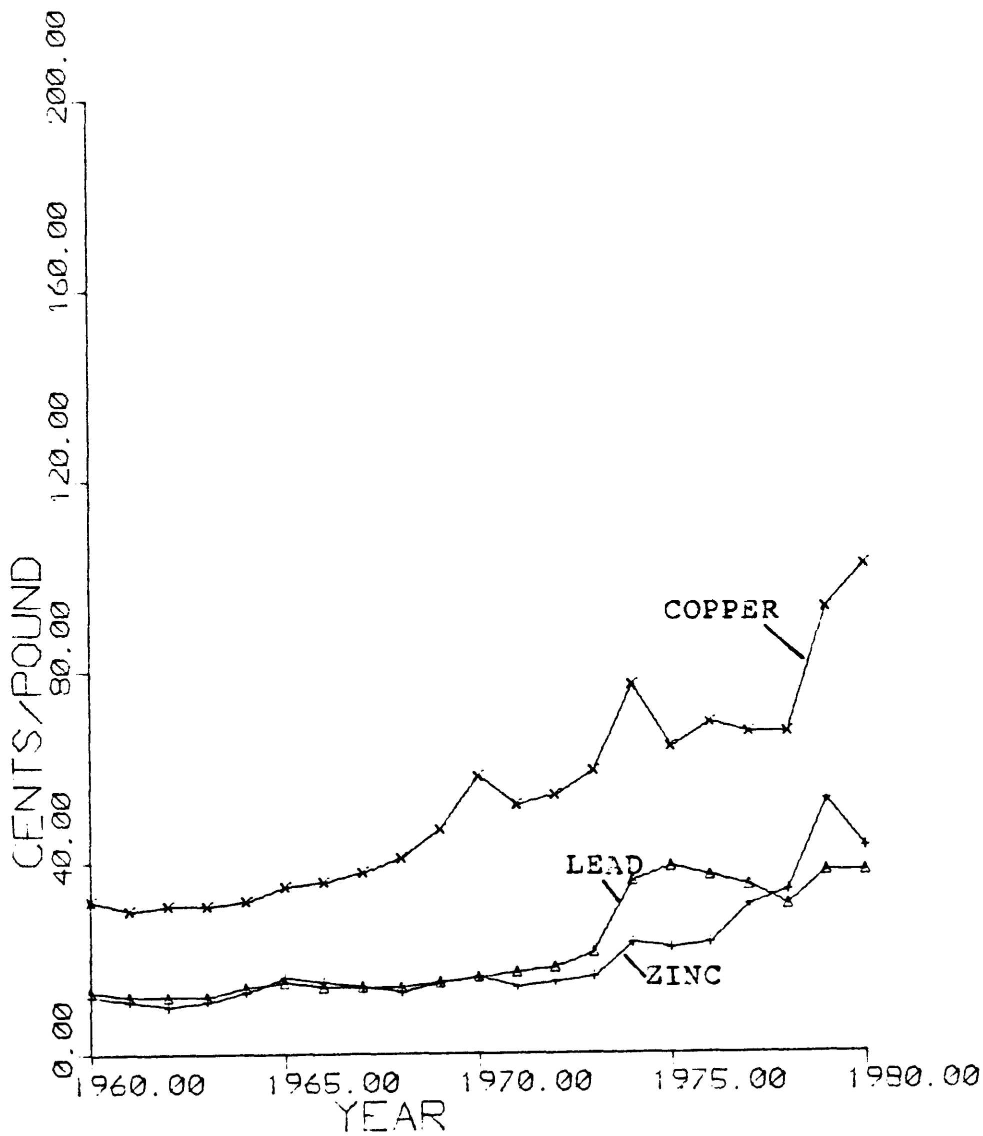
2.1 PRICES

Metals prices are basic to the industry and the comparison of current and constant dollar prices provides an insight into the economics of the industry. For this study, constant dollar values were calculated using 1967 as the base year from the non ferrous metals producer price index (Appendix A, Table A-2-1).

In current dollars, prices for copper and lead trended upward from 1960 and reached record levels in 1979 and 1980. Prices began falling in 1980 and this decline has continued in 1982 (Appendix A, Table A-2-2 and A-2-3). Zinc prices have not followed the current dollar trends of copper and lead, and have trended gradually higher. After a slight decline in the late 1970s, zinc prices have remained fairly constant (Appendix A, Table A-2-4). The current dollar price trends for all three metals are illustrated in Figure 2.1-1.

The gradually increasing price trends for copper, lead, and zinc are reversed when examined in constant dollars. For copper, prices trended erratically higher until 1973, then fell, reaching record lows from 1980 to 1982. Lead prices remained fairly static until falling to record lows in early 1982. Again zinc is an exception. In real terms, zinc demonstrated an increase in the mid-1970s. Constant

Figure 2.1-1 <u>**Current Dollar Prices for Copper, Lead, and Zinc, 1960-1980**</u>



zinc prices have since fallen to price levels comparable to the late 1960s, but have not reached the record lows for the two decades that copper and lead have shown. The metal prices in constant dollars for copper, lead, and zinc are also summarized in Appendix A, Tables A-2-2, A-2-3, and A-2-4. A comparison of current and constant prices for each metal is illustrated in Figures 2.1-2 through 2.1-4.

An examination of the producer price index for non ferrous metals explains the difference between current and constant dollars. With 1967 as the base year, an increase of up to 18% in prices was seen in the early 1960s. From 1967 to 1973, the index increased 35%. From 1973 to 1974, there was an additional increase of 52%. With 1967 as the base year, the index increased an additional 103% from 1974 to 1982 (see Appendix A, Table A-2-1). These large increases illustrate why current dollar prices can be misleading.

2.2 METAL CONSUMPTION

Prices are one of several components of the industry. Consumption and the relative trends are also important. World consumption of copper, lead, and zinc have been increasing, and since 1960 each metal has shown considerable gains. The consumption patterns for each metal have been different, as can be seen in Figures 2.2-1 through 2.2-3.

World consumption of copper has increased 125% since 1960. The unique pattern of copper consumption is in relatively sharp cycles occurring approximately every seven years. Domestic consumption, which accounts for approximately 25% of the world total, has increased 92% since 1960. This rate, which is slightly lower than the world growth rate, indicates the maturing demand in the United States. These figures are based on the data in Appendix A, Table A-2-5.

Figure 2.1-2 Current and Constant Dollar Prices of Copper, 1960-1980

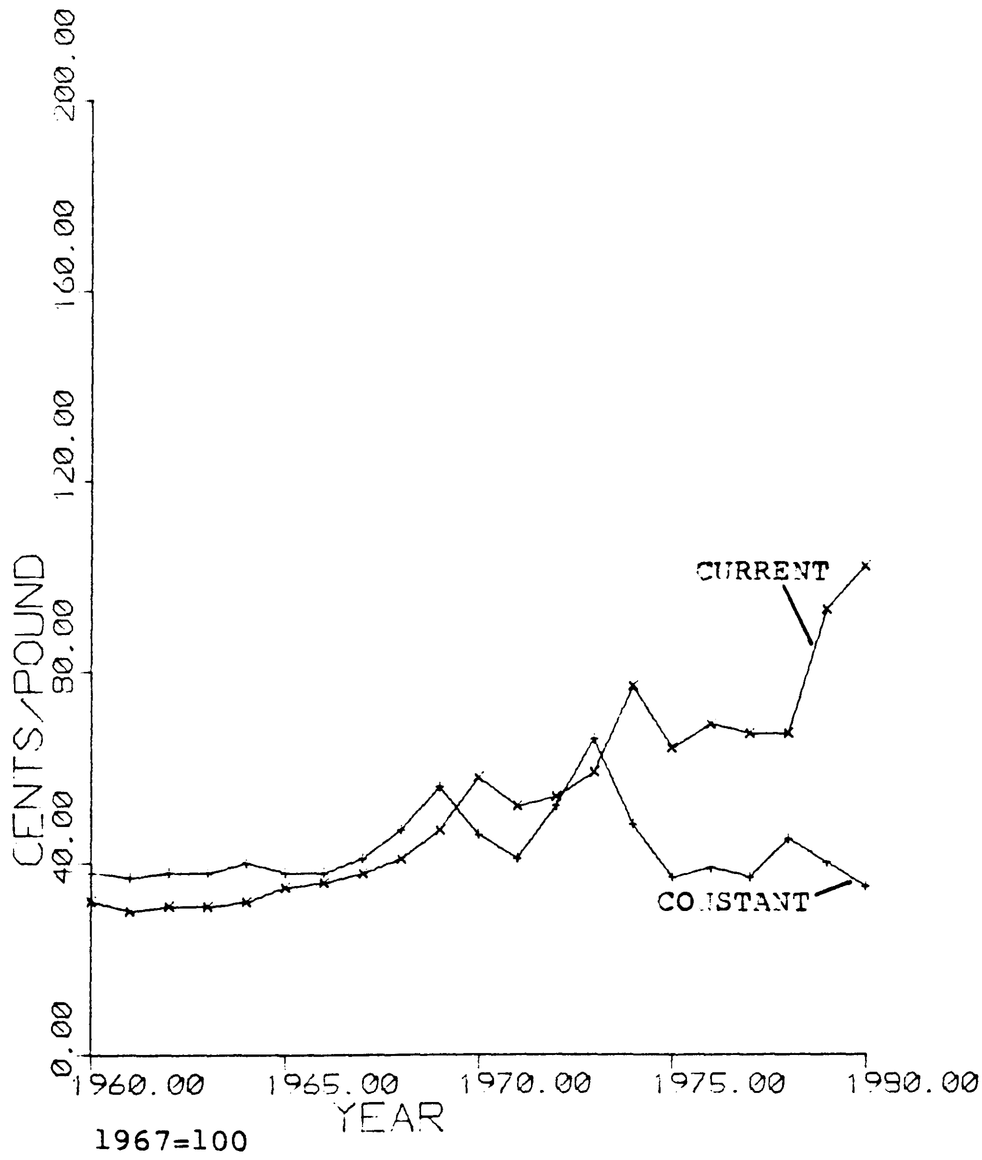
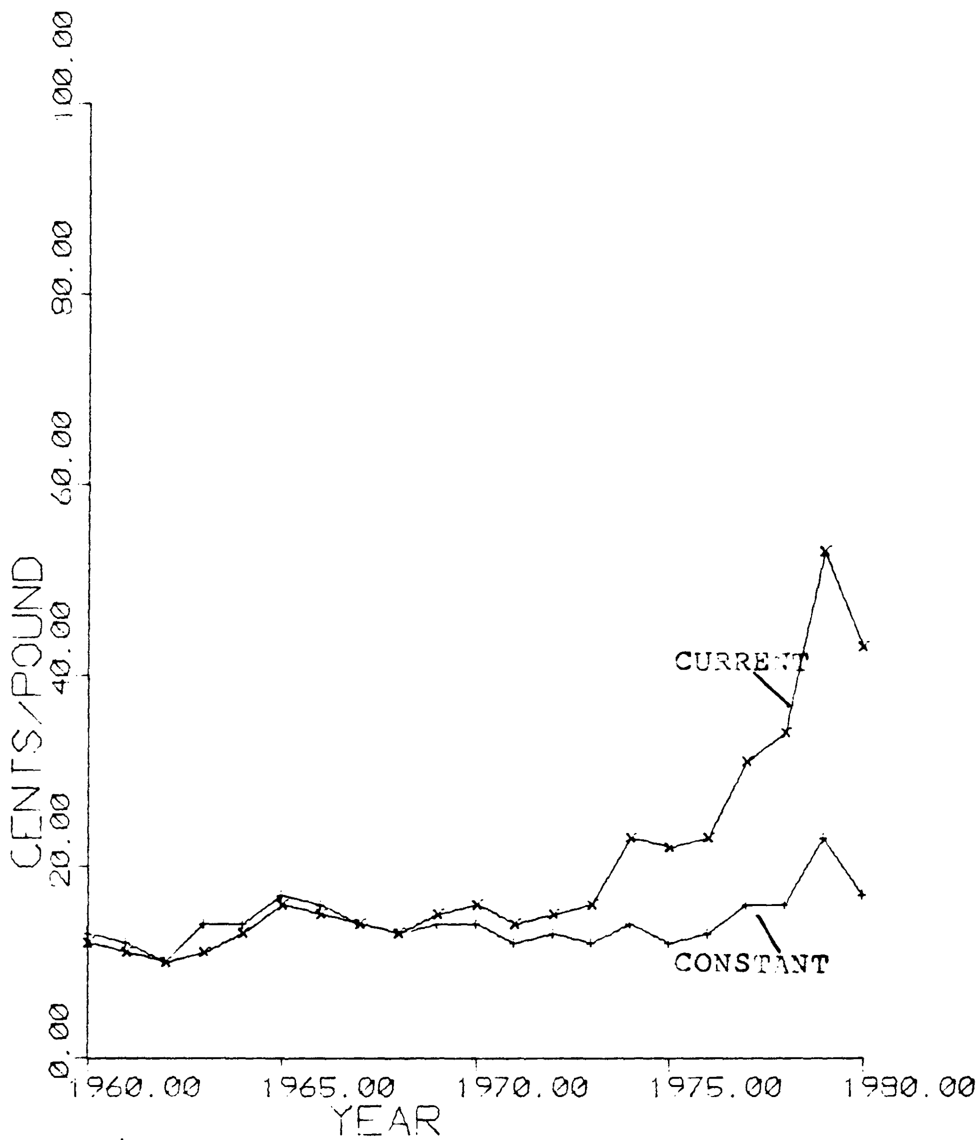


Figure 2.1-3 Current and Constant Dollar Prices of Lead, 1960-1980



1967=100

Figure 2.1-4 Current and Constant Dollar Prices of Zinc, 1960-1980

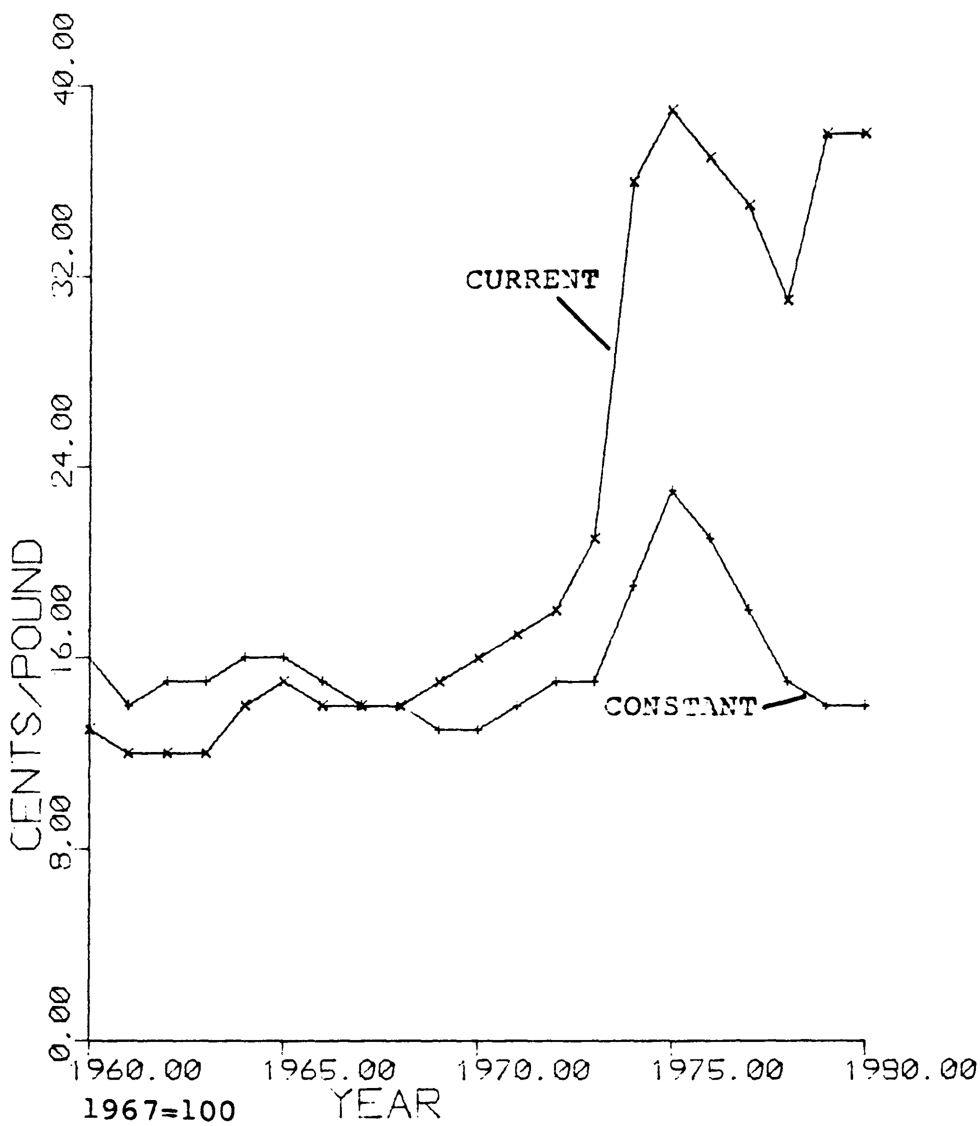


Figure 2.2-1 <u>Consumption of Copper, 1960-1979</u>

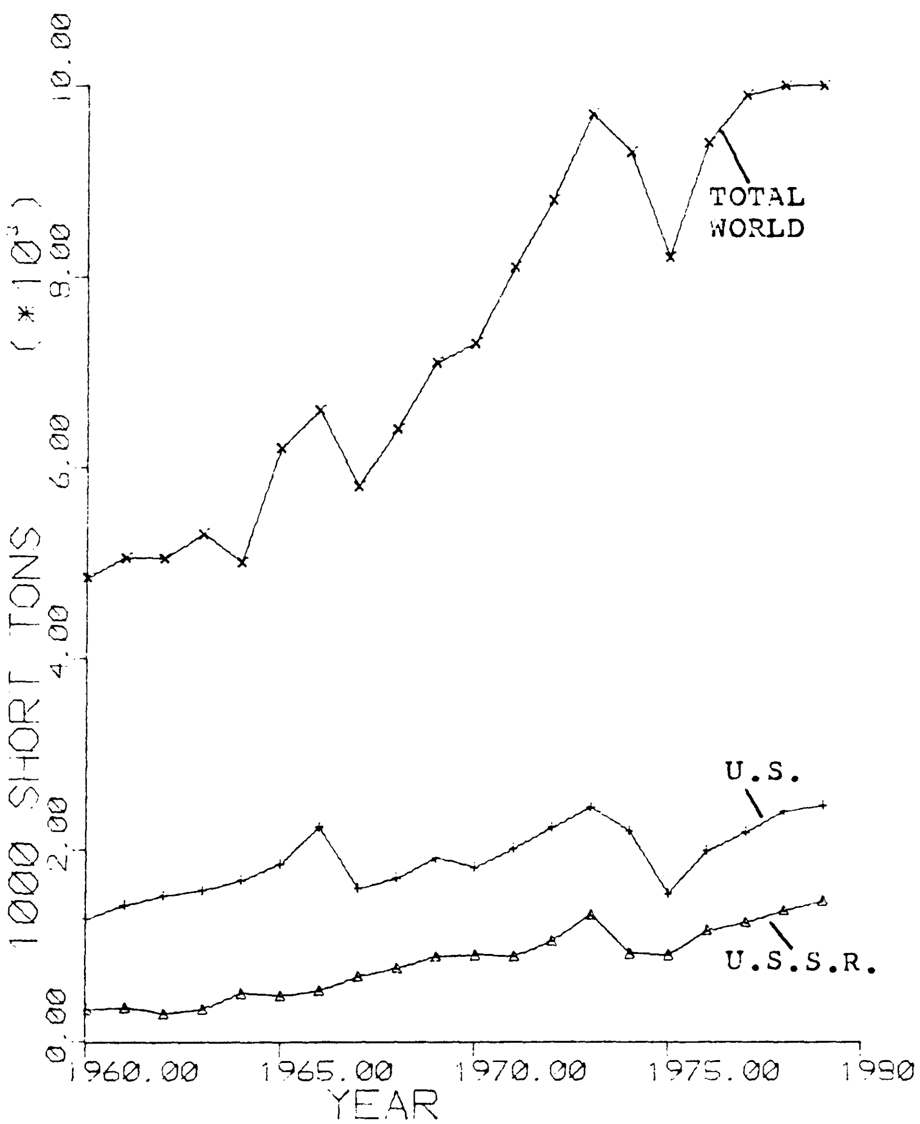
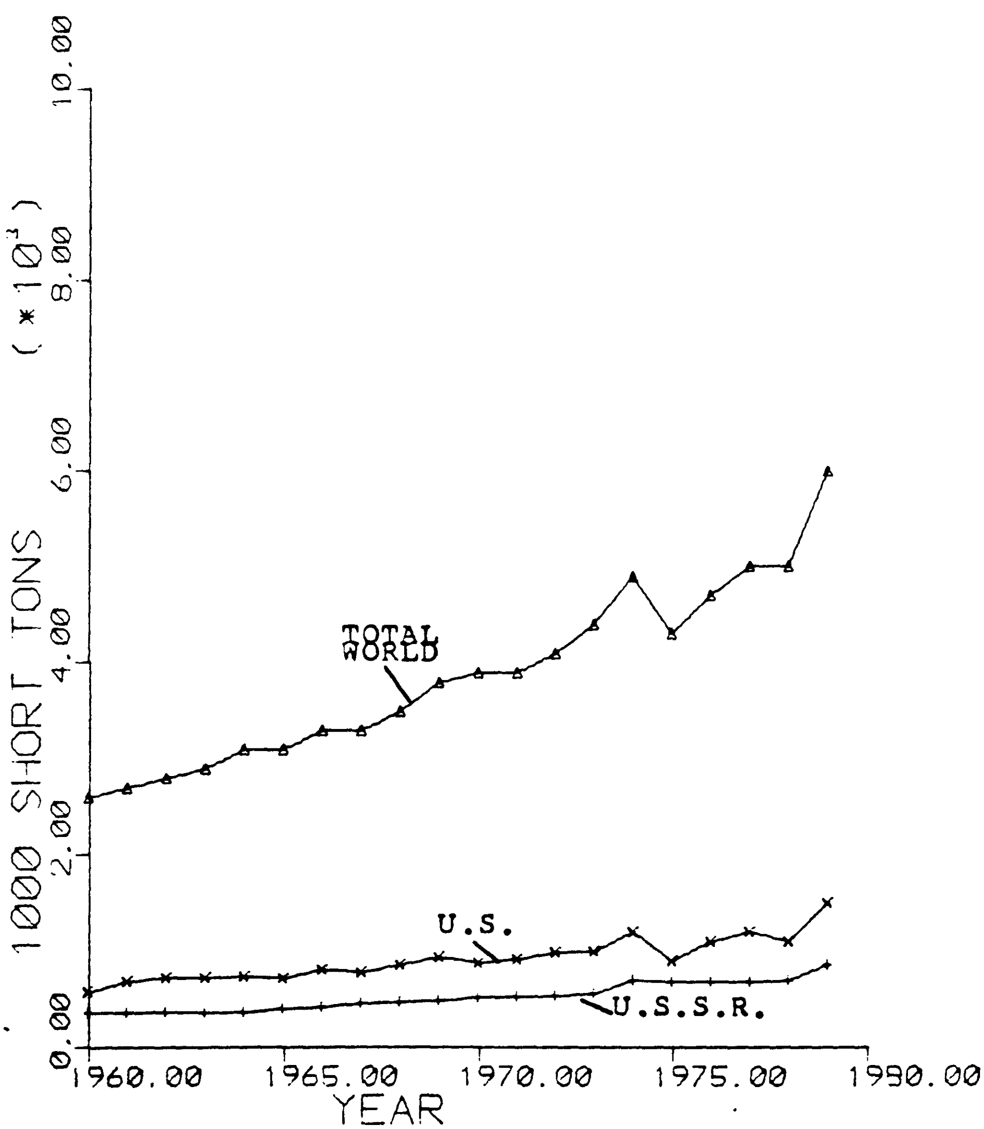


Figure 2.2-2 Consumption of Lead, 1960-1979



In both the world and the domestic market, lead consumption has shown a more stable rate of growth. World consumption has increased 133% since 1960. The U.S. consumption represents about 25% of world demand, and has increased by 154% for the same period. The overall rate of consumption has been slightly higher since 1970 both in the world and the United States, but domestic consumption is expected to be lower in the future (Section 1.1). These figures were calculated from the data in Appendix A, Table A-2-6.

Zinc has had an interesting growth pattern, as can be seen in Figure 2.2-3. On the basis of consumption data in Appendix A, Table A-2-7, consumption until 1968 was fairly constant. From 1968 to 1979, the consumption has been more erratic. Since 1975, world demand has grown 25% while the U.S. demand has grown only 15%. The average annual zinc consumption since 1975 has been lower than the annual consumption from 1960 through 1974.

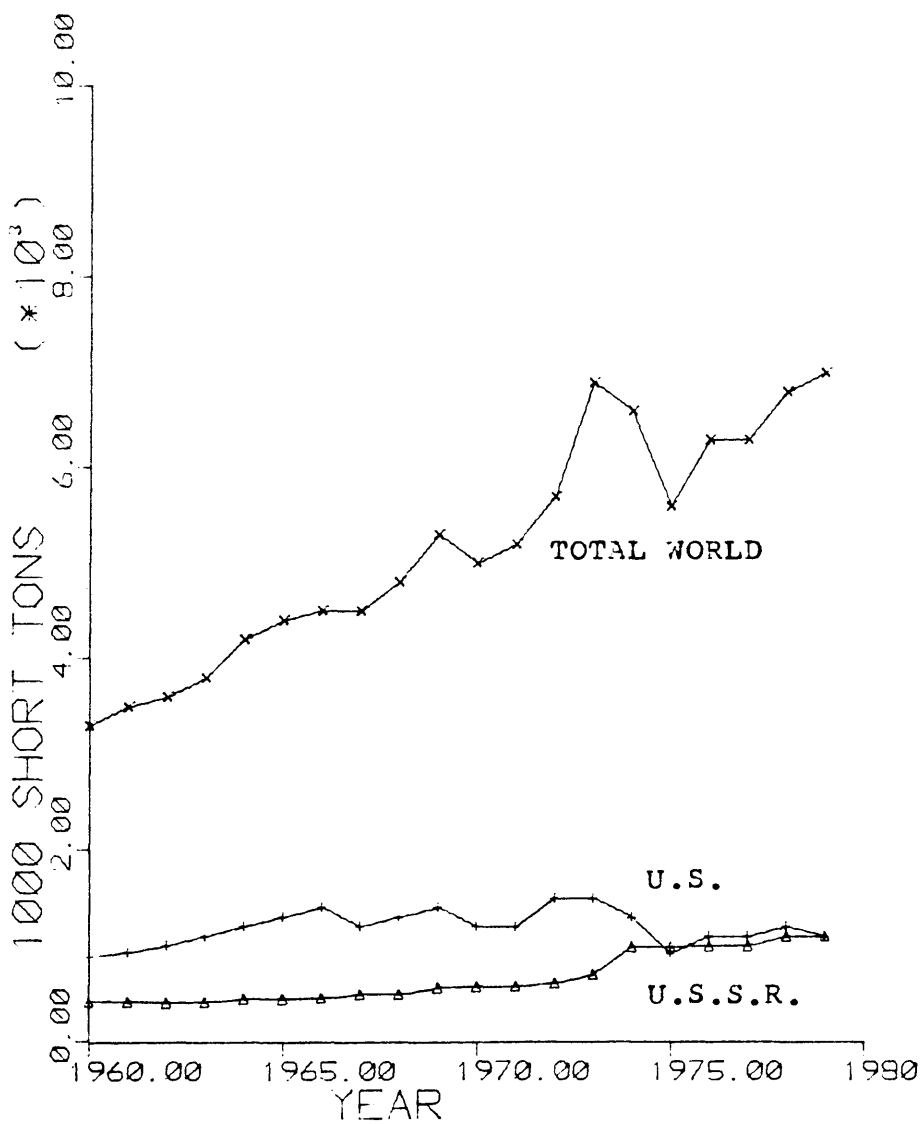
2.3 PRODUCTION

Another variable related to smelting capacity is production. World production of refined copper, lead, and zinc has generally increased at rates which approximately parallel consumption. Domestic trends have been slightly different. It is these trends which have created interest and concern in the industry, the press, and the government (World Mining, 1981; Radetzki, 1979; Sousa, 1981, E&MJ, 1982).

Copper smelters are frequently located some distance from the refinery (see Section 1.1), while lead and zinc smelting and refining typically occur at the same location. Since smelting and refining for copper are separate processing functions, trends for each are discussed separately.

Copper smelting production has roughly paralleled the world mine production (Appendix A, Table A-1-3). Although the Soviet Union, Japan, and Chile have

Figure 2.2-3 Consumption of Zinc, 1960-1979



been steadily increasing capacity, the United States still leads the world with 17% of the total capacity in 1979 (Figure 2.3-1). While production has remained strong in recent years, domestic smelting capacity has been declining. Until recently, when smelters have closed, new smelters have opened and replaced or expanded beyond the lost capacity. For example, when the Superior, Arizona smelter was closed in 1971, Magma Copper Company had already made plans to replace the capacity. Capacity at the San Manuel, Arizona smelter was increased to 403,000 TPY in 1965 and to 670,000 TPY in 1972 (ABMS, 1972). The same smelter was later enlarged to 800,000 TPY in 1974 (ABMS, 1974). In another example, Phelps Dodge smelter capacity gradually declined at the Douglas smelter. This decline in capacity was compensated for by the Hidalgo smelter in New Mexico. This smelter came on-stream in 1976 with a capacity of 640,000 TPY (ABMS, 1976). Table 2.3-1 summarizes the smelter closures and these trends are evident. Sharp reductions in domestic smelting capacity occurred in 1980. The Anaconda, Montana smelter closing removed 750,000 TPY of concentrate capacity, or 8.3% of the current domestic capacity. As of the end of 1980, domestic smelting capacity was down 2% from 1966 to 1968, the previous low for the two decades (Appendix A, Table A-2-8). Figure 2.3-2 graphically illustrates the changes in domestic smelting capacity since 1960. Domestic smelter capacity is the lowest it has been since before 1960 and no new smelter capacity is planned to come on-stream in the next few years (Tobin, 1982, Metals Week, 1981a).

Domestic copper refinery production has roughly followed smelter production. Overall copper refining capacity has grown steadily since 1960 (Appendix A, Table A-2-9). Major reductions were not recorded until 1980, when two refineries were closed. Anaconda closed the Great Falls, Montana refinery for lack of feed (Wall Street Journal, 1981a). ASARCO closed the Tacoma, Washington refinery when the El Paso, Texas refinery came on-stream (Butterman, 1981). The closure of these two refineries reduced electrolytic production capacity by 360,000 TPY, which represents a 15% loss relative to 1979. This new level of capacity is comparable to the domestic electrolytic refining capacity up through 1967. The refinery capacity changes are summarized in Table 2.3-2.

TABLE 2.3-1: Domestic Copper Smelters
(Reported in 1000 tons of 2000 Pounds)

Firm/Location	1965	1970	1975	1980	Year Closed
AMAX					
Carteret, NJ	168	190	180	193	
ASARCO					
El Paso, TX	420	576	576	576	
Hayden, AZ	420	960	960	960	
Tacoma, WA	600	600	600	600	
Anaconda					
Anaconda, MT	1000	1000	750	---	1980
Inspiration					
Miami, AZ	450	450	450	450	
Magma Copper					
Superior, AZ	150	150	---	---	1971
San Manuel, AZ	400	400	800	800	
Kennecott					
McGill, NV	400	400	400	255	
Hurley, NM	400	400	400	360	
Hayden, AZ	420	420	420	360	
Garfield, UT	1000	1000	1000	1000	
Chemetco					
Alton, IL	---	---	---	150	
Phelps Dodge					
Douglas, AZ	1250	875	700	700	
Morenci, AZ	900	900	900	900	
Ajo, AZ	300	300	250	250	
Playas, NM	---	---	---	640	
Tennessee Copper					
Copperhill, TN	90	90	---	18	1972
Galumet & Hecla					
Hubbell, MI	100	30	---	---	1972
Quincy Mining					
Hancock, MI	12	15	15	15	
White Pine					
White Pine, MI	65	90	90	90	
Total	**8548**	**8839**	**8716**	**8317**	

(Compiled from Non Ferrous Metal Data, 1960-1980)

TABLE 2.3-2: Domestic Copper Refineries
(Reported in 1000 tons of 2000 Pounds)

Firm/Location	1965	1970	1975	1980	Year Closed
AMAX					
Carteret, NJ	150	175	175	191	
ASARCO					
Baltimore, MD	198	318	---	---	1975
Barber, NJ	168	168	168	---	1979
Tacoma, WA	103	156	156	156	
Amarillo, TX	---	---	420	420	
Anaconda					
Great Falls, MT	180	1900	252	---	1980
Inspiration					
Inspiration, AZ	70	70	70	70	
Magma Copper					
San Manuel, AZ	---	---	200	200	
Kennecott					
Garfield, UT	186	186	186	191	
Anne Arundel, NJ	198	276	276	276	
Cerro					
St. Louis, MO	42	44	44	44	
Chemetco					
Alton, IL	---	---	40	40	
Phelps Dodge					
El Paso, TX	300	420	420	420	
Laurel Hill, NY	175	155	72	72	
International Smelting					
Perth Amboy, NJ	240	150	---	---	1971
Southwire Copper					
Carrollton, GA	---	---	72	100	
Subtotal	**1973**	**2308**	**2571**	**2180**	
Lake & Fire Refining	410	368	338	482	
Total	**2420**	**2626**	**2909**	**2661**	

(Compiled from Non Ferrous Metal Data, 1960-1980)

Figure 2.3-1 World Smelter Production of Copper, 1960-1979

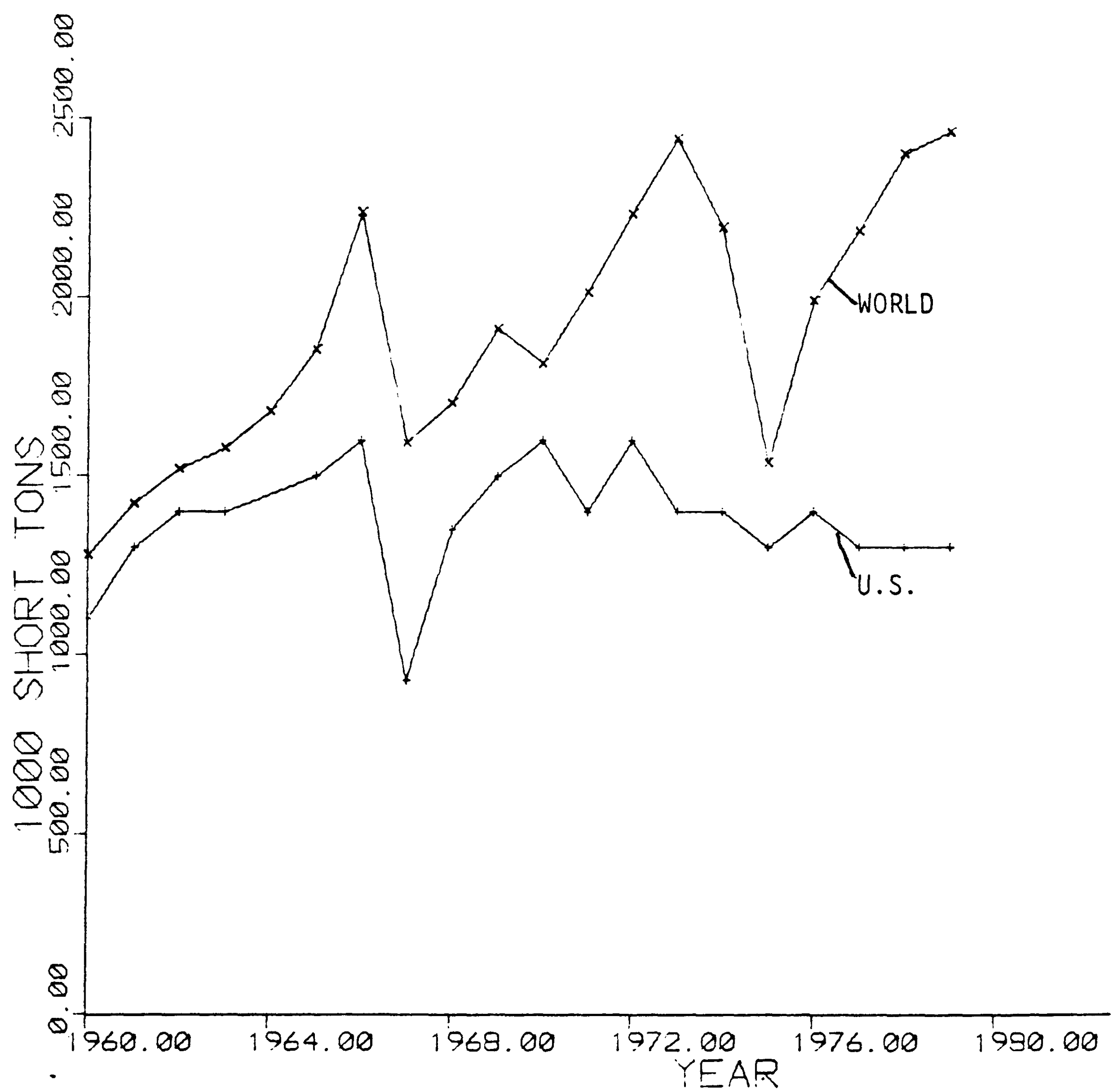
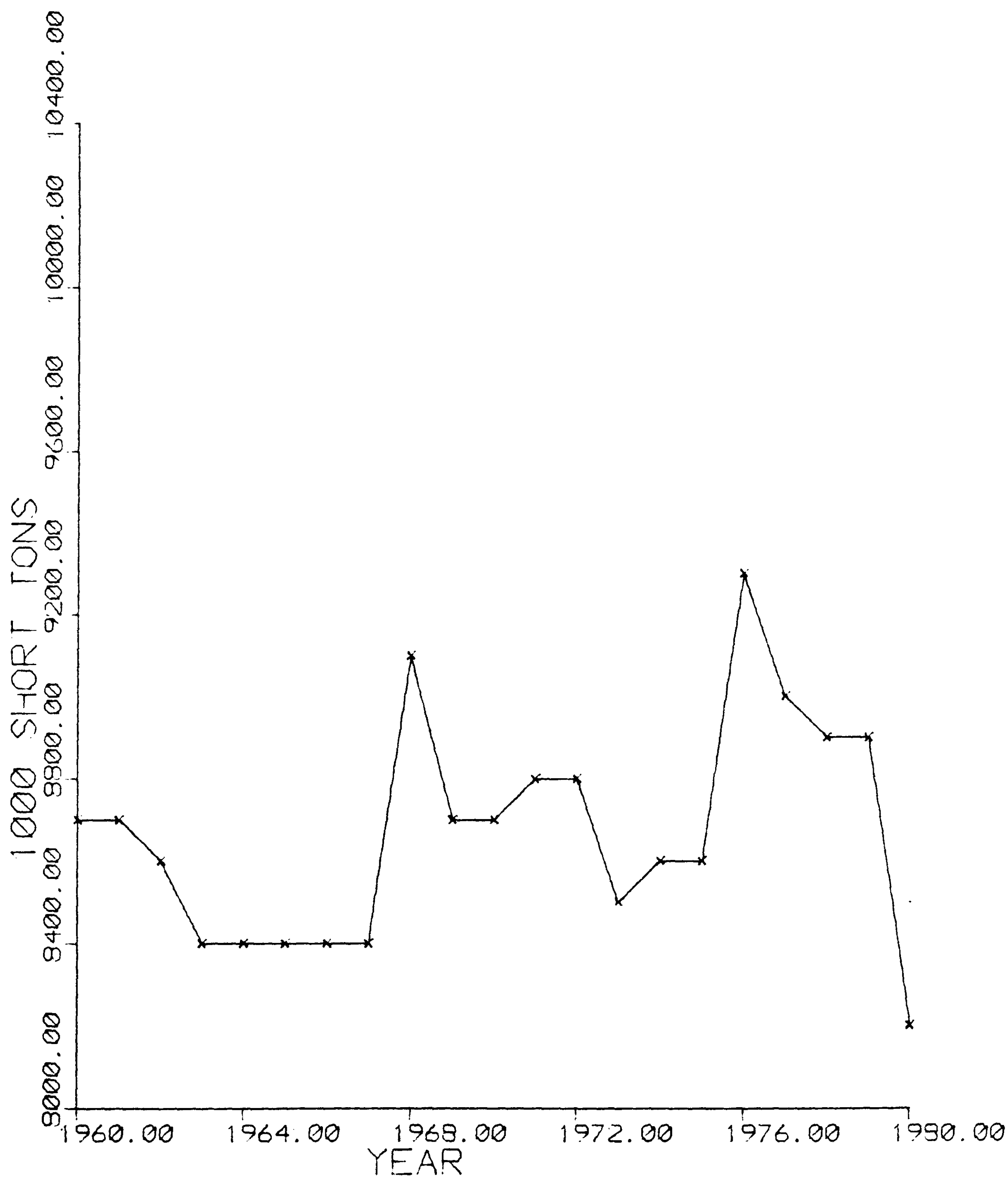


Figure 2.3-2 <u>U.S. Copper Smelter Capacity, 1960-1980</u>



The domestic consumption of copper has consistently exceeded domestic primary copper production since 1964. As Figure 2.3-3 illustrates, the relative consumption-production imbalance has been increasing since 1975. Although primary copper production has closely paralleled domestic mine production since 1960, it has been insufficient to meet domestic demand. The difference between domestic consumption and primary copper production is made up by imports of refined copper and domestic recycling.

Lead production is similar to copper. World refined lead production has steadily increased. Domestic production has followed this trend. World production has increased by 110% since 1960 and U.S. production has increased by 107%. In 1979, the United States produced 15% of the total world refined lead. Europe and the Soviet Union have also been increasing production steadily. These trends are illustrated in Figure 2.3-4. In the U.S., lead smelter capacity increased until 1972, then declined to a new low in 1981 with the closure of the Bunker Hill facility. While the increase in smelting and refining capacity in the New Missouri Lead Belt offset closure of Western smelters in the late 1960s, the recent Bunker Hill closure removed domestic smelting capacity that has not been replaced. These trends can be seen in Table 2.3-3.

Although the U.S. production of primary lead has grown, it has not been sufficient to meet consumption needs. Since 1973, the production of refined lead has remained fairly constant and has come much closer to meeting the total domestic requirements. Secondary production and imports have met the difference. As reported earlier, recycled lead accounted for 58% of domestic consumption in 1980 (Section 1.2). These relationships are illustrated in Figure 2.3-5.

The secondary lead market has recently undergone several structural changes. Batteries of lead-calcium alloy are gaining popularity because they require no maintenance. With this change, secondary producers have now begun to produce refined, or pig, lead rather than lead alloys and compete directly with primary lead producers. This change is reflected in Figure 2.3-6 (Appendix A,

Figure 2.3-3 Copper Consumption and Production in the U.S., 1960-1979

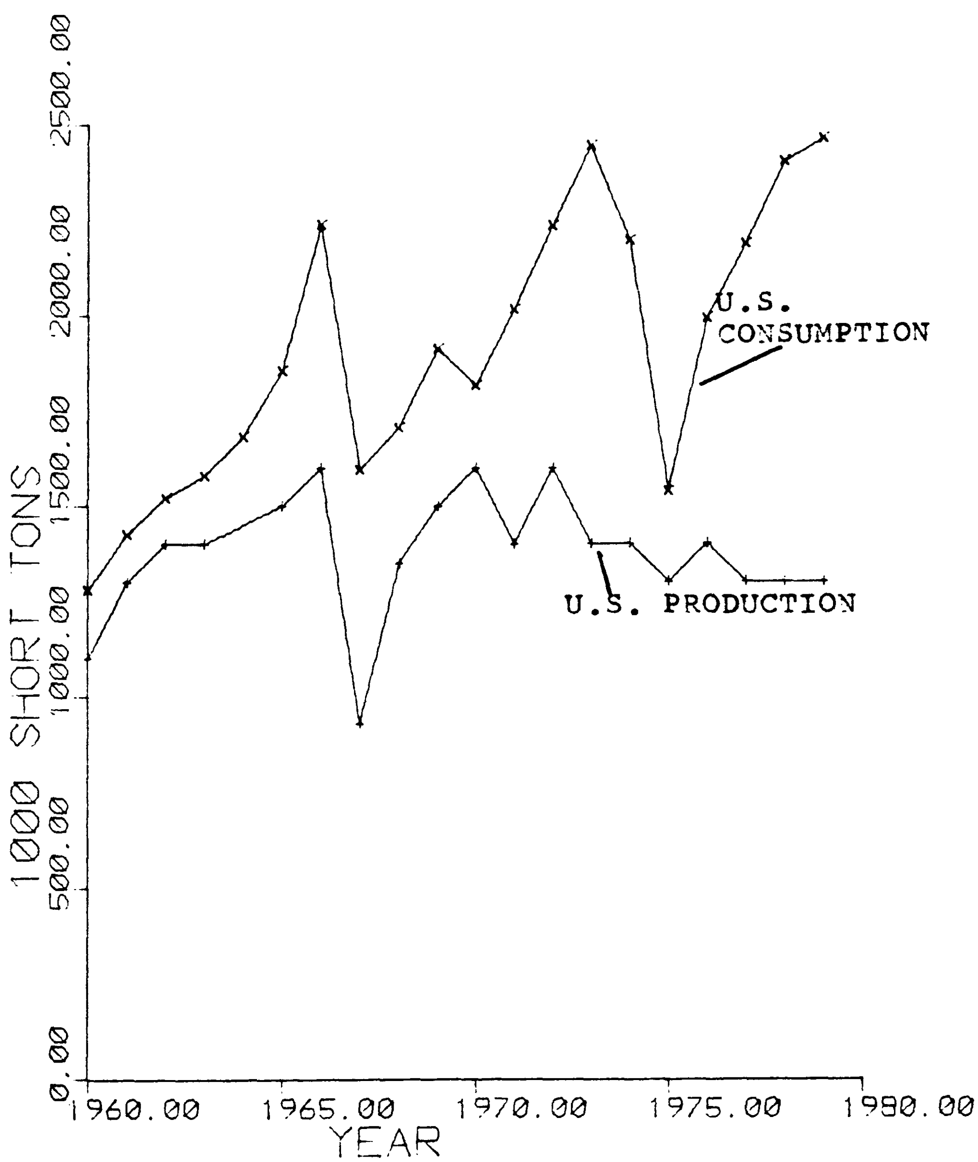


TABLE 2.3-3: Domestic Lead Smelters and Refineries
(Reported in 1000 tons of 2000 Pounds)

	1961	1970	1975	1980	Year Closed
Silver-Lead Smelters					
ASARCO					
East Helena, MT	360	420	420	420	N/A
El Paso, TX	360	420	420	420	N/A
Selby, CA	192	---	---	---	1970
Bunker Hill					
Bradley, ID	300	390	390	(390)	1981
International Smelting & Refining					
Toole, UT	300	300	---	---	1971
Subtotal	**1512**	**1530**	**1230**	**1230 (840)**	
Silver-Lead Refineries					
ASARCO					
Selby, CA	72	---	---	---	1970
Barber, NJ	96	---	---	---	1961
Omaha, NE	180	180	180	180	N/A
Bunker Hill					
Bradley, ID	100	130	130	(130)	1981
U.S.S. Lead Refinery					
East Chicago	40	40	---	---	1973
Subtotal	**488**	**350**	**310**	**310 (180)**	
Missouri Lead Smelters, Ref.					
St. Joe Minerals					
Herculaneum, MO	120	225	225	225	N/A
AMAX-Homestake					
Boss, MO	---	---	140	140	N/A
ASARCO					
Glover, MO	---	90	110	110	N/A
Subtotal	**120**	**315**	**475**	**475**	
Total	**2120**	**2195**	**2015**	**2015 (1495)**	

(Compiled from Non Ferrous Metal Data, 1960-1980)

Figure 2.3-4 World Production of Refined Lead, 1960-1979

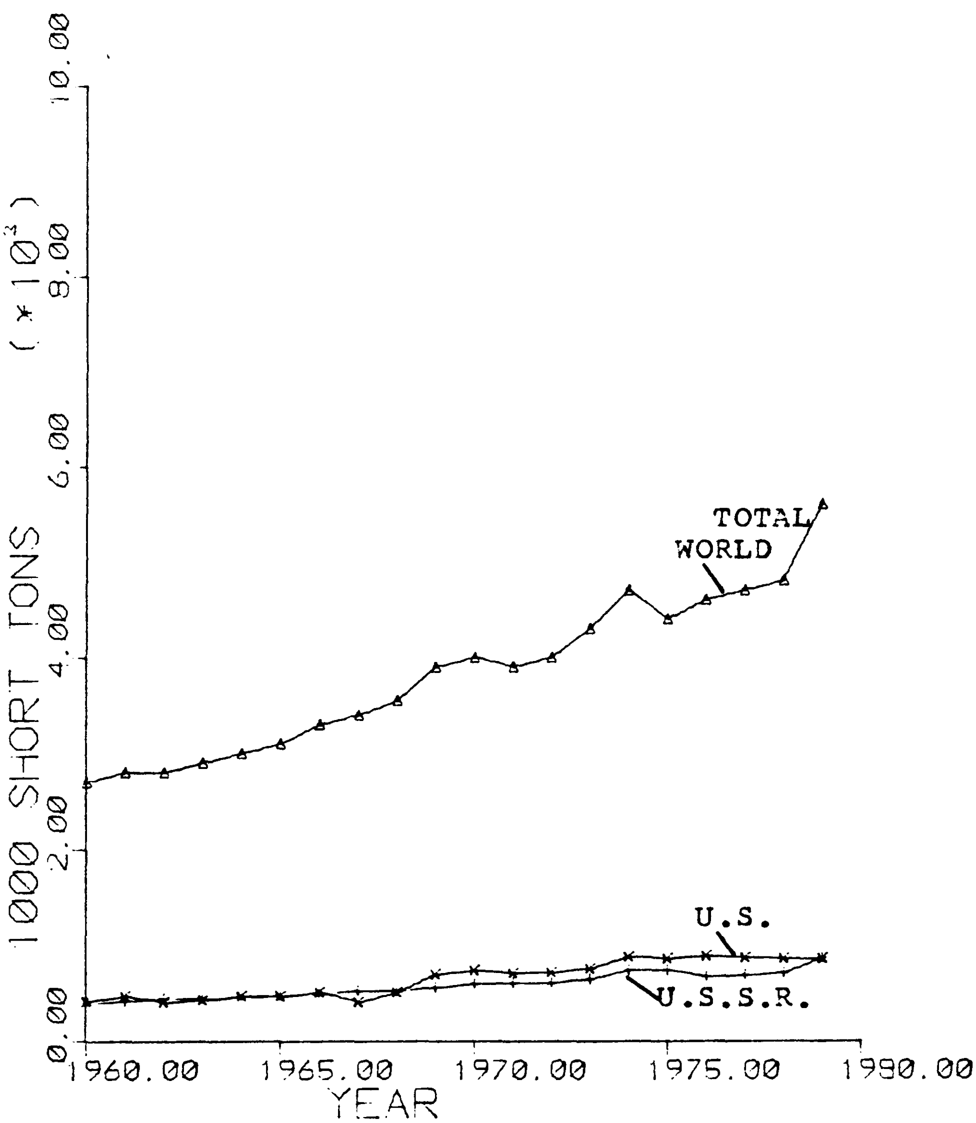


Figure 2.3-5 U.S. Lead Consumption and Production

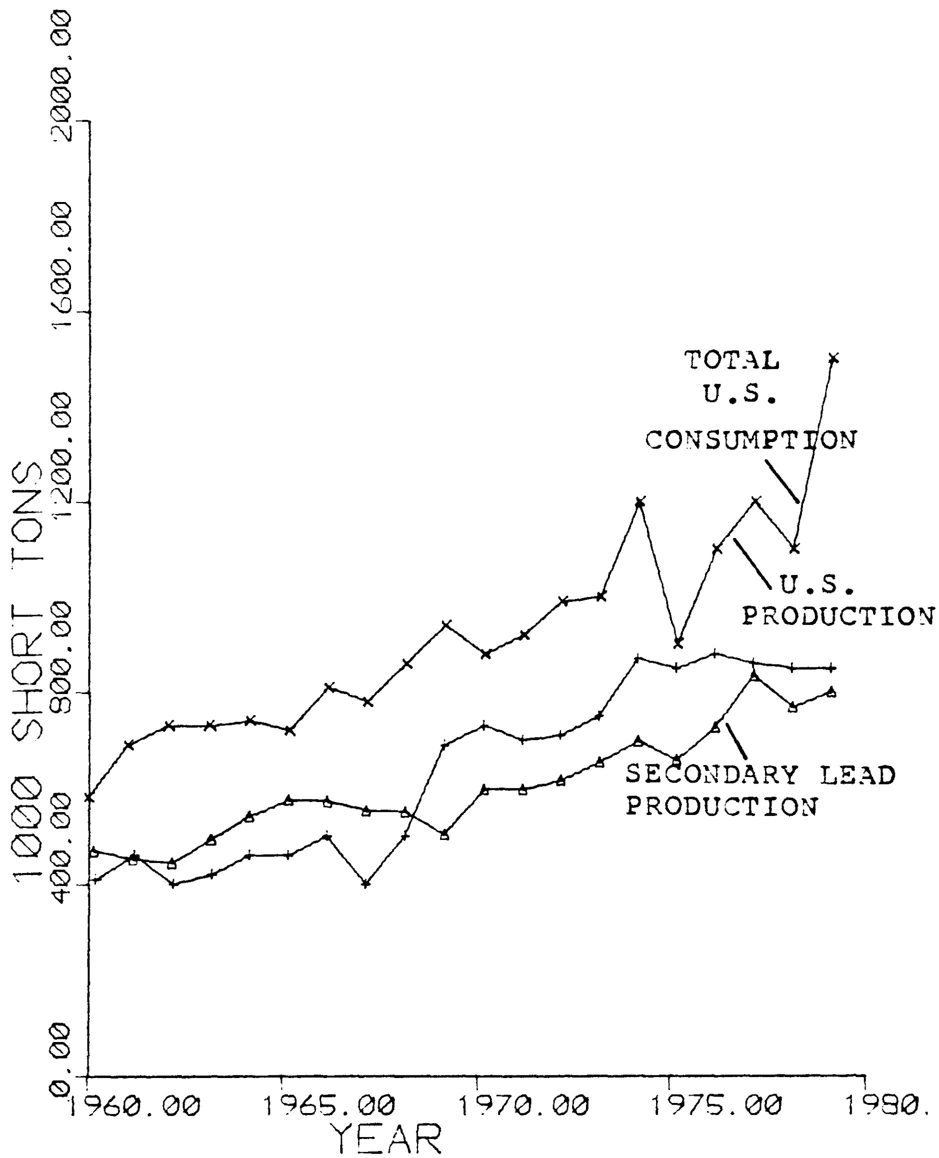


Figure 2.3-6 Secondary Lead Production in the U.S., 1960-1979

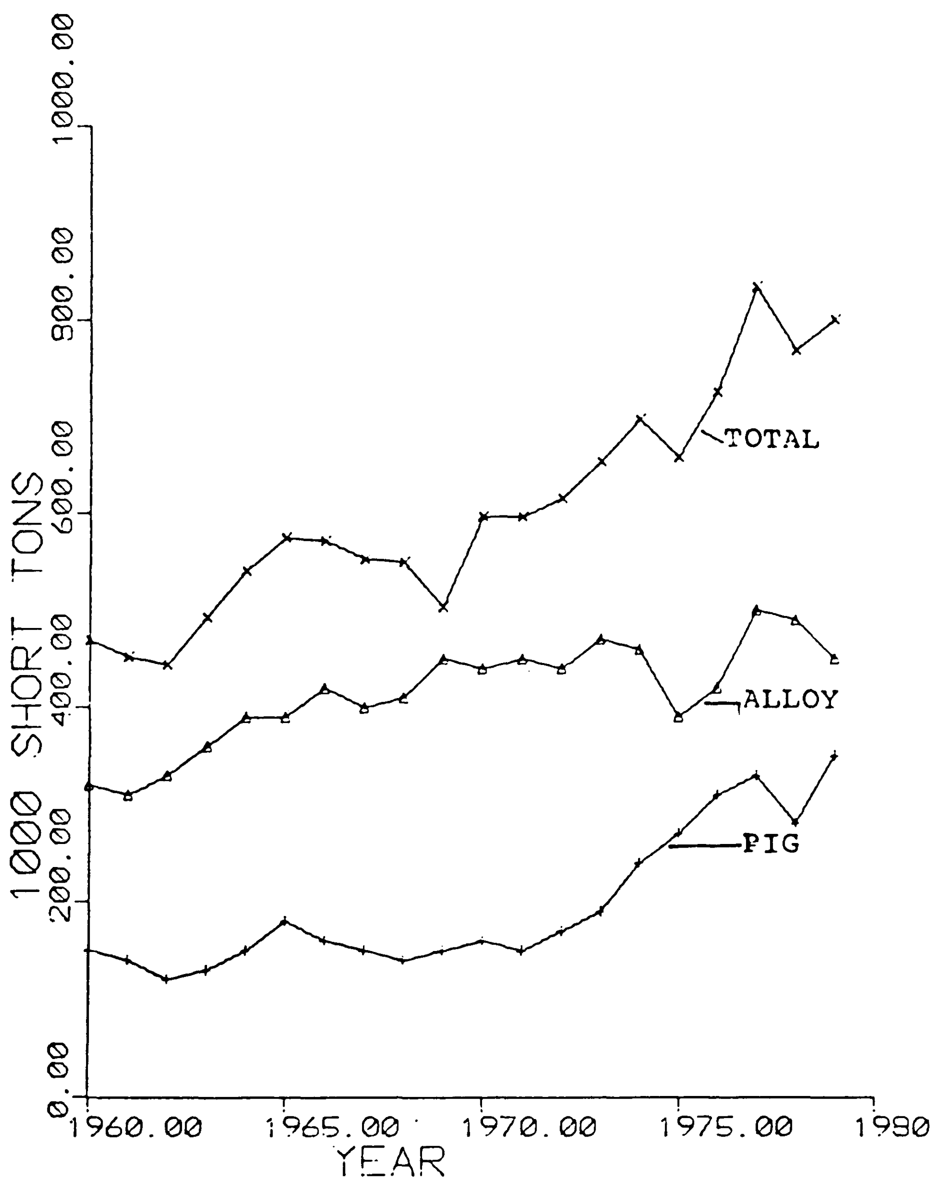


Table A-2-10). A secondary alteration may occur in 1982. Lead prices are low and the supplies of scrap lead have declined, which could force several secondary lead producers out of business if the present low prices (March 1982) continue.

An examination of zinc production shows this metal to be the weakest of the three. World refined (slab) zinc production increased by 108% from 1960 through 1979 while domestic production has declined by 33%. Refined zinc production has declined 48% since the high in 1969. These trends are illustrated in Figure 2.3-7. Domestic production of slab zinc began declining in 1970, when U.S. demand dropped 15%. Although demand increased to record highs in 1971 to 1973, zinc production continued to decline as constant dollar prices fell. Domestic zinc production declined another 33% from 1970 to 1973. From 1974 through 1979, domestic production has remained fairly constant but the 1980s have shown a continued decline in production capacity. Preliminary figures show an additional 15% decline in 1980. Complete data are not available, but the closing of Bunker Hill removed 8% of the domestic smelting and refining capacity and an additional decline in zinc production is expected from this closure (Wall Street Journal, 1981b). The zinc smelters and refineries and their current status are summarized in Table 2.3-4. The increasing divergence between domestic zinc production and consumption is illustrated in Figure 2.3-8.

Several structural changes were occurring during the period from 1969 to 1979. First, smelter feed from foreign ores dropped from a typical 50% to as low as 20%. A second structural change was domestic mine production. Zinc concentrate production dropped 13% between 1969 and 1971. Mine production maintained a fairly constant level until 1977, when production fell again. By 1979, mine production had fallen 47% from the level in 1969. Domestic producers have reacted to this decline by importing foreign concentrate.

Another aspect of the production structure is capacity utilization. Domestic utilization has averaged 75% of capacity for the 20-year period (Appendix A, Table A-2-11). In 1979, it was 70% compared to 60% utilization in 1977 to 1978.

TABLE 2.3-4: U.S. Zinc Smelters and Refineries

Firm/Location	Status
American Zinc	
Monsanto, IL	Closed, 1971
Sauget, IL	Sold to AMAX, 1972
Dumas, TX	Closed 1971
Anaconda	
Great Falls, MT	Closed, 1972
Anaconda, MT	Closed, 1963
ASARCO	
Corpus Cristi, TX	Expansion, 1976
Amarillo, TX	Closed, 1975
Bunker Hill	
Silver King, ID	Closed, 1981
National Zinc	
Dumas, TX	Closed, 1971
Bartlesville, OK	Modified, 1975; Secondary Plant Added, 1981
Eagle Picher	
Henryetta, OK	Closed, 1970
Matthiessen & Hegler	
La Salle, IL	Closed, 1967
AMAX	
Blackwell, OK	Closed, 1976
Sauget, IL	Modified, Opened, 1973
Athletic Mining	
Fort Smith, AK	Closed, 1967
Jersey Miniere	
Clarksville, TN	Opened, 1978
St. Joe	
Monaca, PA	Opened, 1979; Partial Closure, 1980
New Jersey Zinc	
Palmerton, PA	Open, 1979; Closed Slab Zinc, 1980

(Compiled from Non Ferrous Metal Data, 1960-1980)

Figure 2.3-7 World Production of Slab Zinc, 1960-1979

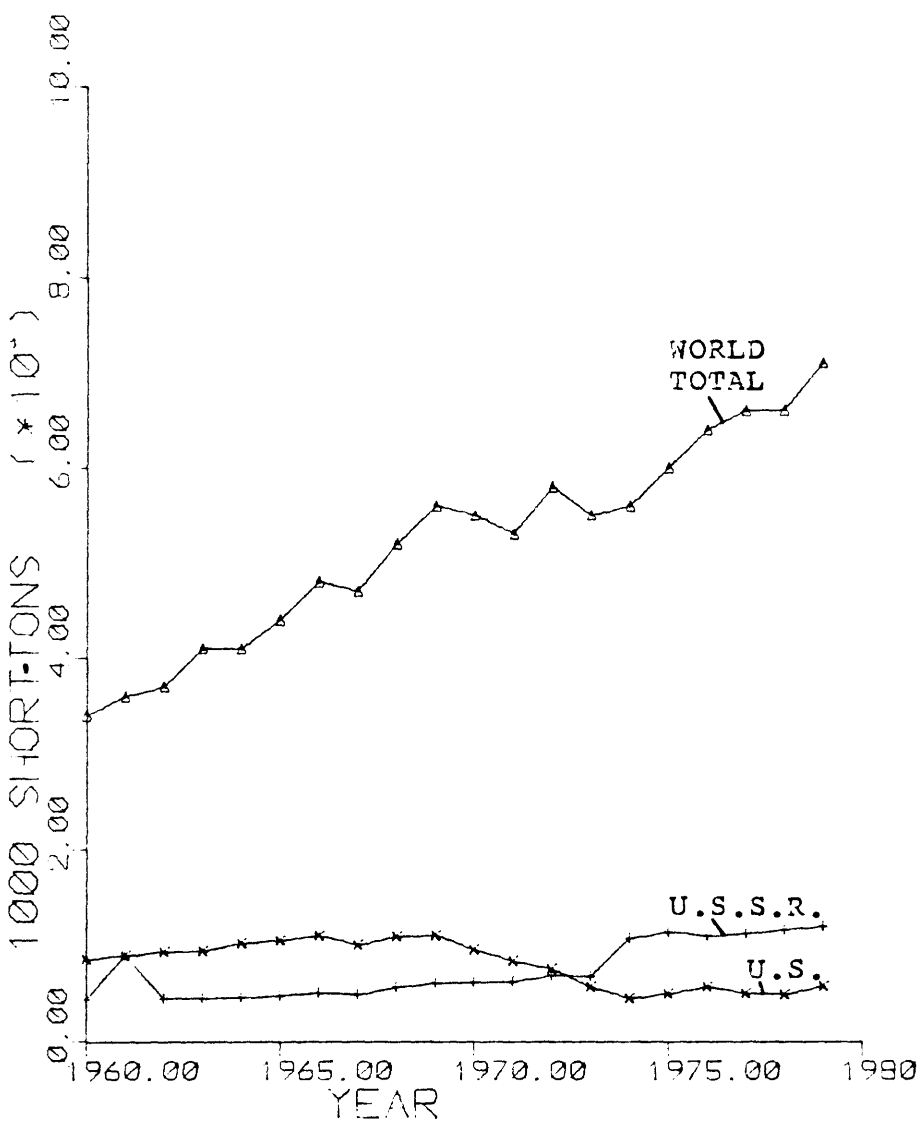
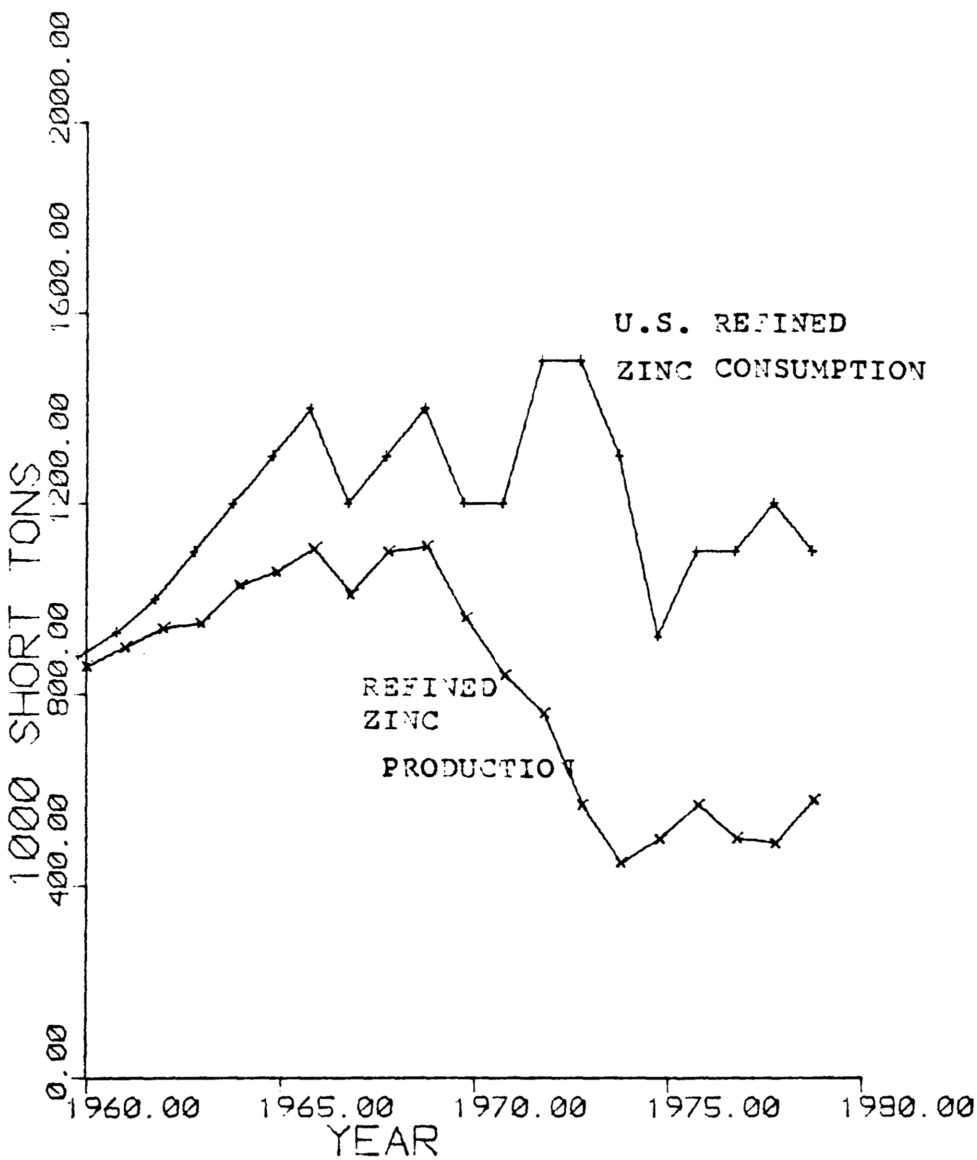


Figure 2.3-8 Zinc Production in the U.S.



These capacity figures for the United States compare to the worldwide average of 80% utilization (Roskills, 1979). The structural changes which were initiated in 1969 have dramatically changed the U.S. zinc industry.

To summarize, all three metals, copper, lead, and zinc have demonstrated production changes. Refined copper production has shown a real decline only since 1979. Domestic refined lead production has slowed while slab zinc production began a decline in 1969 which has yet to stabilize. The implications of these production changes are the subject of Chapter 4.

2.4 INTERNATIONAL TRADE

Trends in international trade can also have implications for the non ferrous processing industry. The U.S. demand for copper, lead, and zinc has been shown to exceed production earlier in this chapter. The difference has been made up by the consumption of recycled materials and by imports.

Historically, copper imports have been irregular. Between 1962 and 1968, imported copper increased with U.S. demand as a result of involvement in Viet Nam. Imports remained relatively constant from 1968 to 1973, but in 1974 imported copper increased by 44%, then fell by 46% in 1975, and then rebounded by 68% in 1976 (see Appendix A, Table A-2-12). Some of this variability can be attributed to U.S. labor strikes. Because these strikes have periodically been long, both producers and consumers lay aside stockpiles to protect themselves from metal shortages. Strikes lasted five and one-half months in 1967 and 20 weeks in 1980 (E&MJ, 1968). Additional variability can be related to the general health of the economy. In 1975, the world was adjusting to energy costs and demand declined. In 1978, world demand was down as the economy adjusted to a mild recession.

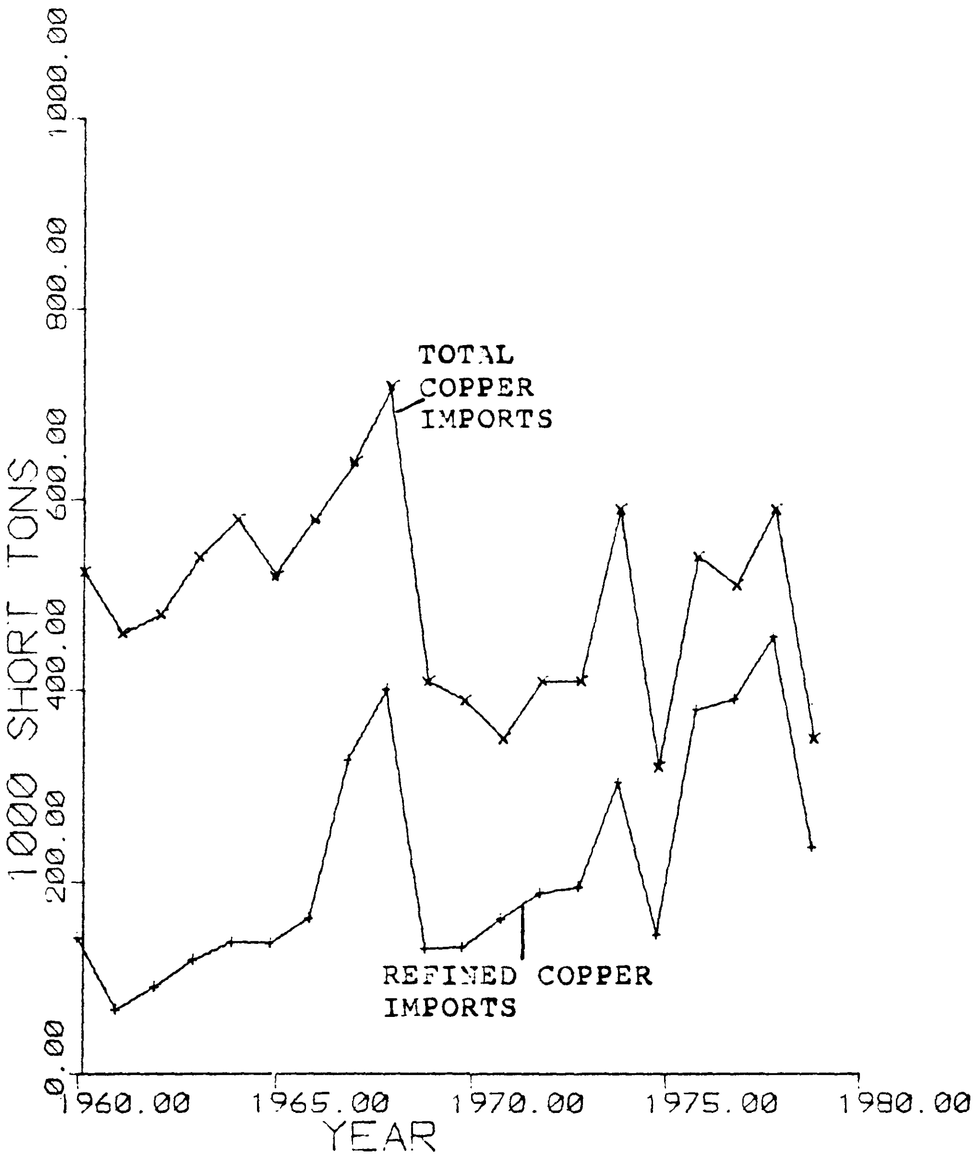
The relative amount of imported copper has declined since the early 1960s, but the relative composition of those imports has changed dramatically. In the early 1960s, imports were 40% of overall U.S. consumption and consisted mostly of blister copper. By the late 1970s, however, the total refined imports supplied only 25% of domestic demand but more refined metal was being imported. In 1960, refined copper was 27% of the imported copper. By 1970, it reached 45%, in 1979 it was 67% and by 1980 refined copper was 85% of the U.S. imports. Figure 2.4-1 illustrates this trend.

Exports of copper have trended downward since 1960 (Appendix A, Table A-2-13). Between 1960 and 1969, exports declined by 58%. The rate of decline slowed in the next decade to an average of 5% per year. Exports have been mostly copper scrap and refined copper. In 1980, there was a significant change. In that year, 58% of the exported copper was in the form of ores and concentrates. This change in exports to the sale of concentrates and the decline in refined copper reflects the change in U.S. smelting capacity. When Anaconda closed the Montana smelter and refinery, concentrates were shipped to Japan (E&MJ, 1981a). Anaconda has signed a seven-year contract with Japan which calls for the delivery of 360,000 tons of copper concentrate per year to Nippon, the primary buyer for seven Japanese smelters.

Trends in the international trade of lead have been the opposite of copper. Imports of lead have been gradually declining with the development of the New Missouri Lead Belt in 1968. Lead imports met 60% of domestic demand in 1960 but by 1970, imports were down to 40% of total U.S. demand in 1960. In 1979, imported lead provided just 16% of total domestic consumption as calculated from the data in Appendix A, Table A-2-14.

While imports have declined, the relative composition has remained fairly constant. Refined lead comprised roughly 65% of the total imports from 1960 through 1975. The relative amount of refined lead increased to 79% for the period 1975 through 1979, but returned to the earlier prior proportions in 1980.

Figure 2.4-1 <u>Relative Importance of Refined Copper in U.S. Copper Imports, 1960-1979</u>



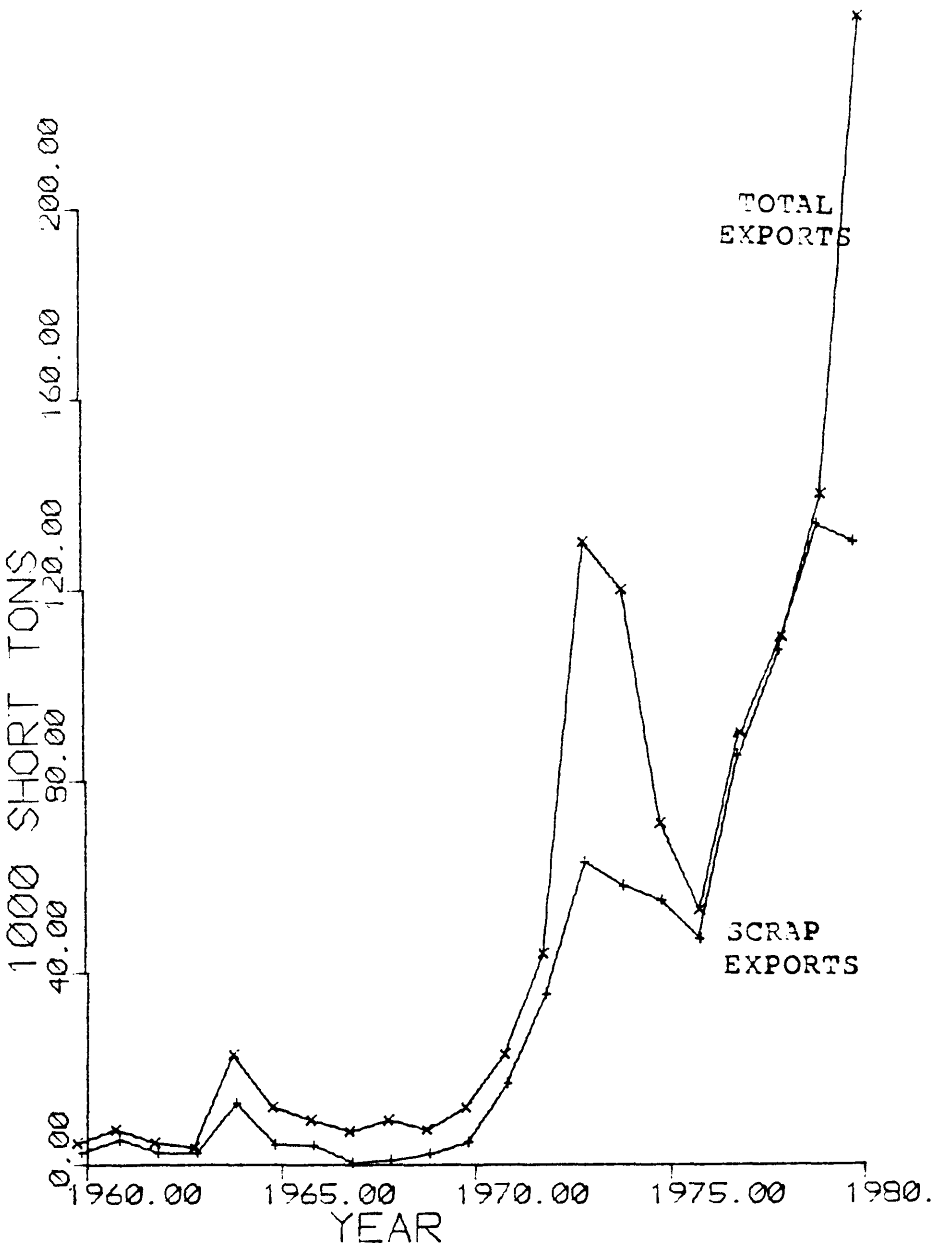
Although total lead exports have been increasing with domestic production, lead imports have exceeded exports until 1980. Lead exports have increased from four million tons in 1960 to 140 million tons in 1979, and the preliminary export figures for 1980 are 240 million tons (see Appendix A, Table A-2-14). A significant aspect is that most of the exports are scrap, which is a low value-added product. With the exception of two years, scrap has been approximately 75% of total lead exports. This relationship is illustrated in Figure 2.4-2. This is an important consideration in the evaluation of overall U.S. balance of trade.

International trade in zinc, the third metal being considered, has been primarily for imports. This is because domestic consumption of slab zinc has consistently exceeded domestic production since 1960. Demand for zinc exceeded supply by 30% in the 1960s and increased to 50% in the late 1970s. The difference between domestic consumption and production in 1980 is estimated to be 52% (Cammaroto, 1980a). These differences have been filled through zinc imports and minor recycling.

Total zinc imports have increased by a relative 43% from 1960 to 1979. This increase in zinc imports has occurred even with the recent decline in domestic consumption to the levels of the early 1960s. This is because of structural changes in the domestic zinc industry. These changes included types of imports, overall demand, and domestic processing and mine production. An examination of the combination of these changes provides a broader perspective of zinc imports.

One structural change that has occurred since 1960 is the type of zinc imports. Overall imports supplied 30% of domestic demand. Within that total, imports were roughly 75% zinc ores and concentrates and the remainder was slab zinc, pigs, and blocks. These proportions changed dramatically in 1971 and 1972 when the relative composition of zinc imports was completely reversed in two years. Beginning in 1973, 70% of zinc imports had become refined zinc and a record of 88% refined zinc imports was reached in 1976. Imports and the relative composi-

Figure 2.4-2 Relative Importance of Lead Scrap in U.S. Lead Exports, 1960-1979



tion of refined zinc are illustrated in Figure 2.4-3. Import data are summarized in Appendix A, Table A-2-15.

The change in composition of zinc imports to the United States can be attributed to the change in domestic processing capacity. As Figure 2.4-4 illustrates, the imports of slab zinc increased during the period when domestic capacity declined sharply due to smelter and refinery closures. Between 1970 and 1973, when production capacity decreased by 40%, the relative amount of refined zinc imports increased by 35%, although the total amount of imports was relatively constant.

Zinc imports are not a major part of the domestic zinc market. Exports have declined from 88,000 tons in 1960 to an estimated 35,000 tons in 1981 (see Appendix A, Table A-2-16). As could be anticipated, the value-added exports have declined with the smelting industry. In the early 1960s, roughly 75% of the exports were as refined metal. This proportion has declined since 1965 to 4% refined zinc in 1978. Zinc dross and scrap have become the primary zinc exports.

To summarize, international trade in metals has shown dramatic changes in the past 20 years. The country relies increasingly on imported refined copper and zinc, while exports are mostly scrap and concentrate. Lead imports are required to satisfy total domestic demand, although the amount required has diminished. All metals demonstrate an increasing national reliance on imported metal and the export of low value-added products.

2.5 COSTS

In contrast to the decline in real metal prices, costs for extracting and producing the metals have increased over the past two decades. This trend has had a significant impact on the industry. An example is the copper industry. Although capital equipment costs have declined in real terms, the indirect costs of energy and labor have contributed to an overall 83% increase in production costs between 1970 and

Figure 2.4-3 Relative Importance of Refined Zinc in U.S. Zinc Imports, 1960-1979

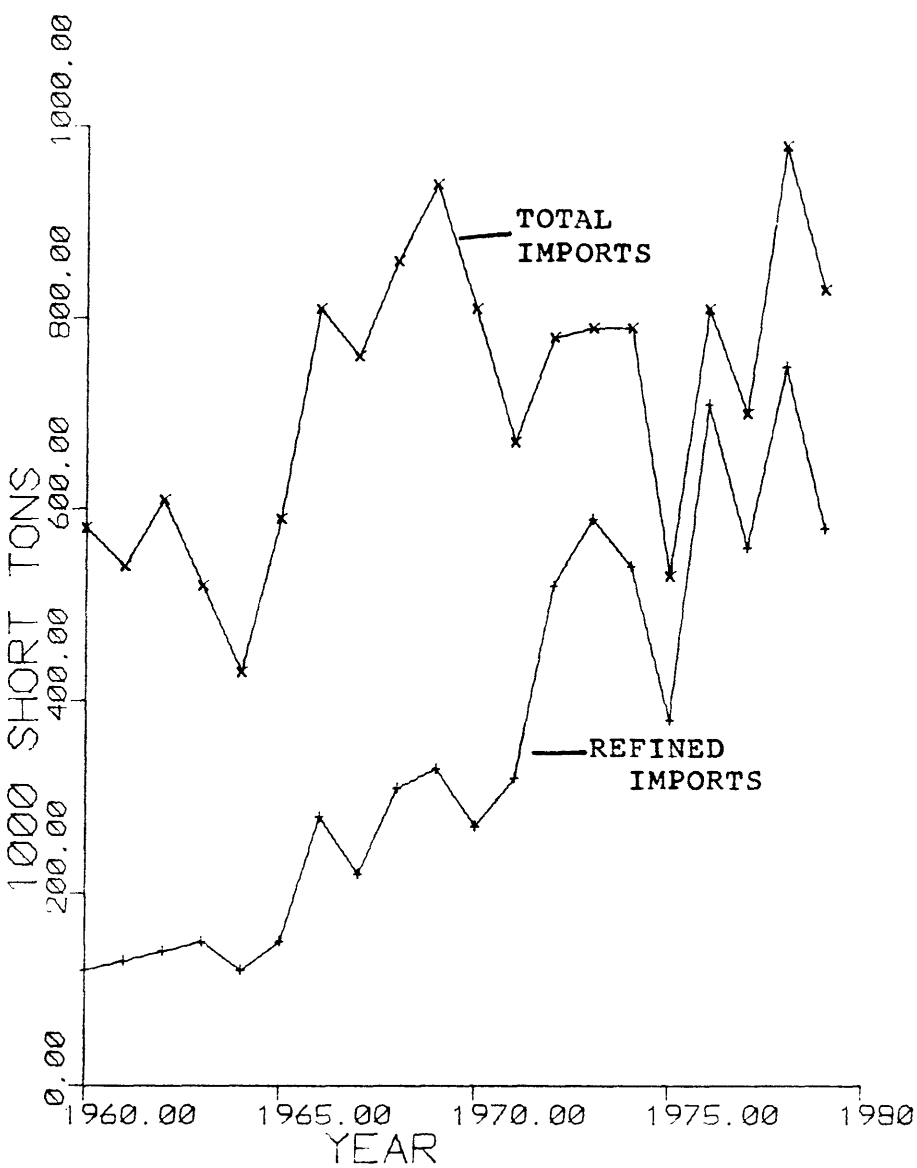
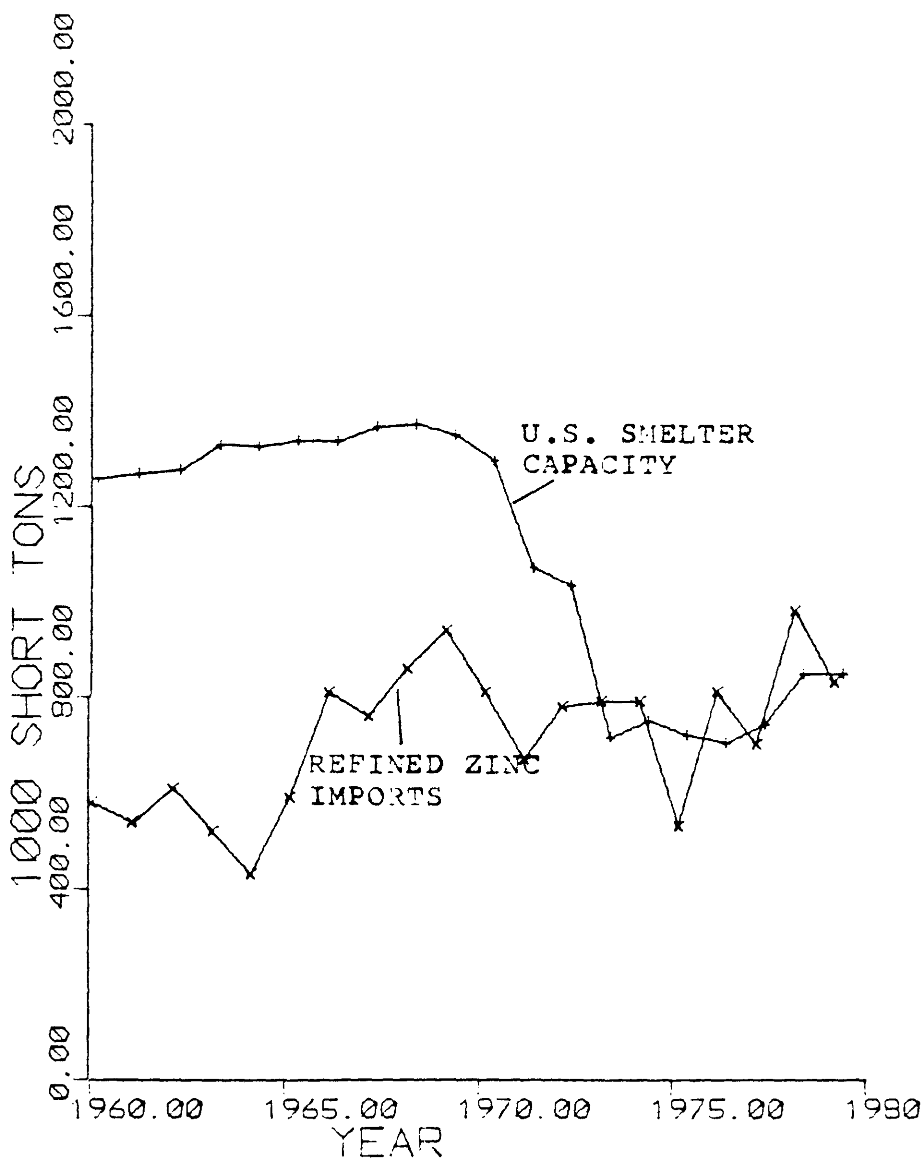


Figure 2.4-4 Comparison of Zinc Imports and U.S. Smelter and Refining Capacity, 1960-1979



1976. This compares to estimates by Sir Ronald Prain that worldwide costs of production increased 56% from 1960 to 1970 (1975).

Capital costs per ton of copper have increased a relative 161% in nominal terms between 1965 and 1982. This percentage is based on recently estimated capital costs which are summarized in Table 2.5-1 (Everest Consultants, 1982).

In constant dollars, capital costs have not increased (Radetzki, 1979). By correcting to 1967 dollars, capital equipment costs have actually declined by 13% since 1965. These figures are included in Table 2.5-2. The components of capital costs, however, have changed for the industry.

During the 1960s, very little money was spent on pollution control for smelting and refining. The firms paid reparations to area farmers for "smoke damage" and conducted research on experimental farms (Torgersen, personal communication). According to a recent study by the Environmental Protection Agency (MIT, 1979), this condition changed in the 1970s. As is shown in Table 2.5-2, capital expenditures for the copper industry increased from $105 million in 1972 to $142 million in 1975. Of these expenditures, two-thirds of the costs were devoted to pollution control and one-third was devoted to expansion. Mr. Tom Osborne, Executive Vice President for ASARCO, estimates that 40% of the total expenditures for the copper industry were spent on pollution controls between 1973 and 1979 (Metals Week, 1981a). Table 2.5-3 shows the estimated percent of total capital expenditures compared to other industries.

Overall average costs to produce copper, lead, and zinc have been increasing. Using copper as a base case, average overall costs in the United States are estimated to be $0.80/lb with estimates ranging from $0.45/lb to $0.95/lb (Prain, 1975; Mining Journal, 1981a). Table 2.5-4 details the relative increases in net costs.

TABLE 2.5-1: Current Estimated Capital Costs for Copper[1]

Year	$/Ton Copper (1980 Dollars)	$/Ton Copper (1967 Dollars)
1955	$3,500	---
1965	$4,100	$4,555
1970	$5,500	$4,982
1975	$7,200	$4,117
1982	$10 - $30,000	$3,966

(1) Everest Consultants, CRU, 1982 Non-Ferrous Smelting Industry - Clean Air Study, unpublished, pages 2-6.

TABLE 2.5-2: Estimated Copper Smelter Capital Expense (Reported in $ Millions)

	1972	1973	1974	1975
$1978[1]	105	150	180	142
$1967	88	111	112	81

(1) Source: MIT, 1978. Effects of Public Regulation on the U.S. Copper Industry, Vol II.

TABLE 2.5-3: Pollution Control Expenditures as Percentage of Capital Spending[1]

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Annual Average 1970-79
Iron & Steel	10.3%	12.8%	12.3%	11.7%	9.3%	14.9%	20.6%	16.7%	17.3%	19.9%	14.6%
Non-ferrous Metals	8.1%	10.3%	15.3%	18.0%	28.3%	27.5%	20.4%	29.1%	12.0%	7.6%	17.7%
Mining	6.1%	2.8%	5.1%	7.6%	7.0%	8.2%	6.9%	17.5%	10.7%	1.6%	7.4%
Electric Utilities	3.8%	4.4%	7.9%	7.6%	7.1%	9.1%	11.5%	10.6%	8.7%	10.7%	8.1%
Gas Utilities	4.4%	2.0%	1.6%	1.5%	2.2%	1.3%	3.5%	2.8%	1.3%	.7%	2.2%
All Business	3.1%	4.0%	5.1%	5.7%	6.2%	6.8%	7.1%	6.7%	5.2%	4.8%	5.5%

(1)Source: McGraw-Hill Publications Company, Economics Department.

TABLE 2.5-4: Comparative Copper Production Costs by Firm

FIRM	1972(1)	1973(1)	1981(2)
Phelps Dodge	0.38	0.42	0.77
Kennecott	0.46	0.42	0.76
Bougainville	---	0.39	0.53
Atlas	0.33	0.45	0.77
Marcopper	0.23	0.35	0.47

(1)Mining company estimates, 1974.
(2)After Thoughts, 1981, World Mining (April), page 80.

Production costs can be roughly attributed to several categories. Using current copper production costs, $0.19/lb is estimated to be for capital expenditures (Everest, 1982). Smelting and refining costs are $0.30/lb to $0.35/lb for Japanese processing compared to $0.40/lb to $0.45/lb in the United States (Mining Congress Journal, 1981). Pollution control expenditures are variously estimated between $0.09/lb and $0.15/lb (MIT, Vol. II, 1978; Rosenkrantz, 1979).

Total energy costs are estimated to be $0.05/lb (Rosenkrantz, 1976). Roughly 30% of the total energy costs are smelting and refining costs. A summary of energy costs is presented in Table 2.5-5.

Zinc production costs are lower than those for copper. Recent estimates are $0.33/lb to $0.42/lb (Roskills, 1980). Of this, smelting is $0.06/lb to $0.08/lb. Lead production costs are also lower and average $0.22/lb to $0.25/lb (Roskills, 1979).

Production costs have changed dramatically since 1970. According to recent studies, the most significant change in the 1970s was the increase in the price of energy. In 1972, energy costs represented a relative 9% of total operating costs. By 1976, they had increased to 15%. In nominal terms, these relative increases totaled 180% between 1972 and 1976 (Lewis, F. M., 1978). This compares to increases in total costs of 85% and smelting and refining increases of 83% (Lewis, F. M., 1978; Rosenkratz, 1979).

Smelters in the United States operate as individual profit centers and the smelter terms apply to captive mines as well as to mines served on a toll basis. A smelting contract is a complex item. The mines say that "smelters never lose money" and the mines must absorb the impacts of low prices (Torgerson, Johnson, Belica, private communication, 1982; Lewis, P. J., 1978). An example and discussion of a smelting contract is presented in Appendix B.

TABLE 2.5-5: Average Energy Consumption and Cost for Copper Production, 1973

	Btu/Pound of Copper	Energy Cost, Cents/Pound
MINING	7,600	0.86
BENEFICIATION	17,900	2.50
SMELTING	17,900	2.50
REFINING	6,000	0.64
TOTAL	49,400	4.83

(Compiled from Rosenkrantz, 1976)

A recent paper by Mr. P. J. Lewis, et al., of Consolidated Gold Fields, Ltd. examined changes in smelter toll charges (1978). This study found that payment to the mine for contained copper has fallen 15% since 1973. Zinc charges have changed as well. Zinc concentrates of 60% or more used to gain a premium of 5% to 6% over 50% to 55% concentrates in the smelting contract. This has declined since 1973 to only 2% in 1978. Lead payments have also declined. Prior to 1972, lead payments were 70% to 80% for all grades. Payments have now decreased to 50% to 65% of contained lead. These increases in smelting costs has reduced the mine incomes. Marginal producers, faced with increasing smelting and refining charges as well as energy transportation and environmental costs, have been forced to close.

For the smelting and refining industry, large expenditures on environmental and workplace safety are needed to meet the current laws. The United States passed the Clean Air Act in 1970 and final National Ambiant Air Quality Standards were established in 1977. These guidelines require recapture of roughly 90% of the SO_2 emissions from smelting. There are also regulations regarding particulate emissions and worker exposure to lead and arsenic. These environmental, health, and safety costs are anticipated to be significant in the coming years, and are the subject of industry debate and litigation (Big Sky Pay Dirt, 1981; E&MJ, 1979; Munroe, 1982; Ridinger, 1980; Mining Journal, 1979).

Several government studies have been conducted in the past few years to assess the economic impact and cost of environmental compliance. These studies indicate that costs for the industry will be high if current pollution limits and compliance regulations are maintained. In 1978, Arthur D. Little analysis suggested that the costs of compliance are very high (1978). To achieve the required air pollution standards by 1988, the copper industry will need to spend $2.8 million in capital costs and $3.0 billion in operating costs (1974 dollars). An MIT study for the U.S. Department of Commerce suggested that the lead industry will need to spend $1 billion in capital costs and $300 million in operating costs under a best case scenario (1977). If workers cannot be rotated to control lead levels in the blood, net costs after tax are an estimated $18 billion (MIT, 1979). Costs for the zinc industry are estimated to be $30.2 million per year for a total of $434.7 million by 1988 (Mining Journal, 1979). These costs are summarized in Table 2.5-6.

At the present time, none of the domestic copper or lead smelters meet the workplace, air, or water quality regulations. Two copper smelters approach the 90% SO_2 recapture requirement. The Hidalgo, New Mexico, smelter, built in 1975, captures 80% to 85% of the SO_2 produced (Everest, 1982). The Hayden smelter captures roughly 80% of process SO_2. The industry average is 60%, which is improved from the 29% average in 1968 (PED Co., 1969). Zinc smelters have achieved compliance by reduced operations and new furnaces. In 1968, these smelters recaptured 60% of process SO_2 (PED Co., 1969). Lead smelters currently achieve compliance by intermittent operation. In 1968, the recovered 27% of the SO_2 generated at the smelter (PED, Co., 1969).

A final aspect of costs affecting the industry is the cost of labor. This cost has been steadily increasing until the United States has become the second highest labor cost producer in the world (Sousa, 1981). Although the U.S. industry is the most efficient in the use of man-hours and capital, this has not been sufficient to reduce the cost of labor.

The 1980 wage settlement in the copper industry is a good example of the wage increases. In that agreement, the overall increase was 39% over three years, or an average increase of 3.5% in hourly wages (American Metals Week, 1980; Metals Week, 1980c).

Data compiled from the Bureau of Labor Statistics indicate that wages in copper smelting and refining have risen an average of 10.7% per year since 1970 (Sousa, 1981). This compares to 7.6% in all manufacturing. Labor costs for copper are estimated to be $0.25 to $0.29 per pound of copper, or roughly 35% of the total cost of production.

TABLE 2.5-6: Estimated Costs to Achieve Environmental Compliance by 1988

	Capital Costs	Operating Costs
COPPER	$2.8 Billion	$3.0 Billion
LEAD (best case)	$1.0 Billion	$300 Million
ALTERNATIVE	$1.0 Billion	$18 Billion
ZINC	$434.7 Million - Total	

(Sources: MIT, 1979, Arthur D. Little, 1978, Mining Journal, 1979)

The costs of benefits are a hidden cost which has also increased significantly. The National Chamber of Commerce reports that average total benefit costs have increased by 199% since 1967 (Mining Engineering, 1979a).

Productivity in the mining industry has also been declining. This measure is determined by the output per unit of labor per year. According to the U.S. Department of Commerce, the mining industry as a whole posted a 6.1% decline for the period 1973 to 1977 (1978). Primary copper, lead, and zinc showed a 3.8% decline for the same period. These declines compare to an average increase in all industries of 1.1% (Table 2.5-7).

Rising labor costs and declining productivity have been a part of the reason for a high average total production cost. Improvements in relative labor efficiency may reduce these costs, or additional advances in technology will be needed to reduce the cost for the marginal producers.

In summary, the market aspects for the copper, lead, and zinc industries have changed during the past 20 years and several trends are apparent. In constant dollars, metal prices have reached record or near record lows. The growth in domestic consumption has moderated. Smelting and refining capacity has declined, with the zinc representing the most severe case. In international trade, metal imports have shown an increase in the value-added products, while exports have increasingly become concentrates and scrap. Chapter 4 will discuss the ramifications of these trends, along with the industry changes and cost trends which are summarized in Chapter 3.

TABLE 2.5-7: Productivity Changes in the Mining Industry

	1965-1973	1973-1977	1978
Primary Copper, Lead, and Zinc	-7.5	-3.8	-1.0
All Industry	2.0	1.1	0.5

(Compiled from Economic Report to the President, 1979 and Productivity Indexes, 1979)

CHAPTER 3: TRENDS OF THE FIRMS

The major smelting and refining firms in the United States are also the major producers of primary metal. The structure of these firms has changed with the total industry trends which were discussed in Chapter 2.0. The financial capacity to change and grow in the smelting and refining industry depends on the strength and investment attitudes of the parent firm, as well as the metals marketplace. This chapter examines the financial trends of the major metals firms and the structural changes which have occurred for the participating firms as a whole.

3.1 MAJOR FIRMS

The production of primary copper, lead, and zinc in the United States is dominated by only a few firms. In 1980, four firms produced 56% of the total primary copper production, two firms contributed 65% of the primary lead production, one firm contributed 64% of the primary zinc, and two firms comprised nearly 90% of the supply. These firms and their relative domestic market share are listed in Table 3.1-1. All the firms are characterized by some degree of vertical integration, from ore extraction through smelting and refining the primary metal. Some firms also have the fabrication facilities for end-use production.

The relative dominance of the firms in each metal has changed over the past two decades. In copper, Kennecott has been the domestic leader since before 1960. Phelps Dodge has grown from 16% of the market share in 1960 to 20% in 1980, and Newmont Mining (Magma) has consistently maintained a 6% market share. ASARCO has grown from a 2% share in 1960 to 4% in 1980. St. Joe Minerals Corporation is the leading domestic producer of lead. St. Joe produced 56% of the domestic lead in 1960 and by 1970 was producing 70% of the nation's primary lead. St. Joe was also the leader in domestic zinc production until 1968, when

TABLE 3.1-1: Major Mining Companies in the United States, 1980

	U.S. Production (1000 Short Tons)	Relative Percent
Copper		
Kennecott Minerals	335.9	24.7
Phelps Dodge	267.8	19.7
Duval	144.6	10.6
Anamax	115.0	8.4
Magma Copper	99.3	7.3
ASARCO	56.4	4.1
U.S. Total (1980)	**1,362.0**	**66.4**
Lead		
St. Joe Minerals	235.7	38.7
AMAX-Homestake	170.6	28.0
U.S. Total (1980)	**609.9**	**66.7**
Zinc		
New Jersey Zinc Co.	144.9	64.0
St. Joe Minerals	59.0	26.0
U.S. Total (1980)	**226.8**	**90.0**

(Tomimatsu, 1980)

New Jersey Zinc opened the Pennsylvania mines and became the largest zinc producer.

3.2 OWNERSHIP TRENDS

The mining industry has been the object of considerable acquisition activity, mostly from the oil companies, and very few have remained independent. Since 1963, 15 companies have been purchased, or a major equity position has been taken by another company. All but two acquisitions were by oil companies. The acquiring firms and their ownership are summarized in Table 3.2-1. It is interesting to note that of the leading copper companies, only Phelps Dodge and ASARCO have remained independent of "outside" purchasers. Bendix did buy a 20% position in ASARCO, but sold it back to the company in 1980 for a significant profit (Business Week, 1981). St. Joe Minerals, the leading lead producer, has been acquired and the second and third largest producers are joint ventures. One is between AMAX Lead Company and Homestake Lead Company, and the other is between Cominco American and Dresser Minerals. The fourth largest producer, Bunker Hill, closed in 1981. In the case of zinc, New Jersey Zinc is owned by Gulf and Western, a large conglomerate, and has joint ventured mines with Union Miniere. As can be seen, very few of the major primary metal producers remain as independent mining companies.

3.3 FINANCIAL TRENDS

The primary metals industry demonstrated fairly stable growth in the 1960s. As mentioned previously, prices for the metals were high. Most firms financed expansion and new ventures from funds generated internally or private equity capital and were able to maintain a low debt-to-equity ratio. The advent of the 1970s brought major changes to the primary copper, lead, and zinc industries through the issuance of new debt. The degree of new debt is summarized for selected firms in

TABLE 3.2-1: Non Ferrous Producers that have Merged or Placed A Significant Share of Equity with Other Corporations

Company	Date	Description of Transition
AMAX	May 1975	Sold 20% equity interest to Standard Oil of California
Anaconda	January 1977	Acquired by Atlantic Richfield
Calument and Hecla	1968	Acquired by Universal Oil Products
Copper Range	May 1977	Acquired by Louisiana Land and Exploration
Cyprus Mines	September 1979	Acquired by Standard Oil of Indiana
Duval	1965	Acquired by Penzoil Company
Inspiration Cons. Copper	December 1978	Merged into Inspiration Holdings, Inc., an affiliate of Anglo American Corp.
Kennecott	January 1978 June 1981	Merged with Carborundum Merged with Standard Oil of Ohio
Magma	1969	100% acquired by Newmont Mining
Miami Copper	1960	Acquired by Cities Service
Molycorp	July 1977	Acquired by Union Oil of California
St. Joe Minerals Corp.	June 1981	Merged with Fluor Corporation
Tennessee (Copper & Chemical) Corporation	1963	Acquired by Cities Service
U.S. Smelting, Refining, & Mining Company	1965	Acquired by Mueller Brass and name changed to UV Industries, Inc.
Utah International	December 1976	Acquired by General Electric

(Source: Everest Consulting Associates, 1982)

Table 3.3-1. These changes in long-term debt-to-equity and relative debt are illustrated in Figure 3.3-1. and summarized in Appendix A, Table A-3-1. The profitability of the firms also declined, as can be seen from the decline in return on shareholders' equity from 15% to 5% or less (Appendix A, Table A-3-2). The operating efficiency of the firms suffered as well, declining from roughly 15% to an average for all firms of 6% (Appendix A, Table A-3-3).

There is some indication that these effects may be moderating. Companies are regaining control of their debt, and even in the weaker market of 1970 to 1980 they have been able to stabilize debt and earnings. This condition may be only temporary, however, if the firms are required to make the major pollution abatement investments currently estimated to be between $2 billion and $3 billion (see Section 2.5).

3.4 JAPANESE SMELTING CAPACITY

There has been considerable controversy about Japanese industry in general and smelting capacity in particular. A discussion of trends in U.S. firms would not be complete without an analysis of their primary competitor, the Japanese.

Japan is a small country with limited land and a large population. It has a cultural history of caring for the land and loyalty to family, company, and government. These characteristics are significant when examining Japanese industry and are apparent in the smelting industry.

Japan has 14 smelters, ten of which exceed 40,000 TPY capacity (Rosenbaum, 1976). Japan has had a small copper industry since the late 1800s, and most of the smelters were built in the early 1900s. The oldest, which has since been renovated, was built in 1856. The smelters, capacities, age, and renovation are listed in Appendix A, Table A-3-4.

Figure 3.3-1 Long-Term Debt and Debt-to-Equity Ratios for Selected Firms

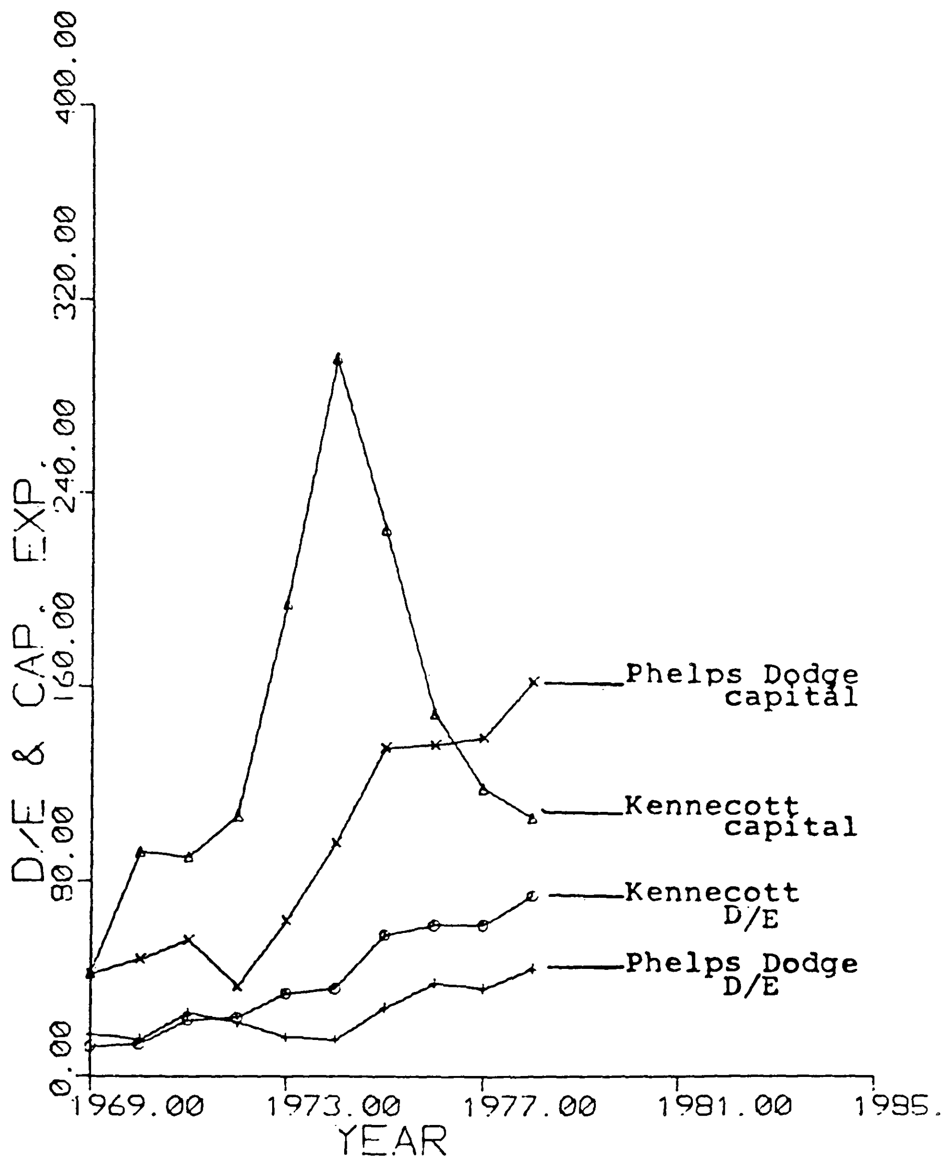


TABLE 3.3-1: U.S. Copper Producers, Total Capital Expenditures, 1969-1978
($ Million)

Companies	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Kennecott Copper Corp.	42.3	48.2	56.3	36.6	63.6	96.1	134.6	136.1	139.2	161.7
Phelps Dodge Corp.	101.8	94.1	90.2	107.2	194.2	296.4	225.6	149.3	117.6	105.9
Newmont Mining Corp.	57.0	135.3	129.1	44.1	47.6	55.8	53.2	53.9	48.2	58.3
ASARCO, Inc.	25.1	72.2	55.4	66.7	96.7	137.7	167.5	76.0	95.9	79.4
AMAX, Inc.	139.0	169.0	130.0	148.0	256.0	408.0	550.0	532.0	409.0	403.0

(Source: Sousa, 1981)

Japanese smelters must meet very stringent pollution requirements because of their location. The smelters operate in close proximity to industrial and residential areas where excessive pollution cannot be tolerated. The smelters are frequently located near the ocean. Although they are usually on the windward side of the island, emissions must be controlled to protect ocean fisheries which are a major source of food.

The Japanese SO_2 emissions regulations are very stringent. The smelters recapture 91% to 97% of the sulfur in the feed and have been reported to recapture as high as 99% (Dresher, 1981; Rosenbaum, 1976). A recent tour of these facilities suggests doubt that all the smelters attain the recapture levels as rated, but all are significantyly more efficient than the U.S. smelters (Dresher, 1981).

Japanese smelters are located to take advantage of several factors. Most notably, the smelters are located at seaports and industrial centers. This location provides an avenue of inexpensive transportation. In addition, fertilizer and chemical plants are located nearby in order to use the sulfuric acid which is generated from the SO_2 scrubber systems. The gypsum and slag generated by the process are used by wallboard and construction material firms which are also nearby or easily reached by sea. Although smelter firms say they do not make money on the sales of these products, the economic loss is minimal (Dresher, 1981). The access to inexpensive water transportation makes shipment of concentrates from abroad feasible. The proximity to industries which can utilize the by-products relieves the firms of waste disposal and provides an income from the pollution control facilities.

The United States, on the other hand, has most of the smelting capacity located far inland. This has two disadvantages. First, concentrates cannot be shipped too far because of high transportation costs. This removes most of the smelters from international competition. The only exceptions are ASARCO's Texas and Washington facilities. The second disadvantage is that the smelters are a considerable distance from the markets for their product as well as the by-products generated in the course of copper production. While U.S. firms do ship the sulfuric acid by-product, losses are reported to be between \$12 per ton at the McGill smelter to \$22 per ton at the Hidalgo smelter (Everest Associates, 1982; Judd, 1982).

The differences between the United States and Japanese smelters have their basis in the philosophical attitude and the geography of the two nations. Whereas Japan is a culture directed toward cooperation, the U.S. Government and U.S. industry have always been adversaries to some degree. Japan has recognized that her future depends on natural resources, of which she has very few. The United States has not fully acknowledged this fact or evaluated the implications. The Japanese Government and business developed a plan to assure the resources the country needs for livelihood and growth. Part of this plan was to develop firm sources of supply and to refine the ore at home to capture as much value-added benefit as possible. The United States is still discussing the country's true needs for raw and refined materials.

The geography and population of the two countries are also very different. The United States has always had more land than could be populated. If smelter smoke made some land less productive or unpleasant, there has always been somewhere else for people to go. Japan has a higher use for the land because of its high population density.

Other differences exist. In the early 1960s the Japanese made a determination to reduce the industrial pollution in their country. When the modifications for anti-pollution were undertaken, the firms received government assistance to help pay for the renovation. The government has also erected trade barriers against refined copper materials. This tariff, on a sliding scale, applies only to refined metal. At \$0.94/lb, the tariff is roughly 2.5¢. When copper is \$0.97/lb or greater, there is no tariff (Metals Week, 1982b). The refined metal in Japan is sold at a Japanese producer price which is \$0.05 to \$0.08 higher than the LME price (Everest Associates, 1982). These tariffs and prices help to protect the industry during periods of low copper prices.

Another difference between Japanese and U.S. smelter businesses is the average feed grade. Japanese smelters receive concentrate which averages 25% to 35% copper, compared with the U.S. grade of 12% to 25%. The Japanese smelters are designed to be energy efficient which now saves in operating costs. Finally, and most significantly, the Japanese smelters were remodeled in the late 1960s and early 1970s, when copper prices were high and interest rates and equipment costs were low. The U.S. industry is faced with remodeling, renovating, and new construction when copper prices are at a record low and interest rates are near a record high.

In summary, the U.S. smelting and refining industry has undergone several structural changes. The leading metal producers in lead and zinc have been acquired by other firms. Two of the four major copper producers have also been acquired. The industry incurred significant debt in the early 1970s to meet energy constraints and pollution controls. Firms were beginning to recover from these expenses in 1980, but the soft metal markets of 1981 and projected heavy pollution control expenses may still affect the industry. Japan has become a formidable competitor in the world copper processing market and considerable effort will be required from domestic firms in order to compete successfully.

CHAPTER 4: DISCUSSION

The preceding chapters have described the U.S. and world marketplace and the firm and industry trends for copper, lead, and zinc. This chapter will examine the changes in the context of an industry hypothesis developed by D. F. Hewett in 1929. The Hewett hypothesis will be explained, then the changes, the possible reasons, and the implications for the copper, lead, and zinc industries will be discussed.

4.1 THE D. F. HEWETT HYPOTHESIS

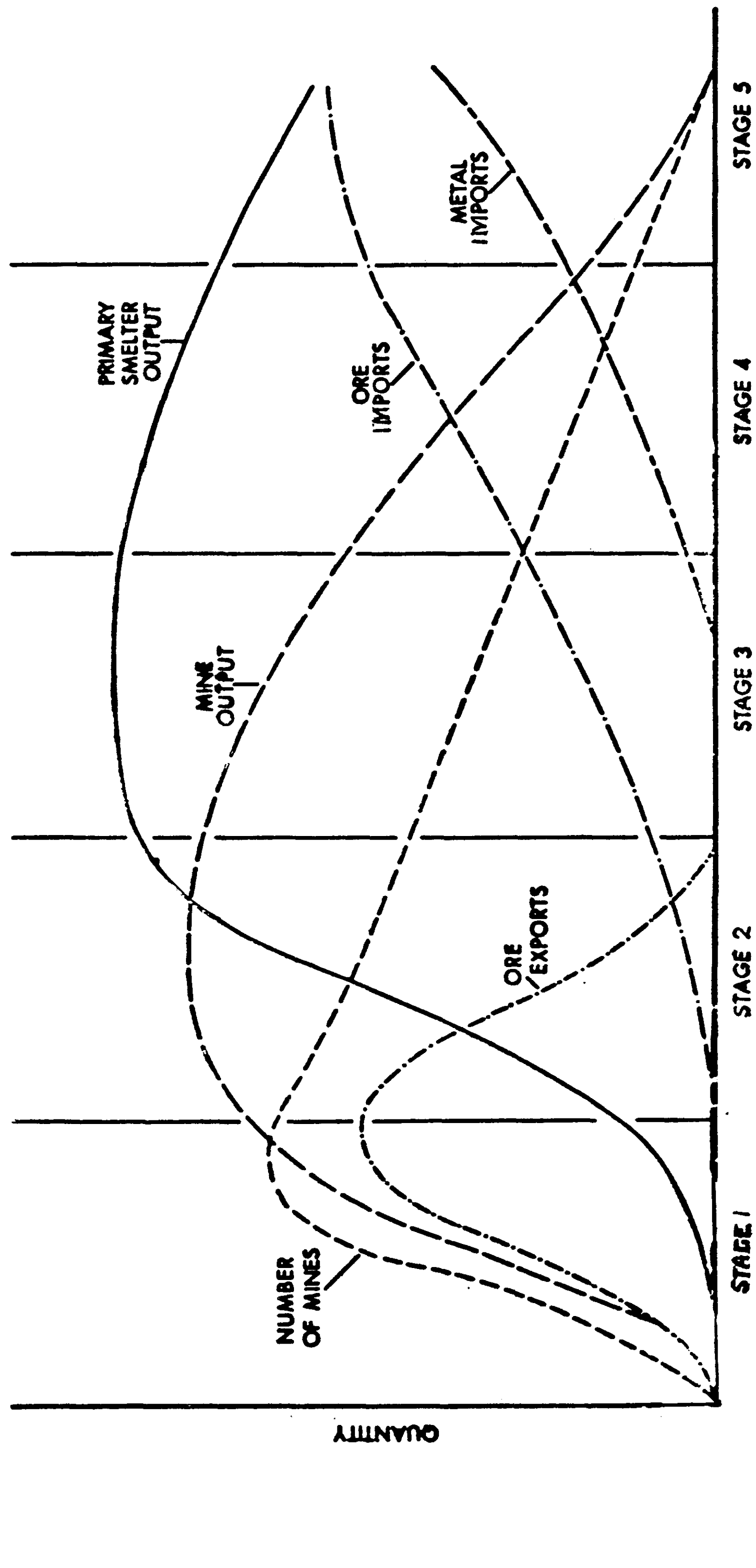
This hypothesis was proposed by D. F. Hewett in a paper published in 1929 (Hewett, 1929). Hewett proposes a general model for countries which produce metal. The hypothesis will be referred to as the Hewett hypothesis through the remainder of this thesis.

D. F. Hewett used the historical data from several centuries to develop a model for metal producing countries which have a source of energy. Hewett proposes that these countries will go through cycles as illustrated in Figure 4.1-1. There is an increase, then a decrease in the exports of crude ore, the number of mines in operation, the number of operating smelters and refineries and the production of metal from domestic ore. As domestic production declines, there is a concurrent increase in imports. Hewett noted these cycles first in England and extrapolated:

> In the study of metal-producing districts in the U.S. I have noted the same tendency; first a peak in the number of mines operating, next a peak in numbers of smelting and refining units, and then peaks in production of metals (page 90).

Hewett recognizes that first the minerals must be present. Second, costs must be considered, including "all man-made devices . . . such as taxes and tariffs,"

Figure 4.1-1 Stages of Industry Development from D. F. Hewett Hypothesis



(page 67). The price for the metal must be sufficient to recover these costs. He indicates that a smelting and refining industry can flourish after the exhaustion of local mines if there is concentrate economically available from other sources. One comment regarding the United States seems particularly applicable:

> . . . for our own part (U.S.), most of our smelters lie inland and when their sources of ore fail they will face serious problems. Moreover, at some remote time - how remote I shall not discuss - our seaboard smelters and refineries will depend largely on imported ores (page 87).

Hewett also suggests that as the resource availability declines, the smelting and refining capacity declines to adjust to the available feed. The exception to this trend is if the smelters/refineries are located so as to take advantage of inexpensive transportation and process imported concentrates. Hewett proposes that they can survive after area mines are exhausted if the smelter location is economically accessible to other sources.

This model of the mineral extraction industry and the proposed stages of development will be used as the framework for assessment of the trends described in Chapters 2 and 3.

4.2 METAL INDUSTRY TRENDS

Using the Hewett hypothesis, the copper, lead, and zinc industries can represent various phases or cycles as shown in Figure 4.1-1. Lead may be on the leading edge of mine development (Stage 1 or 2), copper mine production and smelter capacity at a crossroads (Stage 2 or 3), and zinc production in a declining cycle (Stage 4 or 5). The status for each industry is a reflection of the overall domestic supply, prices, consumption trends, and other market conditions.

On the basis of the trends developed in Chapter 2.0, lead may be in Stage 1 or early Stage 2 of Hewett's model. As was noted earlier, lead mine production was increasing slowly from 1960 through 1968. With the advent of the new Missouri mines, lead production increased markedly for Missouri and for the nation, while numerous smaller, marginal operations in other states declined. Several states had no lead production at all within two years after the opening of the Missouri mines (see Appendix A, Table A-1-7). Lead imports have been declining, in spite of the increasing domestic demand. Lead exports are also increasing. Primary smelter capacity and output have been increasing, although the closure of Bunker Hill may effect this trend. The combination of these trends in lead appears to fit the late Stage 1 or Stage 2 in Hewett's model.

Based on the trends developed in Chapter 2.0, copper mines and smelters may be a crossroad in Stage 2 or well into Stage 3. The argument for Stage 2 is based on a relatively stable, high level of mine production, whereas Stage 3 could be supported by the static smelter production and the declining smelter capacity. Imports and exports of copper concentrate are approximately equal, but the increasing importation of refined metal supports Stage 3.

The stage for copper is not as easily defined as lead because many of the trends have developed only recently. These may not be indications of a more long-term condition.

The status of zinc smelters appears to be in Stage 4 or Stage 5, on the basis of the industry trends. Smelter output has fallen 40% from the peak production levels of 1969 and capacity has declined by 33% since 1960. Mine production has gradually fallen by 50% relative to the high in 1965. Refined zinc imports have been steadily increasing. Very little zinc concentrate is imported for two reasons. First, total domestic zinc smelting capacity is small. Second, the market for zinc concentrates is highly competitive because of a near equilibrium worldwide. The combination of these trends appears to indicate that the U.S. zinc industry is in late Stage 4 or Stage 5 of Hewett's model. This may change, however, if the zinc-copper mine at Crandon, Wisconsin is developed.

4.3 INDUSTRY FUTURE

The stages in Hewett's model are relatively defined, and the cycles he proposes can fluctuate in the near term. His hypothesis is developed for the overall, long-term outlook. Factors which can cause the cycles to fluctuate for a nation are metal prices, world economic health, and global politics. Other effects, such as taxes, tariffs, and regulations can also cause these cycles to occur sooner or further into the future. Some of these factors may be affecting the cycles for copper, lead, and zinc in the United States.

The case of lead in the United States may be a good example of an acceleration of the cycles in Hewett's hypothesis. Domestic lead production has been growing since the development of a world class lead deposit in Missouri. There are indications that the U.S. lead cycles and thus the stage of development could be altered by the "man-made devices" of environmental and health regulations. The lead industry maintains that it cannot meet the worker exposure limitations currently being sought by the Occupational, Health, and Safety Administration (OSHA). The industry has stated that it will have to close its smelters and ship concentrate elsewhere if it is forced to meet the OSHA workplace exposure levels. If the industry is correct, the effect is sobering. The lead smelters would close while the Missouri world class mines are still in operation. These closures may not be idle warnings. AMAX is currently shipping some of the lead-zinc concentrates from its Boss, Missouri mine to Belgium for processing (Rathjen, 1980b).

The closure of smelting facilities before the mines have matured is not a part of Hewett's model. Such an occurrence would place the loss of processing before reserves as depleted. One implication of this could be the eventual mine closure at a higher cutoff grade.

The current status of copper smelters may be a prelude to what could happen to the lead industry. The future for copper smelting may be in a delicate balance right now. The crossroads for copper, in terms of the Hewett hypothesis, is in the reasons for the recent declining copper production. Hewett states that costs, including all "man-made devices" will affect mine and smelter refinery production. The reasons for the recent copper smelter closure may be an important difference. Rather than smelter capacity declining as the surrounding mines are exhausted, it may be that a decrease in copper smelter capacity will force the premature closure of mines. Certain "man-made devices" such as the U.S. Environmental Protection Agency regulations in concert with high interest rates and low capital availability, may be accelerating the "smelter cycle" for copper. If the recent closure of the Anaconda smelter and the capacity reductions of several other copper smelters are valid examples, than these "man-made devices" may be in the process of changing the historical cycle of Hewett's hypothesis as it applies to copper in the United States and the current declining smelter capacity may be only a prelude to the mine and smelter closures yet to come. This is the apparent crossroads for the copper industry in the United States.

It may be useful to examine the history of zinc with the current status of copper and lead in mind. The Hewett hypothesis indicates that smelter capacity will decline after the peak in mine capacity and imports of refined metal will increase. Zinc mine production peaked in 1965 and 40% of the smelter capacity was closed between 1971 and 1973. A question remains, however. Zinc mine production stabilized between 1971 and 1976 then began declining steeply in 1977. Did smelter capacity regulations precede the mine production decline and precipitate the loss in production capacity? If no smelters were located within an economic distance of the mines, did the loss convert reserves back to resources? If this is the case, then similar conditions may be experienced in the future by lead and copper if the current conditions and trends continue.

The future for copper and lead smelting capacity is in some question because of the high cost of implementing measures to meet the current laws regarding pollution and worker safety and health. It may be that the costs of operation will force the early closure of U.S. smelters before the mines are exhausted.

Using the Hewett model, it appears that these changes accelerate the cycles of national capacity. According to Hewett, this will ultimately lead to a modest domestic capacity with a large dependence on imported refined metal.

In the broader view of Hewett's hypothesis, it seems that the relative stages are functioning. The lead industry is growing and operating profitably. The smelters which serve these mines were operating at capacity until reductions were ordered to meet air quality standards.

On the other end of the scale, zinc appears to be in Stage 5. The mines in the United States are not profitable in the world market and several have closed. It can be questioned whether a decline in smelter capacity forced the early closure of these mines or whether closure was for broader market reasons. The data seems to indicate that marginal producers were forced to close because of the marketplace as a whole.

The copper smelting industry may be at a crucial time. Most of the smelters are located close to the mines, so access to imported concentrates has limitations. Mine production has been level and grade is steadily declining. The imposition of "man-made devices" may be critical to near-term survival, but it is uncertain how much extra time will be gained. It may be that the copper industry has already entered the declining phase, and the "man-made devices" have only accelerated the process.

4.4 IMPLICATIONS OF INDUSTRY STRUCTURE

The changes and future of domestic smelting capacity may be linked to the change in the ownership in the mining industry. As ASARCO's President, Charles F.

Barber, recently commented, "The mining industry responds to a very long-term rythmn, unlike most other businesses." (Metals Week, March 31, 1981, page 9.)

The oil industry evaluates projects differently than has been the tradition in the mining industry. The oil companies have a broad range of investment options to consider, and the projects receiving funding are those which will maximize the return to the shareholder (Tobin, 1982). Mining investments must now compete with oil investment options, which traditionally have had a higher rate of return. A commodities vice president for Dean Whitter Reynolds made this timely speculation in March 1981:

> Let's say a crisis hits the oil industry and causes its earnings to slow down. What would happen to major expansion and modernization plans in the metals? Copper, lead, and zinc, for example, would not be high priority areas for investment. They would be the first to go. (Metals Week, March 31, 1981, page 9.)

These market conditions have been realized in recent months. Oil prices are declining and industry growth projections have changed dramatically (Gammons, 1982). Exxon, which established a grass-roots Minerals Division, is reexamining the zinc-copper property in Crandon, Wisconsin and the Chile expansion at Disputada (Metals Week, 1981; Metals Week, 1982). Further impacts are yet to occur. Metals Week recently speculated that the Berkeley Pit in Montana may be closed (1982a). These may be indications of the trend of mine management in the future. The long lead times, lower rates of return, large capital investment, and cyclical demand may discourage development.

The volatility of the industry cannot be understated. The Federal Trade Commission (FTC) recently released a report summarizing statistics for various industries (Metals Week, 1981). In 1974, primary lead production was ranked the most profitable business on the basis of operating income as a percentage of total assets. In 1975, the lead industry dropped from first to 76th place when ranked with 237 industries. Copper displays the same volatility. In the same study, copper ranked seventh in profitability in 1974 and was the 237th in 1975. The metals are also very capital-intensive. In 1975, copper ranked first of 237 industries, with assets 205% of sales, while primary non ferrous metals totals ranked fourth and zinc was seventh. When high capital intensity is combined with the high market volatility and the mining risks, it is questionable how much investment will be undertaken by mining firms owned by oil companies. When the pure economics of rate of return are applied across the spectrum of oil and mineral projects, it would seem that the mineral prospect must be a bonanza to compete successfully for funding.

There are important ramifications of this management style and the broad range of options available to oil firms with regard to smelter capacity in the United States. ARCO's Anaconda closed the Anaconda smelter on the basis of economics (Cox, 1980). The company is now considering the option of continuing to toll its copper concentrate with Japan or to develop a smelter of its own (American Metal Market, 1980). According to industry spokesman, this smelter must meet certain hurdle rates and demonstrate that operation as a viable profit center is feasible. Cost estimates for such a smelter are roughly $1 billion to $1.3 billion (Tobin, Senne, 1981). With investments of this magnitude, the risks and alternatives must be carefully examined.

The ownership of mining companies and mineral properties by oil companies is anticipated to have far-reaching effects on the mining industry. With the broad range of investment opportunities available to the parent companies, it is doubtful that marginal properties or processing facilities will be developed or that marginal projects already operating will be allowed to continue.

In summary, the domestic smelting and refining industry is facing changes which directly affect the future. According to Hewett's hypothesis, all the industries can ultimately anticipate decline, unless plans are made for an expanding source of concentrate feed. Zinc may be in the final stage of maturity, copper beginning to decline, and lead is a robust industry with a longer future. The smelting/refining industry may progress through the stages of Hewett's model more quickly if environmental costs become excessive. The changing management philosophy may also affect the lifetime of these industries. It has been said that only optimists are in mining. The economic tests that mining projects will face under the new management philosophy may slow the development of new mining properties and remove marginal properties from the marketplace.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

The first three chapters of this Thesis have developed an understanding of the copper, lead, and zinc industry and the changes which have occurred in these industries since 1960. Chapter 4.0 assessed these changes and examined the possible ramifications of a continuation of these trends. This Chapter will discuss the proposed solutions offered by industry and increasingly by the government. The author will also present conclusions and discuss other possible avenues of development.

5.1 INDUSTRY SOLUTIONS

The domestic industry has become increasingly vociferous in presenting the industry position to the public. Two smelter closures, Anaconda and Bunker Hill, have focused greater media attention on the industry problems and proposed solutions.

The trend in smelter closings is a part of the overall condition of the U.S. mining industry, according to the industry. Nichols T. Camicia, Chairman of the American Metal Mining Congress, cites three major problems with the industry: land withdrawals, foreign dependence on minerals, and excessive environmental regulations (Mining Engineering, 1979a). The adversary relationship between government and the mining industry has only served to hamper communication. The statement by Mr. David Ridinger of Magma Copper summarizes the tactics the mining industry has adopted: "Change the laws, change the regulators, or change their minds (Mining Engineering, 1979b)."

The mining industry is urging reasonable environmental and workplace regulations and a strategic mining stockpile. These would provide an economic environment and an established planning horizon for the industry. Mr. Ralph Cox, President of

Anaconda, made a statement to the Montana State Legislature which seems to summarize the industry's perspective:

> "(I would like to make one more point) which could be the most important of all. That point is the difficulty that all businesses face in dealing with what I will call 'the moving target syndrome'. Perhaps more than any single factor, business and industry need an element of stability and consistency . . . Significant investments can only be made based upon regulations . . . which are consistent . . ." (1980).

The industry is particularly concerned about the SO_2 standards currently promulgated by the government. These standards are designed to allow a margin of safety for infants and disabled persons. Industry maintains that this is unreasonable for smelters located in remote areas. Current laws require standards be set without regard to cost, and industry is requesting that cost/benefit studies be required.

The costs of environmental controls are being imposed at a time of historic low metal prices and thus low income for the entire industry. In addition, the industry has not yet recovered from the inflation and high costs of the early 1970s. Mining companies are requesting moderation or they will have to close their facilities. The anticipated costs for air and waste alone are $3 billion (Chapter 2.0). It is estimated that the proposed copper smelter retrofits will add costs of $0.19/lb of copper (Everest Associates). These costs will make copper produced in the United States the highest priced in the world.

The metals industry recognizes that there are a combination of effects which are making metals production less profitable or, in some cases, nonprofitable. The world economic downturn and the slowing rate of metals consumption are all important to the economic decisions to be made. The industry points out, however, that in this weakened market, the additional nonproductive uses of capital may force several operations to close.

As well as addressing the environmental issue, the mining firms are addressing the demand issues. They strongly support a national stockpile of strategic minerals, as long as it is operated with the national perspective. ASARCO proposes that the government guarantee a floor price it will use to purchase metals (Barber, 1982). This will provide mining firms with an assured economic environment that warrants the commitment to development and expansion.

The mining industry points out that there are several items which must be remembered. First, a recent study (Gluske, 1980) points out that significant development and expense will be required to assure just the supply of copper needed for the world in the next 20 years. Mining companies, particularly those owned by oil companies, have a market basket of options from which to choose, and they will select those with the highest rate of return. This has two very important implications. The first is that industry, given the marketplace to choose from, may choose to invest in foreign countries rather than maintain a domestic capability. For example, Anaconda is evaluating construction of a world-class smelter. While sites in the United States are being considered, other options in other countries are also viable alternatives. The second implication is that industry, hampered by high, nonproductive costs, will not make the required investments to meet future demand. With high current debt, very tight markets for capital, and restrictive legislation in the United States, no growth or preparations for future demand will occur. As the national economy regains strength and demand increases, domestic suppliers will not be able to meet demand and more metals will have to be imported. This will have the effect of weakening the U.S. balance of payments and increasing U.S. reliance on imported materials.

Basically, then, the industry position is one of frustration and warning. The industry agrees that improvement in environmental operations is warranted. They also maintain, however, that these improvements must be within limits. Regulations must also be consistent, so that a company has the confidence that the control expenditures they commit to will meet the requirements existing when the project is completed. The regulations must also include economics. Several operations will be closed down if they are required to meet certain existing laws because the costs will make them uneconomic. Finally, the industry points to the steadily increasing reliance on imported metals. They warn that increased reliance on the imported basic commodities makes the nation's economy more susceptible to manipulation.

5.2 AUTHOR'S ASSESSMENT

In the market economy, there are two objectives of business. One is to make a profit in order to provide an adequate return to the company owners or shareholders. The second is to survive. Businesses may have additional corollaries to this statement, such as being a good corporate citizen with the ramifications of providing a safe workplace and becoming an asset to their communities. These are subsidiary to the objective of profits or a positive cash flow, however, because survival is the most important consideration for a firm. Environmental protection and worker health and safety have been nationally accepted as a requirement for doing business. Most companies have accepted this and have made significant steps to improve their operations. While environmental laws are necessary, the industry request for reasonable enforcement should also be considered.

The reasonable enforcement should be qualified by two considerations. First, the investment climate is strained, with a high inflation, record interest rates, and historically low prices for metals. In order to build the modifications, the investor must believe that there will be a satisfactory return on the money required, and the mining company must have the ability to repay the loan. This confidence and ability have declined over the past ten years. The second item of reasonable enforcement is the rationale of the standards. In the case of $S0_2$ emissions, the remote locations of most smelters mean little affect on any community and may have some benefits. Phelps Dodge has conducted studies which show that $S0_2$ has actually improved the desert alkaline soils (Judd, 1982)

The severity of the standards that are currently promulgated (1982) is due, in part, to the shortsightedness of the mining industry. Historically, mine trailings have been left unrestored, and acid mine drainage has seriously polluted rivers. The air, water, and quality standards are in part a backlash in public sentiment to those practices. The punitive nature of the laws will probably continue until the industry improves its operating practices.

The industry, however, can be criticized for a lack of planning and community awareness. During the 1960s, when the Japanese were investing to modernize and improve their smelter capacity, the U.S. firms were reaping high real profits and developing new mine capacity. Smelters and refineries had been fully amortized many years before and, although they were (and are) relatively inefficient, they functioned. This lack of awareness of the global competition is affecting the metal processing industry now, as it is affecting other U.S. industries, most notably in automobiles.

The U.S. Government can also be criticized for a lack of planning and confusion. The United States has not defined or pursued a consistent policy toward mining and minerals, or business in general. A long-term plan in the typical U.S. definition is five years, and for government policy it is usually three and one-half to four years in cycle with the Presidential election. When business must consider billion dollar investments, volatile prices, and worldwide competition, this time frame is insufficient.

In addition, the Hewett model proposes that an important consideration for smelting and refining in the United States is the source of feed. His model demonstrates that for smelter survival, the facility must be located where it is accessable to imported concentrates. Most of the U.S. smelters cannot economically take advantage of this fact. The smelter industry now recognizes this aspect and is publically discussing this needed characteristic for a new smelter. Informal discussion between companies and internal company studies are acknowledging the need for access to foreign concentrate as well as access to markets for the pollution control by-products. This is an important step in maintaining a viable metal processing industry in the United States.

Finally, the issue of national security and its ramifications is an important one which has not yet been dealt with by the government. Steps are being taken to bring this issue to the forefront in order to resolve the current controversy over the need for mineral stockpiles. This consideration deserves the full attention of the government.

This nation has never had a coherent minerals policy, although such a policy has been the subject of discussion for many years. The lack of policy is being criticized now by the industry that must operate in this framework as well as be the government's own observer, the General Accounting Office. Perhaps this issue will finally be resolved in the next few years.

5.3 CONCLUSIONS

This study was conducted to answer two basic questions. They were, first, to assess whether the current decline in U.S. smelting and refining capacity is representative of a longer term phenomenon and second, to examine the implications. The third part of the study was to make recommendations based on the answers to these questions. This study concluded that the decline in smelting capacity can be altered but is representative of current conditions. The implications are far-reaching for the smelting and refining industry as well as for the United States. These conclusions are summarized below.

1. The decline in domestic smelting and refining capacity is real.

This decline may be attributed partly to the typical cycles of mineral development and basic microeconomic principles and partly to the imposition of expensive environmental regulations. The decline in capacity represents a real decline under the current conditions.

2. The decline in domestic capacity has important ramifications for the metals industry and the U.S. economy.

For the domestic economy, the decline in smelting capacity represents a loss of jobs and a displacement of communities with few or no alternative sources of income. More broadly, the tax base is eroded for the states and ultimately the nation. If the trend continues, the country will rely increasingly on imported metals, thus losing value-added advantages. The country will then rely more heavily on foreign sources for the basic materials of an industrialized economy.

For the mining firm, the declining capacity means either increasing transportation costs to more distant facilities or closure of the mines. Increasing costs require a higher cutoff grade at the mine. This may ultimately mean that domestic reserves will become resources. These metal values would then not be recoverable until world reserves approach the costs of reopening these mines.

The decline in domestic smelting capacity is only one indicator of many currently in the economy of the shortfall in long-range economic planning by industry and the government. Steps can be taken that can lessen or reverse the trend. The success of these actions will depend on the perserverance and patience of all concerned.

5.4 RECOMMENDATIONS

There are several steps that can be taken which can slow the decline in domestic smelting and refining capacity and preserve the national benefits that a strong domestic industry provides.

First, the nation can adopt a more cooperative relationship with business. Business needs regulation to ensure public responsibility, but this can be accomplished without punitive effects. A wishful recommendation is that government adopt a longer range perspective so that business has a more positive framework for investment decisions. More specifically, the environmental regulations must be applied with an acceptance of the economic limitations of the firm. These requirements and business responsibility are absolutely necessary, but the basis for and the limits of these regulations must be reasonable and valid, not punitive.

Second, the mining industry must recognize the global scale of competition which exists in their markets and plan accordingly. Mines and smelters must be internationally competitive. The marginal producers will not succeed when the economy cycles through periods of low prices. Technological innovation will be required to make these marginal properties competitive.

Third, and perhaps most importantly, the industry must recognize the value of public opinion. The U.S. society has historically been a "me" society. The mining industry must educate the public to view their business more favorably. This can be accomplished by continuing to demonstrate improved responsiveness to public concerns, and making the public aware that mining and processing ores ultimately makes automobiles and refrigerators. The industry must begin a careful, credible, and intensive campaign to raise public awareness. A recent headline in the Denver Post (1981) exemplifies the degree of action which the industry needs to undertake. It reads, "Mining's Quiet Crisis." Public opinion is an integral part of the national policy. A "quiet crisis" for the industry implies failure.

The decline in U.S. smelting capacity is real. The decline is on the basis of economic principles which can be altered to greater and lesser degrees through several actions. First, a cooperative rather than a punitive relationship between government and industry can be fostered. This can be aided by educating the public about the various issues and ramifications. In addition, technological progress in mining techniques, ore concentration, and processing can be developed to reduce costs and improve by-product recovery. Regulations can be required to consider the relative costs. Finally, industry and government need to adopt a longer term perspective to provide an environment with stability and direction.

The adoption and implementation of all these recommendations is a naive hope. There are encouraging indications, however, that efforts are being made to pursue them. A continued large smelting industry in the United States depends on the success of the combined efforts by industry and government.

5.5 RECOMMENDATIONS FOR FURTHER RESEARCH

This study revealed several areas which could be explored further. The author proposes the following topics:

- The enactment of a National Minerals Policy.

  What should it contain and why? What would be the costs and benefits? How should it be implemented?

- The quantitative implications of the current trends.

  Apply forecasting techniques and current costs estimates to quantitatively assess the impacts and implications for the longer term.

- Other metals that fit with Hewett's hypothesis.

  Is the aluminum industry, for example, in the same position.

- The probability of success for importing foreign concentrate.

  Will developing and lesser developed countries be willing to accept the export of lower value products? For how long?

- Locations for new smelters.

  What are the criteria? How different are they for different metals?

- Other smelter criteria.

  What should be (or needs to be) the economic life? How large must it be? Can smaller capacities meet the need with the benefit of reduced capital risk?

- The environmental and health regulations.

  How can they be modified? How can costs be reduced and meet the same objective?

- The impacts of changed ownership.

  What are the impacts of the changed ownership of the mining industry? Can the changes be forecast and quantified? Are further changes expected?

These are a few of the apparent questions. The answers to them are needed by both industry and government.

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APPENDIX A: TABLES OF SUPPORTING DATA

TABLE A-1-1: Mine Production of Copper in the United States—By States, 1960-1979 (In 1000 Tons of 2000 Pounds)

State	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Arizona	539	587	644	660	690	703	739	501	627	801	910	820	908	927	858	813	1,024	923	982	946
California	—	—	1	1	1	1	1	—	1	1	—	—	—	—	—	—	—	—	—	—
Colorado	3	4	4	4	4	3	4	3	3	3	3	4	3	3	3	3	2	1	1	—
Idaho	4	3	3	4	4	5	4	4	3	3	3	4	2	3	2	3	3	4	4	4
Michigan	56	70	74	75	69	71	73	58	74	75	69	56	67	72	67	73	43	42	38	—
Montana	93	104	94	79	103	115	128	65	69	103	123	88	123	132	131	87	91	86	74	38
Nevada	77	78	82	81	67	71	78	50	77	104	101	97	101	93	84	81	58	67	22	—
New Mexico	67	80	82	83	86	98	108	75	90	119	165	—	168	204	196	146	162	164	140	140
Tennessee	—	12	14	13	13	14	15	14	14	15	15	—	11	8	6	10	11	6	12	—
Utah	219	213	218	203	199	259	265	168	228	296	295	—	259	256	230	177	185	194	205	193
Other States	22	10	8	6	5	7	9	10	13	19	18	7	18	13	16	17	13	13	14	53
TOTAL	1,000	1,200	1,200	1,200	1,300	1,300	1,400	950	1,200	1,500	1,700	1,500	1,700	1,700	1,600	1,400	1,600	1,500	1,500	1,400

(Compiled from Metal Statistics, 1970, page 92; 1975; page 61; 1981, page 57)
Data Corrected for Metric Reporting

TABLE A-1-2: Twenty-Five Leading Copper-Producing Mines

Mine	County/State	Operator	Rank by Output 1978	1979	1980
Utah Copper	Salt Lake, UT	Kennecott Copper	1	1	1
Morenci	Greenlee, AZ	Phelps Dodge	2	2	2
San Manuel	Pinal, AZ	Magma Copper	3	4	7
Sierrita	Pima, AZ	Duval Sierrita	4	6	3
Twin Buttes	do	Anamax Mining	5	3	5
Ray Pit	Pinal, AZ	Kennecott Copper	6	7	6
Tyrone	Grant, NM	Phelps Dodge	7	5	4
Berkeley Pit	Silver Bow, MT	The Anaconda	8	8	11
Pinto Valley	Gila, AZ	Cities Services	9	9	10
Metcalf	Greenlee, AZ	Phelps Dodge	10	12	20
Bagdad	Yavapai, AZ	Cyprus Bagdad Copper	11	10	8
Chino	Grant, NM	Kennecott Copper	12	11	9
New Cornelia	Pima, AZ	Phelps Dodge	13	--	--
Mission	do	ASARCO Inc.	14	17	25
Magma	Pinal, AZ	Magma Copper	15	16	19
White Pine	Ontonagon, MI	White Pine Copper Div.	16	13	12
Inspiration	Gila, AZ	Inspiration Cons. Copper	17	15	13
Sacaton Unit	Pinal, AZ	ASARCO Inc.	18	19	21
Silver Bell	Pima, AZ	do	19	18	23
Mineral Park	Mohave, AZ	Duval	20	22	22
San Xavier Unit	Pima, AZ	ASARCO Inc.	21	--	--
Copperhill/3 Mines	Polk, TN	Cities Service	22	23	24
Yerington	Lyon, NV	The Anaconda	23	--	--
Ruth Pit	White Pine, NV	Kennecott Copper	24	--	--
Miami Unit	Gila, AZ	Cities Service	25	25	--
New Cornelia	Pima, AZ	Phelps Dodge	--	14	16
Continental	Grant, NM	UV Industries	--	20	17
Esperanza	Pima, AZ	Duval	--	21	18
Pima	Pinal, AZ	Cyprus Pima Mining	--	24	15
Eisenhower	Pima, AZ	Eisenhower Mining	--	--	14

(Compiled from Butterman, Rathjen, 1978-1980. Minerals Yearbook)

TABLE A-1-3: Smelter Production of Copper (Reported in Metric Tons)

Location	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Canada	439	396	370	361	397	422	410	465	428	388	465	462	473	495	500	488	457	481	413	398
US	1109	1323	1400	1393	148	1520	1580	929	1350	1508	1560	1421	1596	1652	1424	1312	1392	1302	1288	1335
Chile	---	578	614	615	646	615	667	695	686	646	647	625	630	589	724	724	856	888	927	946
Mexico	66	46	57	55	53	52	56	55	61	56	59	59	72	73	78	70	85	87	87	82
Peru	---	200	165	173	168	174	166	173	205	170	176	166	176	172	179	161	190	316	318	371
Total America	**1600**	**2550**	**2600**	**2600**	**2690**	**2740**	**2880**	**2320**	**2800**	**2774**	**2913**	**2739**	**2953**	**2986**	**2909**	**2759**	**2981**	**3075**	**3035**	**3135**
W Germany	---	335	339	330	370	390	413	421	478	184	217	205	260	314	174	176	193	189	165	158
Total Europe	**120**	**520**	**550**	**550**	**500**	**630**	**670**	**700**	**770**	**503**	**545**	**582**	**699**	**779**	**536**	**517**	**546**	**536**	**507**	**486**
Total Africa	**107**	**1030**	**1010**	**1050**	**1150**	**1230**	**1200**	**1240**	**1300**	**1260**	**1281**	**1267**	**1363**	**1364**	**1440**	**1356**	**1362**	**1367**	**1314**	**1220**
Japan	98	305	298	325	376	403	446	518	604	501	606	661	777	1000	868	742	769	848	854	853
Total Asia	**200**	**330**	**340**	**370**	**420**	**440**	**490**	**560**	**660**	**529**	**644**	**698**	**811**	**1049**	**937**	**822**	**854**	**940**	**938**	**962**
Australia	**118**	**68**	**97**	**99**	**90**	**82**	**101**	**82**	**103**	**124**	**120**	**149**	**150**	**166**	**196**	**180**	**167**	**167**	**165**	**173**
USSR	507	523	550	600	675	710	770	850	905	875	925	990	1050	1100	1060	1100	1130	1100	1170	1170
Poland	---	---	---	---	---	---	---	---	---	50	72	92	150	155	185	230	270	290	320	340
China & Other	---	---	---	---	---	---	---	---	---	187	198	204	216	179	291	355	319	330	328	329
Total	**630**	**710**	**770**	**850**	**950**	**980**	**1060**	**1130**	**1200**	**1112**	**1195**	**1287**	**1416**	**1470**	**1536**	**1640**	**1719**	**1720**	**1818**	**1839**
Total World	**4500**	**5100**	**5300**	**5400**	**5800**	**6100**	**6300**	**6000**	**6700**	**6300**	**6700**	**6700**	**7300**	**7800**	**7600**	**7300**	**7600**	**7800**	**7800**	**7800**

(Compiled from Metal Statistics, 1981, page 57; 1975, page 63; 1969, page 93)

TABLE A-1-4: Forecast U.S. Copper Mine Production (Thousand Metric Tons)

		2000			Probable	
	1978	Forecast Base	Low	High	1990	2000
Production	1358	2860	2500	3200	2000	2860
Cumulative	---	---	42000	4800	20,000	44000

(Schroeder, 1980 Mineral Facts and Problems)

TABLE A-1-5: Mine Production of Lead in the United States—By States (In 1000 Tons of 2000 Pounds)

State	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Arizona	8.4	5.9	6.9	5.8	6.1	5.9	5.2	4.8	1.7	---	---	---	---	---	1.0	---	---	---	---	---
California	---	---	---	---	1.5	1.8	1.9	1.7	4.0	2.5	1.7	2.2	1.1	---	---	---	---	---	---	---
Colorado	18.0	17.7	17.4	19.9	20.5	22.4	23.0	22.5	19.7	21.7	21.8	24.3	31.3	28.1	24.6	27.0	26.7	22.9	16.7	8.3
Idaho	42.9	71.4	84.0	75.7	71.3	66.6	72.3	58.7	54.7	65.5	61.2	65.0	61.4	61.7	51.7	50.3	53.6	47.2	49.3	47.0
Missouri	111.9	98.7	60.9	79.8	120.1	133.5	132.2	149.7	212.6	355.4	421.7	427.7	489.3	487.1	562.0	515.9	500.9	500.2	509.0	520.4
Montana	4.8	2.6	6.1	5.0	4.5	6.9	4.4	---	1.8	1.7	---	---	---	---	---	---	---	---	---	---
New Mexico	1.9	2.3	1.1	1.0	1.6	3.3	1.5	1.5	1.3	2.3	3.5	2.8	3.5	2.5	2.3	1.9	---	---	---	---
Utah	39.3	40.8	38.1	45.0	40.2	37.7	64.1	54.8	45.2	41.3	45.3	38.7	20.7	13.7	10.5	12.6	16.2	10.7	2.8	---
Washington	7.7	8.0	6.0	5.3	5.7	6.3	5.8	2.6	5.6	8.6	6.7	5.1	2.5	2.2	1.2	---	---	---	---	---
Wisconsin	1.1	---	1.3	1.1	1.7	1.6	1.6	1.6	1.1	1.1	---	---	---	---	1.2	---	---	---	---	---
Other States	9.6	13.2	14.2	13.6	12.4	14.7	76.9	4.9	6.5	5.8	6.1	5.7	5.9	5.6	8.1	12.7	11.3	9.8	5.3	2.9
TOTAL	246.6	261.9	236.9	253.3	286.0	301.1	327.3	311.1	359.0	509.0	571.7	573.3	618.9	603.0	663.8	621.4	609.5	592.4	583.8	579.0

(Compiled from Metal Statistics, 1981, page 107; 1975, page 141; 1969, page 203)

TABLE A-1-6: Twenty-Five Leading Lead-Producing Mines in the United States

Mine	County/State	Operator	Rank by Output 1978	1979	1980
Buick	Iron, MO	AMAX Lead Co. of MO	1	1	1
Fletcher	Reynolds, MO	St. Joe Lead Co.	2	2	2
Magmont	Iron, MO	Cominco American, Inc.	3	3	3
Ozark	Reynolds, MO	Ozark Lead Co.	4	---	---
Brushy Creek	do	St. Joe Lead Co.	5	4	6
Viburnum No. 29	Wahington, MO	do	6	6	5
Viburnum No. 28	Iron, MO	do	7	7	7
Lucky Friday	Shoshone, ID	Hecla Mining Co.	8	8	9
Bunker Hill	do	The Bunker Hill Co.	9	9	8
Star Unit	do	Hecla Mining Co.	10	11	10
Indian Creek	Washington, MO	St. Joe Lead Co.	11	10	11
Leadville Unit	Lake, CO	ASARCO Incorporated	12	12	12
Viburnum No. 27	Crawford, MO	St. Joe Lead Co.	13	---	---
Idarado	Ouray & San Miguel, CO	Idarado Mining Co.	14	---	---
Sunnyside	San Juan, CO	Standard Metals Corp.	15	20	13
Burgin	Utah, UTah	Kennecott Copper Corp.	16	---	---
Bulldog Mountain	Mineral, CO	Homestake Mining Co.	12	14	15
Austinville & Ivanhoe	Wythe, VA	The New Jersey Zinc Co.	18	13	14
Balmat	St. Lawrence, NY	St. Joe Lead Co.	19	17	16
Tamarack	Shoshone, ID	Day Mines, Inc.	20	---	---
Millikin	Reynolds, MO	Ozark Lead	---	5	4
Galena	Shoshone, ID	ASARCO	---	16	18
Shullsberg	Lafayette, WI	Eagle-Pitcher Ind.	---	18	---
Mission	Pima, AZ	do	---	---	19
Hilltop	Lemhi, ID	Petro Chemical	---	---	20

(Compiled from Rathjen, 1978-1980, Minerals Yearbook)

TABLE A-1-7: Zinc Mine Production in the United States—By States (In 1000 Tons of 2000 Pounds)

State	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Arizona	36	30	32	25	24	21	16	14	6	9	10	10	10	8	9	8	9	4	—	—
Colorado	31	43	43	48	53	53	54	53	50	53	52	56	63	58	49	48	50	40	24	11
Idaho	37	58	62	63	59	58	60	54	55	55	40	39	38	46	39	40	46	30	35	38
Illinois	30	27	27	20	13	18	15	19	18	13	17	15	11	5	4	—	—	—	—	w
Missouri	3	6	2	—	1	4	3	6	11	41	51	54	61	82	91	74	83	81	65	72
Montana	12	10	37	32	29	33	28	2	2	6	4	—	—	—	—	—	—	—	—	—
New Jersey	—	—	15	32	39	38	26	25	26	25	29	30	38	33	32	31	33	33	31	35
New Mexico	14	23	22	12	29	36	29	22	22	24	27	20	12	12	13	11	—	—	—	w
New York	66	55	53	53	60	69	73	72	64	58	57	59	60	81	93	76	73	70	29	32
Pennsylvania	14	23	24	27	30	27	27	35	30	33	29	20	18	18	20	21	22	22	21	23
Tennessee	91	82	71	95	115	122	116	110	120	124	120	110	101	64	85	83	82	90	96	107
Utah	35	37	34	36	31	27	36	35	35	34	36	34	21	16	12	19	22	17	3	43
Virginia	20	29	26	23	21	20	17	19	19	18	17	16	16	16	17	15	11	13	12	13
Washington	21	20	21	22	24	22	24	21	13	9	n/a	6	6	6	6	—	—	5	—	w
Wisconsin	18	14	13	15	26	26	25	28	26	22	20	20	6	8	8	—	—	—	—	w
Other States	4	5	10	13	12	13	11	10	7	3	—	—	—	—	3	24	38	30	13	5
TOTAL	432	462	505	529	574	611	583	542	529	553	546	489	478	478	499	469	484	449	333	294

w = withheld

(Metal Statistics, 1963-1981)

TABLE A-1-8: Twenty Leading Zinc-Producing Mines in the United States

Mine	County/State	Operator	Rank by Output 1978	1979	1980
Buick	Iron, MO	AMAX Lead Co. of MO	1	1	2
Sterling	Sussex, NJ	The New Jersey Zinc Co.	2	2	4
Balmat	St. Lawrence, NY	St. Joe Zinc Co.	3	11	3
Friedensville	Lehigh, PA	The New Jersey Zinc Co.	4	3	5
Young	Jefferson, TN	ASARCO Incorporated	5	9	1
Elmwood	Smith, TN	The New Jersey Zinc Co.	6	4	6
Zinc Mine Works	Jefferson, TN	United States Steel Corp.	7	6	7
Star Unit	Shoshone, ID	The Bunker Hill Co. and Hecla Mining Co.	8	5	10
Bunker Hill	do	The Bunker Hill Co.	9	7	11
Immel	Knox, TN	ASARCO Incorporated	10	13	9
Magmont	Iron, MO	Cominco American, Inc.	11	10	15
Leadville	Lake, CO	ASARCO Incorporated	12	15	13
Austinville and Ivanhoe	Wythe, VA	The New Jersey Zinc Co.	13	8	12
Idol	Grainger, TN	do	14	16	16
Jefferson City	Jefferson, TN	do	15	14	14
Idarado	Ouray and San Miguel, CO	Idarado Mining Co.	16	---	---
Ozark	Reynolds, MO	Ozark Lead Co.	17	19	18
Ground Hog	Grant, NM	ASARCO Incorporated	18	---	---
Brushy Creek	Reynolds, MO	St. Joe Lead Co.	19	17	17
Copphill Plant	Polk, TN	Cities Service	20	18	20
New Market	Jefferson, TN	ASARCO Incorporated	---	18	20
Viburnum No. 27	Washington, MO	St. Joe Lead	---	20	19

(Compiled from Cammaroto, 1978-1980)

TABLE A-1-9: World Production of Slab Zinc, 1960-1979
(Reported in Metric Tons)

Location	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
US	859	901	938	952	1029	1058	1108	1012	1100	1111	961	840	765	570	452	495	567	500	486	578
Mexico	58	57	62	61	65	65	79	83	90	94	95	97	96	74	146	164	199	192	190	176
Canada	260	268	280	283	337	358	382	405	426	466	460	410	524	532	481	469	520	545	547	639
Total America	**1187**	**1227**	**1280**	**1297**	**1428**	**1502**	**1570**	**1500**	**1617**	**1671**	**1517**	**1348**	**1386**	**1301**	**1414**	**1278**	**1499**	**1396**	**1381**	**1580**
Belgium	272	270	227	226	243	264	277	250	276	283	258	234	286	276	323	251	269	302	256	279
France	164	178	181	185	209	212	216	204	228	279	246	239	281	259	305	199	257	262	254	274
Great Britian	82	104	108	110	121	117	111	114	157	166	161	128	81	84	92	58	46	90	81	84
W Germany	201	204	188	172	171	170	230	200	224	310	332	282	392	395	440	325	336	391	338	391
Africa	92	96	106	113	112	115	114	117	128	124	129	133	131	174	215	199	188	201	210	202
Australia	134	155	188	201	207	222	217	217	225	267	287	285	328	292	305	213	268	274	319	334
Japan	198	234	270	311	348	405	489	569	667	785	745	789	887	844	936	769	818	857	845	869
USSR	441	446	451	463	480	510	518	565	565	610	615	630	690	680	1079	1135	1100	1124	1163	1196
Poland	193	200	199	199	206	209	212	216	223	228	230	242	244	224	257	268	261	251	246	230
Total World	**3396**	**3593**	**3731**	**3856**	**4142**	**4367**	**4608**	**4670**	**5128**	**5587**	**5494**	**5266**	**5762**	**5518**	**6603**	**6027**	**6393**	**6586**	**6644**	**7094**

(Compiled from Metal Statistics, 1967-1981)
Data Corrected for Metric Reporting

TABLE A-1-10: Consumption of Lead in the United States, 1977 (In 1000 Tons of 2000 Pounds)

Item	Consumption	Item	Consumption
Metal Products:	**1978**	**Pigments:**	**1978**
Ammunition	55,776	White Lead	2,908
Bearing Metals	9,510	Red Lead & Litharge	73,523
Brass & Bronze	16,502	Pigment Colors	14,772
Cable Covering	13,851	Other Pigments	439
Caulking Lead	9,909		
Casting Metals	3,611	**Chemicals:**	**1978**
Collapsible Tubes	1,412	Gas, Antiknock Addit.	178,331
Foil	5,286	Other Chemicals	142
Pipes, Traps & Bends	10,479		
Sheet Lead	12,626	**Misc. Uses:**	**1978**
Solder	68,390	Annealing	2,320
Storage Batteries (antimonial lead)	412,564	Galvanizing	1,630
		Lead Plating	382
Storage Batteries (oxides)	466,710	Weights & Ballasts	22,296
Terne Metal	3,778	**Unclassified:**	39,134
Type Metal	10,795		
Other Metal Pro.	---		
Total Metal	**1,101,199**		

Grand Total Consumption of Lead in United States, 1977: 1,432,944

(Compiled from Metal Statistics, 1981, page 118)

TABLE A-1-11: Uses of Slab Zinc in the United States, 1978
(In Tons of 2000 Pounds)

Use	Consumption	Use	Consumption
Galvanizing:	**1978**	**Brass Products:**	**1978**
Sheet & Strip	296,174	Sheet, Strip & Plate	77,361
Wire & Wire Rope	25,134	Rod & Wire	51,019
Tubes & Pipe	52,226	Tube	7,473
Fittings (for tube & pipe)	7,635	Castings & Billets	4,880
Structural Shapes	36,667	Copper Base Ingots	7,254
Fencing Wire Cloth & Netting	27,554	Other Copper Base Products	7,976
Other & Unspecified Uses	55,071	**Total**	**155,962**
Total	**500,461**	**Zinc Base Alloy:**	**1978**
		Die Casting Alloys	381,360
Rolled Zinc:	27,413	Dies & Rod Alloy	600
Zinc Oxide:	41,008	Slush & Sandcasting Alloy	8,402
		Total	**390,362**
Other Uses:			
Light Metal Alloys	---		
Other	42,855		

Grand Total: 1,158,061

(Metal Statistics, 1981, p. 244)

TABLE A-2-1: Producer Price Index, 1960-1982

Year	All Commodities	Non-Ferrous Metals	Year	All Commodities	Non-Ferrous Metals
1960	94.6	85.9	1971	114.0	114.6
1961	94.5	83.0	1972	119.1	116.9
1962	94.8	82.1	1973	134.7	135.0
1963	94.5	82.0	1974	160.1	187.1
1964	94.7	87.6	1975	174.9	171.6
1965	96.6	95.3	1976	183.0	181.6
1966	99.8	100.0	1977	194.2	195.4
1967	100.0	100.0	1978	209.3	207.8
1968	102.5	103.5	1979	235.6	261.7
1969	106.5	113.5	1980	268.8	260.0
1970	110.4	124.7	1981	290.0	285.0

TABLE A-2-2: Producers' Prices of Electrolytic Copper, 1960-1980

Year	Average[(1)] Price	Non-Ferrous[(2)] Metals	All[(2)] Commodities
1960	32.3	37.6	34.1
1961	30.3	36.5	32.1
1962	31.0	37.8	32.7
1963	31.0	37.6	32.8
1964	32.3	40.3	34.1
1965	35.3	37.8	36.5
1966	36.0	38.1	36.1
1967	38.1	41.1	38.1
1968	41.1	47.4	40.1
1969	47.4	56.1	44.5
1970	58.0	45.9	52.5
1971	52.0	41.2	45.6
1972	51.4	51.9	43.2
1973	59.5	65.9	44.2
1974	77.0	47.8	48.2
1975	64.5	37.2	36.9
1976	69.6	38.9	38.3
1977	69.7	36.6	34.3
1978	66.5	44.6	31.8
1979	92.7	39.5	39.3
1980	102.1	37.9	39.3

(1) Metal Statistics, 1981, page 125.
(2) Prices corrected using Producer Price Index.

TABLE A-2-3: New York Lead Prices, 1960-1980
(Reported in Cents/Pound)

Year	Average Price[1]	Non-Ferrous Metals[2]	All Commodities[2]
1960	11.95	14.1	12.6
1961	10.87	13.1	11.5
1962	9.63	11.7	10.2
1963	11.14	13.6	14.4
1964	13.62	15.5	14.4
1965	16.00	16.8	16.6
1966	15.12	15.8	15.8
1967	14.00	14.0	14.0
1968	13.21	12.8	12.9
1969	14.93	13.1	14.0
1970	15.69	12.6	14.2
1971	13.89	12.2	12.2
1972	15.34	12.9	13.1
1973	16.31	12.1	12.1
1974	22.49	12.0	14.0
1975	21.52	12.5	12.3
1976	23.10	12.7	12.6
1977	30.74	15.8	15.8
1978	33.68	16.1	16.0
1979	53.03	20.3	22.5
1980	42.91	(15.3)	(17.0)

(1) Metal Statistics, 1981, page 113.
(2) Prices corrected using Producer Price Index.

TABLE A-2-4: Prime Western Zinc Prices in New York, 1960-1980
(Reported in Real and Constant Dollars)

Year	Average[(1)] Price	Non-Ferrous[(2)] Metals	All[2] Commodities
1960	13.4	15.5	14.2
1961	12.0	14.4	12.6
1962	12.1	14.7	12.7
1963	12.5	15.2	13.2
1964	14.0	16.0	14.8
1965	15.0	15.7	15.5
1966	15.0	15.0	15.0
1967	14.3	14.3	14.3
1968	14.0	13.5	13.6
1969	15.1	13.2	14.3
1970	15.8	12.8	14.3
1971	16.9	14.7	14.8
1972	17.7	15.1	14.9
1973	20.8	15.4	15.4
1974	35.9	19.2	22.4
1975	38.8	22.6	22.2
1976	37.3	20.5	20.3
1977	35.2	18.0	18.1
1978	31.3	15.0	15.0
1979	37.7	14.4	16.0
1980	(38.0)	(13.6)	(15.2)

(1)Metal Statistics, 1981, page 245.
(2)Prices corrected using Producer Price Index.

TABLE A-2-5: World Refined Copper Consumption, 1960-1979
(Reported in 1000 Tons of 2000 Pounds)

Location	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
US	1279	1425	1521	1579	1682	1855	2239	1595	1706	1913	1816	2016	2235	2444	2196	1538	1992	2187	2403	2463
Canada	117	141	151	169	202	224	262	219	250	226	237	242	246	273	297	203	227	241	275	268
Total America	**1496**	**1670**	**1772**	**1852**	**2042**	**2241**	**2641**	**1814**	**2086**	**2280**	**2184**	**2503**	**2765**	**3022**	**2868**	**2080**	**2624**	**2861**	**3092**	**3239**
Total Europe	2659	2707	2625	2729	2974	3054	2935	2799	2315	2527	2700	2607	2720	2918	2952	2650	2894	3053	3103	3125
Japan	335	351	288	338	504	477	531	679	766	888	903	888	1048	1324	915	900	1157	1242	1367	1466
Total Asia	**405**	**420**	**365**	**423**	**578**	**549**	**603**	**753**	**811**	**943**	**956**	**1007**	**1180**	**1477**	**1064**	**1000**	**1348**	**1461**	**1614**	**1754**
Africa	32	33	28	41	52	48	40	33	40	36	44	65	73	95	101	95	84	84	95	103
Australia	76	55	70	79	97	88	104	78	88	94	105	122	113	137	137	108	133	119	129	142
World Total	**4843**	**5053**	**5044**	**5333**	**6035**	**6257**	**6615**	**5829**	**6464**	**7093**	**7302**	**8098**	**8798**	**9681**	**9258**	**8211**	**9408**	**9958**	**10501**	**10890**

(Compiled from Metal Statistics, 1967, page 109; 1972, page 109; 1976, page 92; 1981, page 77)
Data Corrected for Metric Reporting

TABLE A-2-6: World Consumption of Lead, 1960-1979
(Reported in 1000 Tons of 2000 Pounds)

Location	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
US	581	695	732	730	739	717	814	779	857	942	880	916	986	1042	1162	903	1045	1145	1076	1477
Canada	44	48	52	54	58	62	71	65	66	74	53	56	64	66	69	61	68	72	75	134
Total America	**710**	**835**	**885**	**901**	**920**	**922**	**1021**	**987**	**1073**	**1179**	**1105**	**1167**	**1234**	**1361**	**1456**	**1176**	**1324**	**1449**	**1395**	**1930**
Total Europe	1045	1071	1124	1142	1155	1166	1190	1172	1204	1335	1396	1296	1371	1462	1570	1325	1488	1550	1498	1833
Africa	23	23	23	22	27	28	28	31	42	40	42	46	45	54	63	82	70	79	92	93
Australasia	41	33	35	54	52	43	47	49	45	49	40	44	49	74	87	89	93	94	90	90
USSR	358	363	368	363	386	400	420	460	469	490	515	530	540	560	694	683	683	683	705	860
World Total	**2590**	**2731**	**2842**	**2928**	**3073**	**3097**	**3247**	**3330**	**3482**	**3802**	**3904**	**3909**	**4104**	**4427**	**4870**	**4348**	**4719**	**4970**	**4968**	**6039**

(Compiled from Metal Statistics, 1967, page 202; 1974, page 166; 1981, page 117)
Data Corrected for Metric Reporting

TABLE A-2-7: World Consumption of Zinc, 1960-1979
(Reported in 1000 Tons of 2000 Pounds)

Location	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
US	877	931	1031	1105	1207	1343	1410	1236	1333	1368	1164	1259	1428	1502	1286	924	1132	1099	1157	1099
Canada	53	63	70	79	103	104	107	110	124	127	117	122	137	168	155	157	160	147	162	172
Total America	**1001**	**1076**	**1198**	**1274**	**1423**	**1564**	**1641**	**1464**	**1577**	**1611**	**1409**	**1499**	**1692**	**1957**	**1719**	**1338**	**1562**	**1522**	**1650**	**1639**
Total Europe	1212	1240	1258	1240	1374	1374	1315	1320	1404	1156	1088	1027	1146	2003	1957	1468	1672	1702	1846	1881
Asia	274	342	340	423	491	442	505	584	658	747	757	757	834	1158	992	856	1083	1116	1240	1347
Africa	25	27	28	33	37	38	53	55	47	49	54	65	65	96	109	106	109	102	128	127
Australia	103	87	94	106	124	110	103	116	105	102	91	93	93	123	133	83	88	81	96	109
USSR	413	413	396	407	435	440	453	488	490	560	565	580	615	700	990	990	1025	1040	1090	1100
World Total	**3324**	**3513**	**3626**	**3809**	**4244**	**4355**	**4471**	**4499**	**4762**	**5246**	**5043**	**5168**	**5662**	**6924**	**6575**	**5549**	**6273**	**6318**	**6838**	**6978**

(Compiled from Metal Statistics, 1967, page 349; 1976, page 279; 1974, page 312; 1981, page 248)
Data Corrected for Metric Reporting

TABLE A-2-8: Domestic Copper Smelter Capacity, 1960-1980
(Reported in 1000 Tons of 2000 Pounds)

Year	Capacity Tons/Year Concentrate	Year	Capacity Tons/Year Concentrate
1960	8700	1971	8821
1961	8700	1972	8821
1962	8623	1973	8496
1963	8423	1974	8626
1964	8423	1975	8611
1965	8371	1976	9258
1966	8371	1977	9013
1967	8383	1978	8962
1968	9079	1979	8962
1969	8689	1980	8213
1970	8704		

(Compiled from Non Ferrous Metal Statistics, 1960-1980)

TABLE A-2-9: Domestic Copper Capacity (Reported in 1000 Tons of 2000 Pounds)

Year	Electrolytic Refinery	Total	Year	Electrolytic Refinery	Total
1960	1800	2300	1971	2425	2793
1961	1860	2341	1972	2385	2723
1962	1963	2334	1973	2512	2850
1963	1963	2334	1974	2512	2850
1964	1993	2334	1975	2771	2909
1965	2010	2420	1976	2771	2909
1966	1995	2430	1977	2592	2930
1967	2117	2522	1978	2572	3104
1968	2278	2643	1979	2404	2936
1969	2308	2676	1980	2180	2661
1970	2308	2676			

(Compiled from Non Ferrous Metal Data, 1960-1980)

TABLE A-2-10: U.S. Secondary Lead Production
(Reported in 1000 Tons of 2000 Pounds)

Year	Pig Lead	Lead in Alloys	Total Lead	Year	Pig Lead	Lead in Alloys	Total Lead
1960	148	321	469	1970	159	438	597
1961	140	312	452	1971	150	446	596
1962	118	325	444	1972	173	443	616
1963	134	358	493	1973	186	468	654
1964	149	392	541	1974	238	460	698
1965	181	393	575	1975	271	387	658
1966	156	416	572	1976	311	415	726
1967	150	403	553	1977	334	500	835
1968	138	412	550	1978	282	486	769
1969	154	449	603	1979	352	449	801

(Compiled from Metal Statistics, 1974, page 164; 1981, page 121)

TABLE A-2-11: Slab Zinc Production Capacity and Output, 1960-1979
(Reported in 1000 Tons of 2000 Pounds)

Year	Total Capacity	Actual Production	% Unused Capacity	Year	Total Capacity	Actual Production	% Unused Capacity
1960	1260	867	31	1970	1296	961	26
1961	1270	896	29	1971	1071	840	22
1962	1278	940	26	1972	1034	765	26
1963	1329	953	28	1973	715	687	4
1964	1326	1030	22	1974	749	590	21
1965	1338	1078	19	1975	719	446	38
1966	1337	1110	17	1976	703	535	24
1967	1367	1010	26	1977	742	434	41
1968	1373	1083	21	1978	847	445	47
1969	1350	1149	15	1979	847	595	30

(Compiled from Metal Statistics, 1967, page 345; 1974, page 309; 1981, page 243)
Corrections Made for Metric Reporting

TABLE A-2-12: U.S. Copper Imports, 1960-1980
(Reported in 1000 Tons of 2000 Pounds)

Year	Ore & Concentrate	Blister	Refined	Total
1960	80	298	142	524
1961	47	340	67	458
1962	43	331	99	478
1963	48	369	119	539
1964	52	390	138	584
1965	37	332	137	519
1966	45	348	163	577
1967	34	267	328	637
1968	34	270	405	716
1969	39	237	131	410
1970	33	224	132	391
1971	31	157	162	355
1972	55	157	189	410
1973	43	153	195	407
1974	56	208	304	593
1975	76	87	146	320
1976	89	44	380	536
1977	56	45	391	506
1978	33	81	456	585
1979	25	75	237	353
1980	(16)	(52)	(505)	(591)

(Compiled from Metal Statistics, 1974, page 123; 1981, page 82)

TABLE A-2-13: Copper Exports form the U.S., 1960-1980
(Reported in 1000 Tons of 2000 Pounds)

Year	Unrefined	Refined & Scrap[1]	Total
1960	11	492	503
1961	5	468	472
1962	2	349	351
1963	1	325	326
1964	5	361	366
1965	15	358	372
1966	2	233	293
1967	60	177	237
1968	86	274	360
1969	5	207	212
1970	69	238	307
1971	36	206	242
1972	26	200	226
1973	31	231	262
1974	22	168	190
1975	10	217	227
1976	18	150	168
1977	24	91	115
1978	31	163	194
1979	57	144	201
1980	(122)	87	(209)

[1]Computed by difference.

(Compiled from Metal Statistics, 1981)

TABLE A-2-14: U.S. Lead Imports and U.S. Lead Exports, 1960-1980
(Reported in 1000 Tons of 2000 Pounds)

LEAD IMPORTS			
Year	**Total Lead Content**	**Year**	**Total Lead Content**
1960	359	1970	364
1961	409	1971	256
1962	402	1972	263
1963	389	1973	280
1964	340	1974	214
1965	348	1975	193
1966	432	1976	224
1967	488	1977	342
1968	424	1978	312
1969	389	1979	240

	LEAD EXPORTS	
Year	**Pigs Bars**	**Total Lead**
1960	1.9	4.5
1961	2.1	8.3
1962	2.1	4.5
1963	1.1	3.5
1964	10.1	2.3
1965	7.8	12.0
1966	5.4	9.3
1967	6.5	6.9
1968	8.3	9.3
1969	5.0	7.3
1970	7.3	12.0
1971	5.9	23.0
1972	8.4	44.0
1973	67.0	130.0
1974	62.0	120.0
1975	21.0	71.0
1976	5.9	53.0
1977	4.7	90.0
1978	2.7	110.0
1979	6.3	140.0
1980	(110.0)	(240.0)

(Compiled from Metal Statistics, 1974, page 167;
1981, page 119)

TABLE A-2-15: U.S. Imports of Zinc, 1960-1980
(Reported in 1000 Tons of 2000 Pounds)

Year	Zinc Ore	Blocks, Slabs, and Pigs	Total
1960	457	122	579
1961	416	128	544
1962	467	141	609
1963	372	145	518
1964	357	118	425
1965	428	153	586
1966	521	278	806
1967	534	222	762
1968	543	307	857
1969	602	329	939
1970	525	270	806
1971	342	319	670
1972	254	522	783
1973	199	592	791
1974	240	539	788
1975	145	380	525
1976	97	714	811
1977	123	577	699
1978	228	750	979
1979	247	581	828
1980	---	---	est./456

(Compiled from Metal Statistics, 1981)
Data Modified to Correct for Metric Reporting

TABLE A-2-16: U.S. Exports of Zinc, 1960-1981
(Reported in 1000 Tons of 2000 Pounds)

Year	Blocks, Slabs, and Pigs	Total	Year	Blocks, Slabs, and Pigs	Total
1960	75.1	88	1971	13.3	13
1961	50.0	58	1972	4.3	11
1962	36.1	44	1973	14.3	39
1963	33.8	42	1974	19.0	63
1964	26.5	35	1975	6.9	29
1965	5.9	18	1976	3.5	24
1966	1.4	34	1977	1.2	18
1967	16.8	28	1978	1.3	34
1968	33.0	57	1979	---	57
1969	9.3	49	1980	n/a	est./35
1970	---	29	1981	n/a	est./35

n/a = not available

(Compiled from Metal Statistics, 1981, page 253)
Data Corrected for Metric Reporting

TABLE A-3-1: Fourteen Leading U.S. Copper Producers, Long-Term Debt-Equity Ratios, 1969-1978

Companies	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Kennecott Copper Corp.	17	15	26	22	16	15	28	38	36	44
Phelps Dodge Corp.	12	13	23	24	34	36	58	62	62	74
Newmont Mining Corp.	11	24	42	45	38	32	38	44	51	47
ASARCO, Inc.	3	3	5	7	11	13	40	46	48	36
AMAX, Inc.	33	38	56	63	50	41	39	40	41	33

(Source: Tomimatsu, 1981)

TABLE A-3-2: U.S. Copper Producers, Return on Shareholders' Equity, 1969-1978
(Percent)

Companies	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Kennecott Copper Corp.	15.62	13.28	7.26	3.99	12 72	15.32	1.52	0.62	0.52	0.36
Phelps Dodge Corp.	15.73	17.96	11.04	11.26	13.93	14.25	5.19	4.60	2.02	3.41
Newmont Mining Corp.	18.18	19.05	11.75	9.29	19.60	18.90	8.22	7.50	.79	5.41
ASARCO, Inc.	16.41	15.60	5.45	6.89	15.46	15.36	2.99	5.00	(3.54)	5.67
AMAX, Inc.	15.27	11.69	7.85	9.77	14.21	15.95	11.59	10.24	4.20	8.88

(Source: Tomimatsu, 1981)

TABLE A-3-3: Fourteen Leading U.S. Copper Producers, Return on Invested Capital, 1969-1978
(Percent)

Companies	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Kennecott Copper Corp.	14.74	13.05	7.71	4.85	12.12	14.41	3.23	2.90	2.76	3.54
Phelps Dodge Corp.	15.13	16.82	10.40	10.65	12.30	12.61	6.36	6.01	4.59	5.59
Newmont Mining Corp.	17.68	16.58	9.54	8.13	16.32	16.10	8.37	7.46	2.95	6.72
ASARCO, Inc.	15.68	15.24	5.46	7.03	15.11	14.87	4.38	6.19	.55	7.05
AMAX, Inc.	11.22	8.87	6.12	6.83	9.40	10.53	9.03	8.34	5.61	9.81

(Source: Tomimatsu, 1981)

TABLE A-3-4: Ownership and Status of Major Japanese Smelters

Owner	Location	Built	Renovation	Capacity
Furukawa Mining	Ashio	1877	1956, 1962	40
Nippon Smelting	Hitachi	1908	1956, 1971	150
Dowa Mining	Kosaka	1900	1967	60
Mitsubishi	Naoshima	1918	1969, 1974	200
Onahama	Onahama	1965	1971	270
Nippon Mining	Saganoseki	1915	1970	150
Hibi Kyodo Smelting	Tamano	1972	---	80
Sumitomo Metal	Toyo	1971	---	120

(Source: Rosenbaum, 1976)

APPENDIX B: THE SMELTER CONTRACT

APPENDIX B: THE SMELTER CONTRACT

The following discussion has been excerpted from Mine Development Monthly, April 1981.

Smelter contracts are complex: the value of a contract is determined not only by the processing charges but also by deductions for metal losses, differing arrangements for how the metal price ruling the contract is determined, provisions for the smelter's participation in metal price movements, and penalties and credits for deleterious materials and by-products. Understanding how the value of smelter contracts is determined is extremely important not only for concentrate sales negotiations, but also for arriving at realistic cost projections for mine feasibility studies.

In the following sections a "typical" smelter contract is reviewed clause by clause and common features of lead and zinc contracts are also discussed. A sample is included at the end of this summary. Each component is discussed below.

The Material

Copper concentrates will typically contain from 22% to 30% copper with iron and sulfur the other major constituents. Zinc concentrates typically run 48% to 60% zinc with iron, sulfur, and often some lead. Lead concentrates typically grade 55% to 75% lead, with some zinc or silver.

Treatment Charge

In the case of both copper and lead, the "treatment charge" refers to the charges for smelting the material. Copper and lead undergo further refining steps, which carry an additional charge. In the case of zinc, the treatment charge covers all processing costs from concentrate through to refined metal. Treatment charges are quoted for material delivered to the smelter, meaning that the miner must bear the costs of freight. Typical ranges of treatment charges for standard concentrates are as follows:

Copper:	\$65 - \$70/mt	
Lead:	\$85 - \$150/mt	with many in the \$110 - \$120 range
Zinc:	\$90 - \$135/mt	with many in the \$90 - \$110 range

Pricing

For copper and lead, the U.S. Producer Price is most often used in the United States and the LME quote for imports and businesses outside the United States. For zinc, the U.S. Producer Price is used within the United States and the European producer prices is used outside the United States.

All of the metal contained in concentrate, as determined by the smelter's assay, is not paid for. This reflects the smelter's need to account for inevitable losses of metal in processing, as well as in some cases, providing another source of income.

Deductions can be either unit deductions or percentage payment deductions. Unit deductions are percentage points deducted from the assay grade. Copper deductions are usually 1.0 to 1.2 points.

Percentage payment deductions are often taken after some unit deductions have been made. Some U.S. copper smelters deduct one unit, then pay for 97.5% of the remainder. Lead is usually paid for on 95% of contained material. Zinc smelters use an interesting combination. Smelters usually pay for 85% of the contained zinc with a minimum relative eight unit deduction. This limit penalizes lower grade material.

Quotational Period

Concentrate buyers try to have the price basis on which they pay the miner as close as possible to the price basis on which they sell the metal. This is usually the third month after the month that the material arrives at the smelter.

Payment Terms

Payment may not be made until the material is sold or in some cases, 70% to 90% is paid upon arrival of the material to the smelter and the rest when the metal is sold or 90 days after arrival. This point is subject to negotiation.

Credits

The most commonly credited by-products are gold and silver. Credits may be given for zinc or lead or they may be penalized. Credits are sometimes paid in lower treatment charges.

Penalties

Penalty charges vary depending on the smelter and are applied to those elements that the process, product, or emission requirements make uneconomic. These include arsenic, bismuth, or antimony. There may also be limits on moisture, mercury, nickel, and other trace metals.

Escalation Clause

For longer term contracts there is usually some provision for price increases. These may be direct pass-through of costs, fixed percentages, or tied to some index of goods and services.

Participation

This clause allows the smelter to participate when there is an increase in the prices of the metals by tying the price to a specific formula. The charges may also be reduced as price goes down, but at a slower rate than the increase.

A HYPOTHETICAL COPPER CONCENTRATE CONTRACT

Assays:	Copper 26%, Gold 0.15 oz/dmt, Silver 2.4 oz/dmt
Quantity:	20,000 wmt quarterly. Ex Canada
Delivery:	CIF Yokohama
Treatment Charge:	$65/mt
Refining Charge:	8¢/lb of payable copper content
Pricing:	Copper less one unit, at the LME monthly wirebar settlement
Quotational Period:	Month of scheduled shipment
Payment:	90% thirty days after arrival, balance upon finalization of assays
Credits:	Gold less 0.03 oz, pay for 95% less $5/oz; Silver less 1.0 oz, pay for 95% less 25¢/oz
Penalties:	Arsenic $1.00 for every 0.10% over 0.50%; Bismuth $1.50 for every 0.10% over 0.10%; Antimony $1.50 for every 0.10% over 0.50%
Escalation:	7% per annum (with the fifth shipment)
Participation:	Add 10% of every 1¢ copper price goes over $1.00 to the refining charge
Length:	Two years starting April 1981