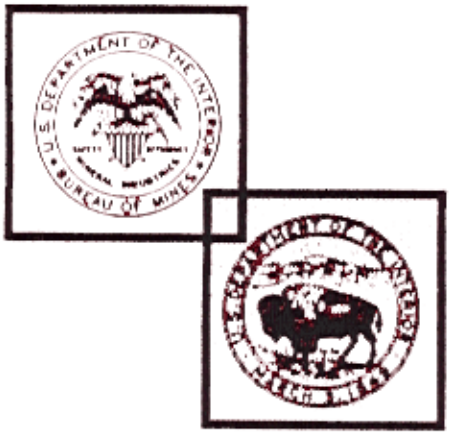
OFR 72-92

OPEN FILE REPORT/1992
BUREAU OF MINES

MATERIALS FLOW OF ZINC IN THE UNITED STATES 1850-1990



UNITED STATES DEPARTMENT OF THE INTERIOR

OFR# 72-92 5-6-92

Materials Flow of Zinc in the United States 1850-1990

By James H. Jolly

April 1992

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Materials Flow of Zinc in the United States 1850-1990

By James H. Jolly [1]

*** ABSTRACT

Although zinc in the environment is generally considered to be beneficial or benign, excessive amounts can cause deterioration of environmental quality and toxicity problems for some plants and animals. High amounts of zinc in the environment are often associated with anthropogenic activities, mainly those involving zinc production and consumption and those related to the use and disposal of zinc-containing products. To obtain some upper limit parameters on the historical quantities of zinc that may have entered the U.S. environment from anthropogenic sources, the Bureau of Mines conducted a materials flow study of zinc from the earliest beginning of the domestic industry through 1990 and for the year 1989. For comparative purposes a generalized historical materials flow of zinc for the world was also prepared.

The United States was the world's leading producer and consumer of zinc in the 1850-1990 period. In that period, U.S. mines and smelters produced 15% and 20%, respectively, of world output, and U.S. zinc consumption accounted for about one-fourth of the world total. Maximum zinc losses into the environment related to the above production, consumption, and disposal of end use products total about 63 million tons. Dissipative uses and landfill disposal have accounted for about 73% of the potential zinc losses to the environment, followed by mining and smelting 22%, and manufacturing, 5%. At the end of 1990, contained zinc in useful end-products in the United States was estimated to be about 23 million tons. In 1989 slightly more than 1 million metric tons of zinc in new zinc-containing products were added to the

domestic pool of zinc in use but in the same year, an estimated 0.9 million tons was dissipated and discarded, indicating only small net gains to the zinc pool of use annually.

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*** INTRODUCTION

Zinc is an ubiquitous element occurring in all rocks in the earth's crust and is a trace constituent in the oceans and atmosphere. Zinc is the 23rd most abundant element in the earth's crust and is estimated to have an average crustal abundance of about 80 parts per million or 0.008%. Based on this average, the amount of zinc in a cubic mile of crustal rock would total a surprising one million metric tons. Zinc is also ubiquitous in modern societies, being found in all sectors of the economy in numerous everyday items. It is widely recognized as one of the most important trace elements in plant and animal growth and nutrition, and currently finds widespread use in fertilizers, animal feed and vitamin supplements. Zinc has also been identified as a toxic agent to some plant and animal species, mainly those found in aquatic systems.

Natural processes--weathering, erosion, forest fires, and volcanic activity--add to and redistribute each year large tonnages of zinc in the general environment but, rarely is the concentration of zinc from these sources-high enough to affect the biota. Zinc derived from anthropogenic sources--agriculture, sewage, industrial production, mining and metallurgy--is also large and can be widely dispersed (by wind and water), but most tends to be localized near its production, use or disposal source. Thus, the higher zinc loadings in the environment, outside of naturally occurring geochemically zinc-rich areas, are those associated with anthropogenic activities, mainly those related to process losses and waste products generated by mining, metallurgical, and zinc-consuming operations and to sites associated with metal corrosion, dissipative use and end-use product disposal.

Throughout history, mankind has mined ores for zinc containing an estimated 350 million tons of zinc. From this output, about 270 million tons was produced as refined zinc, whereas about 80 million tons was returned to the environment in the form of mining and smelter wastes. An estimated 60% of the total refined zinc produced/consumed throughout history has likely been lost, buried, dissipated and/or corroded away; in essence this zinc can be considered to have reentered the earth's geochemical cycle. The remainder, about 110 million tons, is estimated to remain in the pool of use. The above estimates are to a large extent based on the fact that 70% of the world's zinc production and consumption has occurred since 1950 and almost 50% since 1970.

The return of anthropogenic zinc to the Earth's general environment has been large. The United States, having been the world's largest producer and consumer of zinc, also has returned large amounts of zinc back into its general environment. Because of increasing environmental concerns with zinc wastes from zinc production, use and ultimate disposal, the Bureau of Mines conducted a preliminary study to gain a better understanding of environmental zinc losses associated with the industrial flow of zinc in the United States. The principal effort was a historical assessment to place upper limits on losses from major point sources since the early beginnings of the domestic zinc industry. Site-specific information is not available but maximum losses associated with zinc mining and smelting by State are listed. A somewhat similar assessment of domestic zinc losses in the flow for the year 1989 is given in the Appendix B. A generalized view of the historical world flow of zinc and associated losses from the production and consumption of zinc since 1800 is given in Appendix C. No attempt was made to evaluate zinc losses from activities outside the areas traditionally associated with zinc production, consumption, use, recycling and disposal. Losses associated with the mining

and burning/smelting of coal and ores in which zinc is not sought were not included in the historical study but were added to the 1989 assessment to provide the reader some idea of potential zinc losses to the environment from these sources.

*** ACKNOWLEDGMENTS

The author would like to thank Dr. Jerome F. Cole, President, and Dr. Craig J. Boreiko, Manager Environmental Health of the International Lead and Zinc Research Organization, Inc., Research Triangle Park, NC; Michael L. Deelo, Director of Marketing, Zinc Corporation of America, Monaca, PA; Thomas A. Phillips, Bureau of Mines, Salt Lake City Research Center, Salt Lake City, UT; and Carl A. Difrancesco, Division of Minerals Availability, Bureau of Mines, Denver, CO, for reviewing the report and providing valuable suggestions.

*** HISTORICAL PERSPECTIVE OF THE WORLD AND U.S.

ZINC INDUSTRIES

Zinc is the fourth most widely used metal after iron, aluminum, and copper, yet through most its history, zinc was not known as a distinct metal. Zinc has been found in bronze artifacts made 5,000 years ago and has been used as a component of brass in Europe and Asia for more than 2,000 years. Although a few artifacts composed mainly of zinc metal have been dated back to 500 B.C., the extreme scarcity of such items before A.D. 500 suggests the metal was made by accident or the technology was short lived and forgotten. In the 6th century, A.D., the Chinese are known to have produced articles of zinc metal and are generally credited with being the first to develop the technology to make zinc metal. Zinc was smelted in the Zawar area of India as early as 1000 A.D. and was produced there on a relatively large scale beginning in the 13th century. Europeans were apparently unfamiliar with zinc metal until the 16th century, even though they had used earthy forms of zinc compounds for many years to make brass.

Uses before zinc metalmaking involved the naturally occurring zinc minerals and oxidic zinc materials resulting from smelting lead and copper ores. Zinc's presence in early bronze was most likely accidental and dependent on the ores used, whereas, zinc compounds were recognized and were deliberately mixed with copper to produce brass by the cementation process. Some cosmetics and medicines of ancient Egypt contained appreciable amounts of zinc carbonate and/or zinc oxide.

The technology of smelting zinc is thought to have been brought to Europe from Asia around 1730, and in the early 1740's the first European zinc smelter was erected in England. By the end of the 18th century, large-scale commercial smelting had began in Europe, mainly as a result of improved distillation methods utilizing horizontal muffles of large capacity. Zinc distillation by the Belgian method or by numerous small horizontal retorts externally heated in a single furnace followed within a few years. The Belgian method gained widespread acceptance and was the principal production method for the next 100 years.

In the United States, the first zinc metal was produced in 1835 at the Arsenal in Washington, D.C. The Government brought in workers from Belgium to build and operate a small spelter furnace to produce zinc from zincite ore from New Jersey. The primary purpose for the zinc produced was to provide alloying metal to make brass for the manufacture of U.S. standard units of weights and measures.

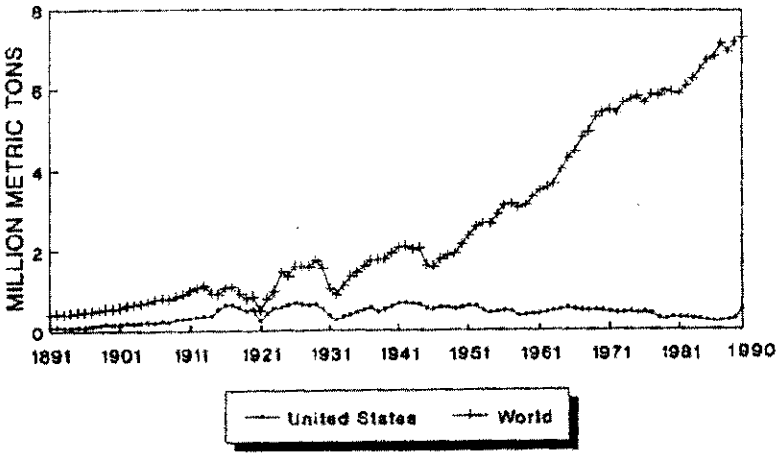
The U.S. zinc mining industry commercially began about 1850 with production of oxides and compounds from zinc ores in New Jersey and Pennsylvania. In 1860 smelters were built in Illinois and New Jersey to produce metal from nearby ores. By the turn of the century, U.S. zinc smelting activity had grown rapidly, mainly developing in Illinois, Kansas, Missouri and Pennsylvania because of closeness to zinc ores and coal or natural gas for smelting fuel. The discovery of low-cost natural gas in Kansas in the mid-1890's led to increased smelting in that State and made Kansas the leading zinc-producing State by 1899. The development of mineral flotation processes early in the 20th century made it possible to recover zinc from fine-grained and complex ores and to produce high-grade concentrates. This led to zinc production in many areas of the United States.

World zinc metal production was centered in Europe in the 18th and 19th centuries; however, toward the end of the latter century, U.S. zinc production had risen substantially, resulting in a second major world production center. By 1901 the United States had become the leading world zinc producer, a position held for most of the next 70 years. After World War I, a number of countries, including Australia, Canada, Japan and the U.S.S.R., began development of substantial zinc smelting industries. Despite increased zinc production elsewhere, Europe, except during the two World War periods, and the United States continued to be the main zinc smelting centers, in part because they also were the large zinc consuming areas. From the late 1960's U.S. zinc production declined because numerous smelters closed for environmental, economic and technical reasons, resulting in the reduction of U.S. zinc smelter capacity to one-third its former level.

Trends over the past 100 years in U.S. and world zinc mine and smelter production are shown in Figures 1 and Figures 2, respectively. For the most part, the trends are similar. U.S. mine and smelter output of zinc was dominant in the world until after World War II, but proportionally declined thereafter, owing largely to new production in many foreign countries. Despite production decreases in recent decades, the United States, cumulatively, has accounted for more of the world's zinc mine and smelter output than any other country and, also, has been the leading consumer.

FIGURE 1

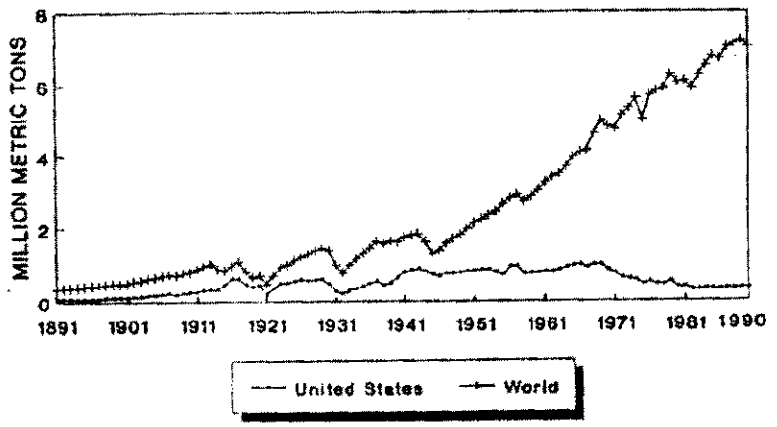
U.S.[1] AND WORLD ZINC MINE PRODUCTION



[1]Recoverable content.

FIGURE 2

SLAB ZINC PRODUCTION UNITED STATES AND WORLD



*** MATERIAL FLOW OF ZINC IN THE UNITED STATES

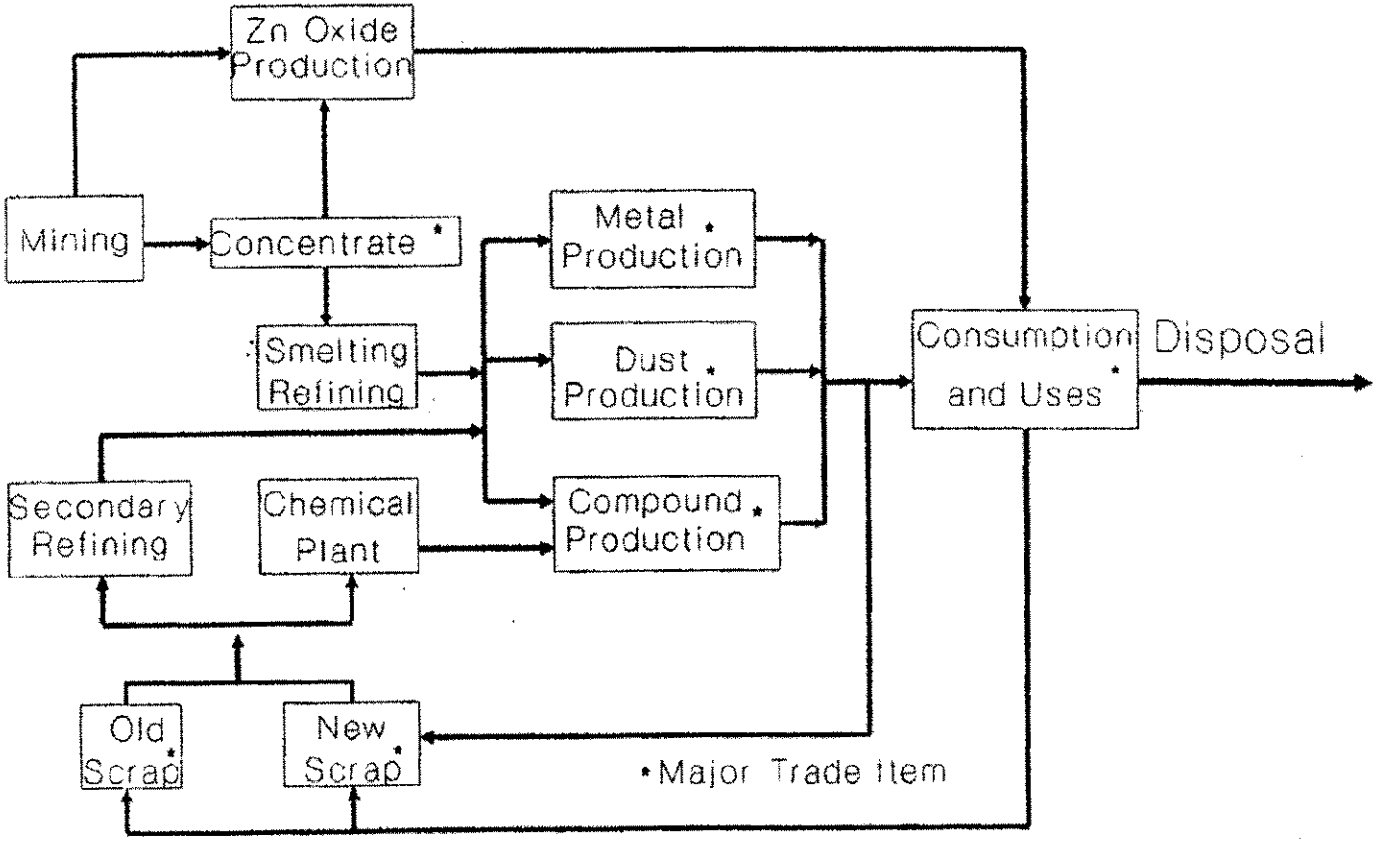
The principal relationships of zinc production, consumption, recycle and disposal in the U.S. economy are shown in figure 3. These relationships essentially have remained unchanged since the early years of the U.S. industry; however the relative importance, technology, and associated zinc losses to the environment of the various sectors may have changed significantly.

Zinc has been mined in 30 States at several thousand mining sites. Most production has come from long-producing mining districts discovered in the 19th century, but in recent years production has shifted to newly discovered districts in Alaska, Missouri, and Tennessee. Several hundred mining operations typically have accounted for annual zinc production throughout most of the industry's history, but in recent years, fewer than 25 mines have accounted for virtually all domestic zinc output. Since 1850 New Jersey has yielded the most zinc, followed by Oklahoma, Tennessee, Missouri and Idaho. Zinc is no longer mined in New Jersey and Oklahoma, the two States with the largest output, overall.

Mine activity can result in substantial zinc loading of the environment but is largely a local phenomenon occurring mainly in the form of zinc-bearing waste rock, ore spilled or wind-blown during handling and transport and discharged mine waters. Each of these contamination sources may or may not be environmentally significant for any given mine operation.

Waste rock can be dumped on surface, used for mine backfill or consumed as construction or agricultural materials. Surface-dumped waste rock including piles leached for copper and the like, rarely results in zinc levels exeeding permissible amounts or that of the local soil and bedrock. Exceptions to above however occurred mainly in the early years of the U.S. mining industry

Figure 3.- Zinc Flow Diagram



when zinc's presence in mixed ores was more hinderance than advantage and in operations where lower-grade, zinc mineralized rock was mined as waste to get at higher-grade ore. Nonetheless, because zinc minerals tend to be leached slowly from waste rock and tailings, zinc concentrations tend to be low and present few problems. Once solubilized, zinc tends to become fixed in soil and clay minerals, to react with carbonate or silica minerals to form stable compounds, or to be diluted in water systems to permissible levels. Similarly, wind-blown dusts from tailings and waste piles may cause problems but rarely are problems directly associated with the zinc content of the dust.

Ore milling and concentration of valuable constituents can be a major source of environmental zinc loading. Tailings, the solid waste product after most of the valuable minerals in an ore have been extracted, is, by far, the largest contributor. As in the case of mine waste rock, zinc mill tailings are largely confined to the mine and/or mill site and are disposed of in surface ponds, used for mine backfill, and consumed for construction and agricultural purposes. Concentrates of other metals, mainly lead, that are produced from mixed ores containing zinc, often are a major source of zinc losses when the concentrates are smelted. Lead smelter slags have yielded up to 100,000 tons of zinc per year by slag fuming; but prior to 1927 and after 1984 no zinc was recovered by slag fuming in the United State. Presently in the United States, millions of tons of lead smelter slags containing 5% to 20% zinc are present at operating smelters and at former lead smelter sites.

Since 1850 numerous domestic zinc smelters in 17 States have processed an estimated 61 million tons of zinc contained in ores and concentrates to produce slab zinc and zinc compounds, mainly American-process zinc oxide. Losses in smelting and refining have been primarily in the form of slags, residues and dusts. Pennsylvania has been the largest metal-producing State.

Other principal metal-producing States, in decreasing order of output, were Illinois, Oklahoma, Montana, and Texas. A breakdown of ore-sourced zinc compound production by State is not available but Pennsylvania, followed by Illinois, Kansas, and Ohio were the leading producing-States of American-process oxide.

Horizontal retort smelters accounted for all domestic zinc metal production until the first electrolytic zinc smelter came on-stream in 1915. In the early 1930's the first vertical retort smelters came on stream. Thereafter, primary zinc metal was produced by all three production methods, but overall, horizontal retort smelters, by far the least efficient in term of zinc recovery, have accounted for the most zinc output. Of 14 smelters operating in 1968, 11 permanently closed, leaving only 3 of the original smelters--2 electrolytics and 1 electrothermic (a type of vertical retort)--in operation. These, plus a new "greelfield" electrolytic smelter built in the late 1970's were the only U.S. smelters operating in 1990. Large tonnages of zinc-containing slags and residues (in total) remain at some of the plant sites of the recently closed smelters and at sites of some long closed smelters.

Domestic mining and smelting accounted for virtually all of U.S. needs for basic zinc products (metal, dust and compounds) up to World War II. During and after the War up to the early 1970's the United States continued to be largely self sufficient in the production of basic zinc products but large quantities of zinc concentrate had to be imported to meet smelter feed requirements.

With the decline of the U.S. zinc smelting industry beginning in the late 1960's the United States fell from near self sufficiency in basic zinc products production to one requiring large imports, mainly metal.. The opening

of several new zinc-producing mines in the past few years has reversed the downtrend in U.S. zinc mine output and, in 1990, output rose to former high production levels. Ironically, because of deficient domestic smelter capacity, the United States in 1990 became, for the first time, a major world exporter of zinc concentrate, but at the same time, continued to be the world's largest importer of basic zinc products.

Ore-sourced domestic zinc oxide production also underwent profound change since its initial production in the early 1850's. Because the ore-sourced zinc oxide process was developed in the United States, this production method became known as the American-process or direct method. Until the New Jersey Zinc Company began French-process zinc oxide production (made by melting and vaporizing metal) in 1893, all U.S. output was American-process. Thereafter both types were produced, but American-process overwhelmingly dominated French-process production in the United States until the last few decades. In 1987, the last domestic ore-sourced zinc oxide plant closed down. Virtually all of the "consumed as ore" category listed in Appendix A represents American process zinc oxide production. Only a few thousand tons of zinc sulfate production fell in this category in 1990.

Recycled zinc is derived from new and old scrap. New scrap is mainly generated when basic zinc and semimanufactured products are consumed or used in a manufacturing process. Old scrap is entirely derived from recycled, obsolete and discarded end products. New scrap consists mostly of drosses, skims, furnace dusts, and residues from galvanizing and diecasting operations, brass mills, and chemical plants, and clippings resulting from the processing (stamping, triming, etc.) of galvanized steel sheet and strip, rolled zinc, and brass sheet. Old zinc scrap has historically consisted almost entirely of diecastings, rolled zinc items and brass products. Only in the past few years

has any zinc been recovered from new and old galvanized steel scrap or from discarded rubber tires. Recovery from used tires is small but recovery from galvanized products has risen dramatically. In tonnage terms, new and old galvanized steel scrap has become the third largest source of secondary zinc after brass scrap and dross.

Zinc materials made from zinc scrap are slab zinc, alloys, dusts, and compounds. Brass scrap, on the other hand, is typically remelted and, with alloy adjustment, is recast as brass. Zinc chloride and sulfate compounds are produced largely by acid leaching of skims, drosses, and residues.

An estimated 4 million tons of refined zinc metal was produced in the 1859-1990 period from secondary materials at primary and secondary smelters in the United States. Secondary slab zinc production has accounted for only 7% of the total historical U.S. refined metal output, although percentagewise it has increased as a portion of total slab zinc output in the last few decades, mainly owing to decreased primary metal production. In 1990, secondary slab zinc accounted for one-fourth of U.S. metal production. The trends and sources of U.S. slab zinc production over the last 100 years are shown in Figure 4.

The United States has been the world's largest zinc-consuming country since the early 1900's. U.S. zinc consumption was about 14% of the world total in 1990; but, cumulatively since 1850, the United States has accounted for an estimated one-fourth of the total world consumption. Figure 5 shows the 100-year trend in U.S. zinc consumption and the component sources of consumption. Slab zinc produc ed from secondary materials is included in "slab zinc" and excluded from "secondary zinc" in Figure 5.

A breakdown of the basic use areas of U.S. slab zinc consumption for the last 90 years is given in Figure 6. Galvanizing has been the largest consumer

FIGURE 4

U.S. SLAB ZINC PRODUCTION PRIMARY AND SECONDARY

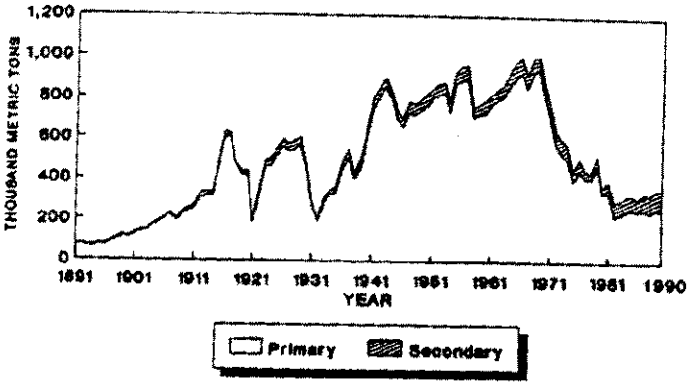
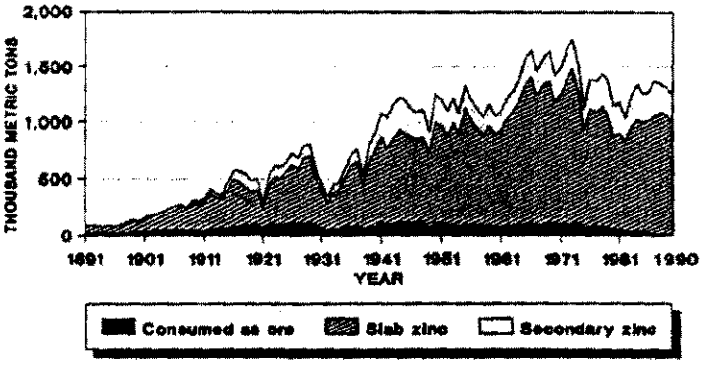


FIGURE 5

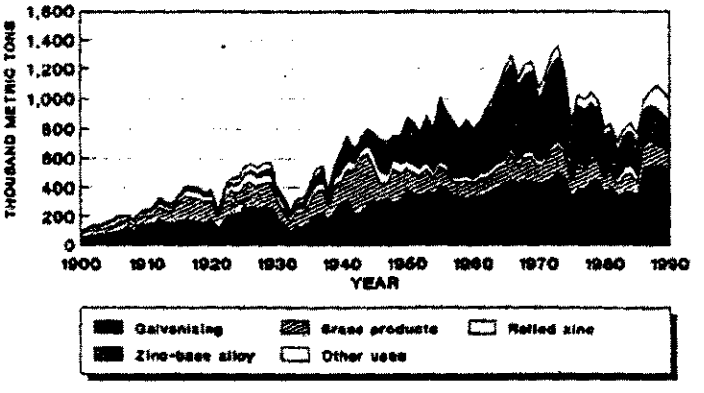
U.S. ZINC CONSUMPTION ALL CLASSES



Note: Data on Secondary consumed unavailable prior to 1907.

FIGURE 6

U.S. SLAB ZINC CONSUMPTION



Source: Bureau of Mines IC 7460, 1900-1945 and Minerals Yearbook 1945-1990.

of slab zinc, and, overall, has accounted for about one-half of the domestic slab zinc consumption. The most significant change in slab zinc consumption was the rapid rise in the use of zinc-based alloy following development of satisfactory alloys for die casting purposes in the mid-1920's. Spurred on mainly by use in the automobile industry, zinc diecasting use expanded many-fold, reaching its highest level in the 1960's and early 1970's. In the mid 1970's the energy crisis led to downsizing and weight reduction programs in the automotive industry and substantial reduction in zinc-based alloy use. Rolled zinc was more extensively used prior to World War II, finding widespread use as roofing, gutters, battery cans, and engraving plates. Rolled zinc use fell in subsequent years owing to substitution and technological change but rebounded sharply in 1982 when "zinc penny" production started. In figure 6, rolled zinc is included in "Other" uses after 1985.

End-use zinc materials can be dissipative or long lasting. Dissipative products include zinc used in fertilizers and animal feeds, pharmaceuticals, vitamins, welding fluxes, engine oil additives, and fungicides. Also considered dissipative are short-term uses such as process chemicals, dry cell anodes and medical rubber products. Other products utilize zinc in a longer-lasting, dissipative way. Unprotected (from weather or corrosive conditions) galvanized surfaces, rubber tires through wear, sacrificial anodes, and exterior paint, all lose zinc over time. The zinc in most other end-products is not dissipated and ends up being landfilled or recycled when the product is discarded. Most zinc disposed of in the United States has likely been landfilled.

Historical salient zinc statistics and graphical illustrations of various aspects of U.S. production and consumption of zinc are given in Appendix A and

in Figures 4, 5 and 6. In the above mentioned statistics and figures some data, especially those prior 1907, were generated based on available information, estimation, and assumption. U.S. trade in most zinc compounds and alloys, semimanufactures and end products (zinc content of) generally is not available and is not included; however, net trade, in ores and slab zinc, by far the largest components of U.S. non-end-use zinc trade, is considered in the data. Information on the U.S. zinc industry, for the most part, has been well documented in annual volumes of Mineral Resources of the United States through 1923 and, thereafter, in volumes of the Minerals Yearbook. These were the principal sources for the statistical data used, including those for world production and use.

*** METHODOLOGY AND ZINC LOSS ESTIMATES

Each section of the flow diagram was analyzed for losses to the environment. The basic data used for the analyses are those shown in Appendix A. As stated before, a number of assumptions and estimates were made for unavailable basic data. A search of the literature provided the basis for many of the assumptions used in quantifying sector losses. Principal references consulted are listed at the end of the report. Loss analyses were made on the three major zinc flow sectors: (1) mining and milling; (2) smelting and refining; and (3) consumption, use and disposal.

Mining and milling and smelting losses were considered by time segments to reflect the general conditions and technology prevailing in that time period. Taken into consideration was type of deposits, minerals involved, mining methods, concentrating methods, mill recovery factors, transportation and handling of ore and concentrates, ore smelting and/or processing technology, and process recovery factors.

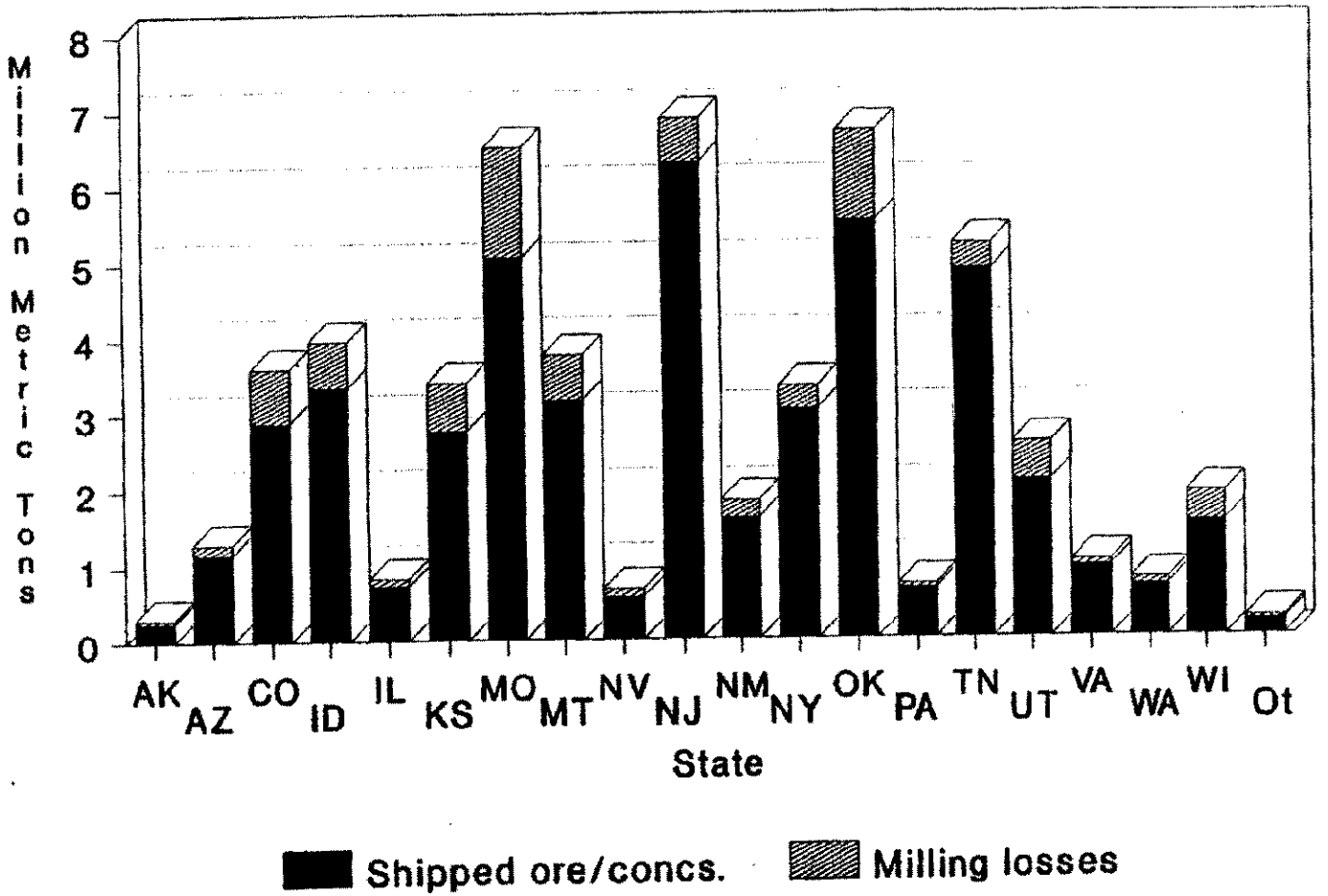
Losses in domestic mine production were calculated by working backward from recoverable mine output (the only available historical mine production data series) to zinc in ore mined. Recoverable mine output is defined as the actual amount of zinc recovered after smelting and/or refining. Estimated mine and smelter recoveries were based on generalized factors for each time period on a State by State basis. The calculations for losses in smelting provided the quantity of zinc in ore and concentrate shipped to smelters. Based on mine and/or mill recovery factors, the amount of ore hoisted or milled was determined. Figure 7 and Table 1 show estimates of the zinc contained in ore mined by State and estimates of zinc losses associated with direct ore shipments and milling and concentration process. The analysis indicates that about 56 million tons of zinc in ores was mined in the United

Table 1. Estimated Zinc Ore Production, Zinc Losses in Beneficiation and Total Zinc shipped for Smelting and Refining by State, 1850-1990 (Thousand metric tons)

State	Ore Mined/Hoisted (Zinc content)	Processing Losses (Zinc content)	Shipped Ore/Concentrate (Zinc content)
Alaska	299	46	253
Arizona	1,289	137	1,152
California	221	39	182
Colorado	3,604	710	2,894
Idaho	3,966	611	3,355
Illinois	824	98	726
Kansas	3,408	638	2,770
Missouri	6,512	1,444	5,068
Montana	3,765	592	3,173
Nevada	675	110	565
New Jersey	6,888	581	6,307
New Mexico	1,832	225	1,607
New York	3,345	307	3,038
Oklahoma	6,714	1,184	5,530
Pennsylvania	710	51	659
Tennessee	5,225	338	4,887
Utah	2,585	499	2,086
Virginia	1,015	74	941
Washington	763	79	684
Wisconsin	1,914	385	1,529
Other[1]	249	46	203
Total	55,803	8,194	47,609

[1]Arkansas, California, Iowa, Kentucky, Maine, Maryland, New Hampshire, North Carolina, Oregon, South Dakota and Texas.

Figure 7.--Zinc Ore Production and Shipments, By State, 1850-1990



Ot=Other: AR,CA,IA,KY,MD,ME,NH,NC,OR,SD

States in the 1850-1990 period, yielding about 48 million tons of zinc contained in direct shipping ore and concentrate. Zinc losses, in mining and milling overall, were about 15% of the total mined and occurred mainly in the form of mill tailings and unrecoverable zinc in other concentrates, mainly lead concentrates.

U.S. zinc smelter production has come from domestic and imported ores and concentrates. In the 1850-1990 period domestic smelters and ore-sourced zinc oxide producers processed an estimated 61 million tons zinc in ores and concentrates producing about 47 million tons of zinc metal and about 8 million tons of zinc in oxides and other compounds. Zinc losses, mainly in the form of smelter dusts, slags, residues, etc., totaled about 6 million tons, or 10% of the zinc in the smelter feed. Primary metal production and losses associated with that production are shown by State in Figure 8 and Table 2. Losses associated with zinc oxide (and other zinc compounds) produced directly from ores and concentrates were estimated to be 10% of production, or about 800,000 tons. Because American process zinc oxide production by State is not known, the distribution of zinc losses by State was judged by where companies operated the longest. Ore-sourced oxide was produced at both primary smelters and plants specifically designed for that purpose. Eighteen American-process zinc oxide plants were in production in 1919 compared with 8 plants in 1956 and no plants in 1987. Pennsylvania was judged to have accounted for about 40% of the output and losses, followed by Illinois, 20%; Kansas, 15%; Ohio, 10% and other States, 15%.

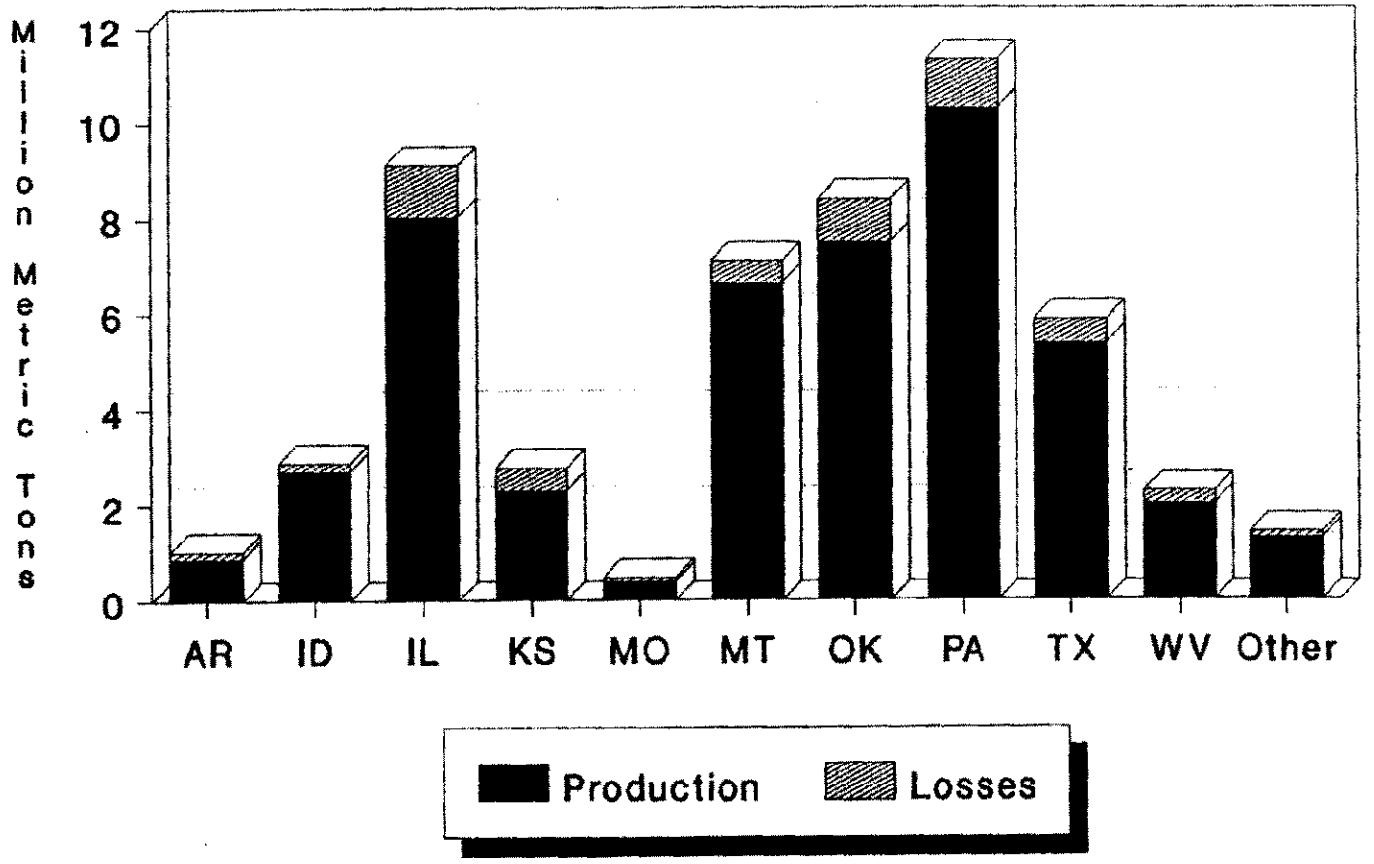
Zinc scrap, waste, and residues have been processed at many secondary plants, brass producers, and all primary zinc plants in the United States. Zinc losses to the environment and the locations of losses associated with secondary recycle are generally not available. The Bureau has a data series

Table 2. Primary Smelter production of Slab Zinc and Estimated Zinc Losses In Smelting in the United States, By State, 1850-1990
(Thousand metric tons)

State	Production	Losses in Smelting	Total Zinc in Smelter Feed
Arkansas	900	130	1,030
Idaho	2,713	167	2,880
Illinois	8,032	1,082	9,114
Kansas	2,307	467	2,774
Missouri	390	85	475
Montana	6,648	456	7,084
Oklahoma	7,502	886	8,388
Pennsylvania	10,300	1,021	11,321
Texas	5,363	504	5,867
West Virginia	2,008	249	2,257
Other[1]	1,285	120	1,405
Total	47,448	5,167	52,595

[1]Colorado, Indiana, New Jersey, Tennessee, Utah, Virginia, and Wisconsin.

Figure 8.--Primary Slab Zinc Production and Associated Smelter Losses, by State 1859-1990



Other: CO,NJ,TN,UT,VA,WI

on zinc recovered from secondary materials but the quantity of zinc in waste and scrap fed to the recovery process is not available. As a result, no attempt was made in this report to quantify or locate zinc losses generated in recycling activities. However, secondary process losses are indirectly included in the overall loss data because they were accounted for as losses at prior points in the flow of zinc; merely the site and, possibly, the disposal form of the zinc has changed.

The zinc use and disposal sectors are the most difficult to contend with because very little information is available to make an assessment. The available data on domestic zinc consumption is essentially that collected by the Bureau of Mines on basic zinc products.--slab zinc, dust, oxide and sulfate; but even then, end-use distribution, except partially for slab zinc and oxide is not well documented. The zinc contents of most end-use products are not known, although average estimates for some items, such as automobiles, have been made at various times.

Basic zinc products enter end products in two principal ways, directly or indirectly. For indirect entry, basic zinc metals and compounds are used to make an intermediate or semi-manufactured product. Such products have been galvanized sheet, strip, and structural shapes, alloys and in some cases intermediate chemical compounds. Zinc oxide for example, is the starting compound for the manufacture of many zinc-chemicals, some of which are used in processes elsewhere. Semi-manufactured sheet products are used to fabricate end products; for example, galvanized sheet is stamped into automobile fenders or rolled zinc is punched to make penny blanks. Direct end uses of basic zinc materials have been paint, rubber tires, castings, and the galvanizing of nails, fencing, etc, which are considered end products. The available data on U.S. zinc consumption, are incomplete and mixed as regards direct or indirect

use, as well as absolute tonnages in any given use area.

The Bureau's consumption data for slab zinc, by far the largest component of zinc consumption, do not generally measure the amount of zinc in a finished end product but provide a measure of the first use of the metal, i.e. when it is first melted for galvanizing or alloying purposes or converted to a compound. If steel is hot-dipped galvanized, for example, the process drosses and skims as well as the zinc coating adhering to the steel are considered to be slab zinc consumption in the Bureau's galvanized sector of use. Further, if the zinc was used to make an intermediate product such as galvanized sheet, brass ingot or sheet, or rolled zinc, additional wastes may be created from stamping, punching, and trimming operations. Again, the quantity of zinc in the end product represents even less of the zinc reported as consumed because not all of the sheet or ingot was used to make the product.

In attempting to determine the amount of useful zinc entering the U.S. economy, total slab consumption and the "consumed as ore" categories in Appendix A and old scrap were assumed to constitute the amount of zinc ending up in end products each year. New scrap was not included as it would constitute double counting. Products made from new scrap, however, were viewed as accounting for the quantity of zinc lost in consumption of basic zinc materials and, therefore, are indirectly included. Old scrap was not distinguished as a separate zinc statistic by the Government until 1939. Estimates for old zinc scrap for the pre-1939 years were assumed to be the same as secondary slab zinc production based on the fact that old scrap and secondary slab zinc production have tended to annually total about the same tonnage in post-1939 years.

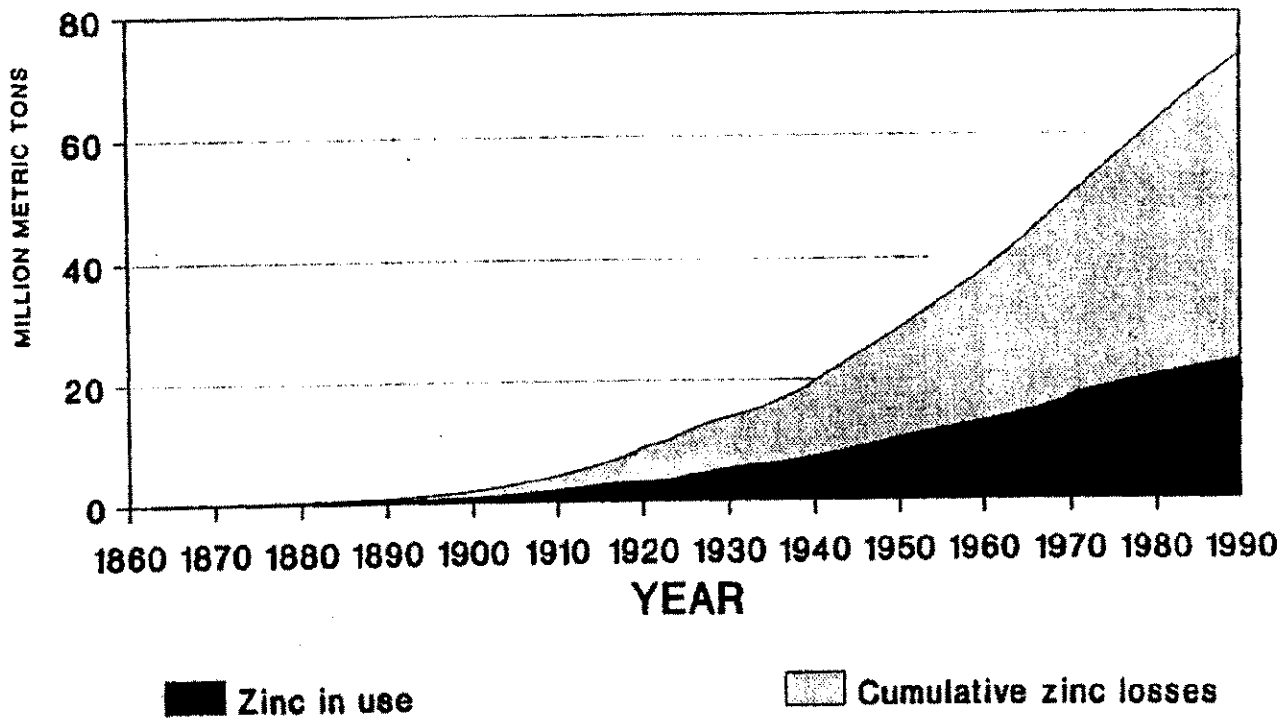
The zinc contents in imported and exported goods are not known, and were not considered in the data, except inclusion of an estimate for the past 15

years when large quantities of galvanized steel, diecastings, brass, and zinc-containing finished products were imported into the United States. The reason for including imports in the end use data for recent years, was based on the assumption that U.S. per capita zinc consumption has remained high despite reduction in consumption measured in the conventional way, i.e. domestic industrial consumption. During and immediately after the two World Wars, U.S. exports of zinc in end products undoubtedly exceeded imports; this aspect however, was not considered in the "zinc in use" data.

The methodology used to determine estimated zinc in use and cumulative zinc dissipated and discarded since 1850 was based on assigned percentage zinc losses over time. The quantity of zinc put in use in any given year was the amount consumed as discussed above. The "in use" or "lost" quantities for x number of years after the year put in use, was determined and applied similarly to all years. For example 90% of the zinc consumed in the first year of any given year was assumed to continue in use; ten percent, of that year's consumption was assumed to have been dissipated or discarded. Only 50% was considered to be in use after 14 years. Annual totals of zinc in use were calculated and plotted for every five-year period from 1860 to 1990. Figure 9 shows graphically the historical cumulative in-use and loss data for the United States.

The data indicate that an estimated 73 million tons of zinc were placed in use in end products in the United States in the 1850-1990 period. Of that total an estimated 23 million tons of zinc was still in use at the end of 1990 and 46 million tons of zinc in end-use products have been used in a dissipative way or were permanently discarded in the 1850-1990 period. Figure 10 shows the principal sources and maximum losses to the environment associated with the historical industrial flow of zinc in the United States.

Figure 9. ESTIMATED ZINC IN USE AND CUMULATIVE ZINC DISSIPATED AND DISCARDED



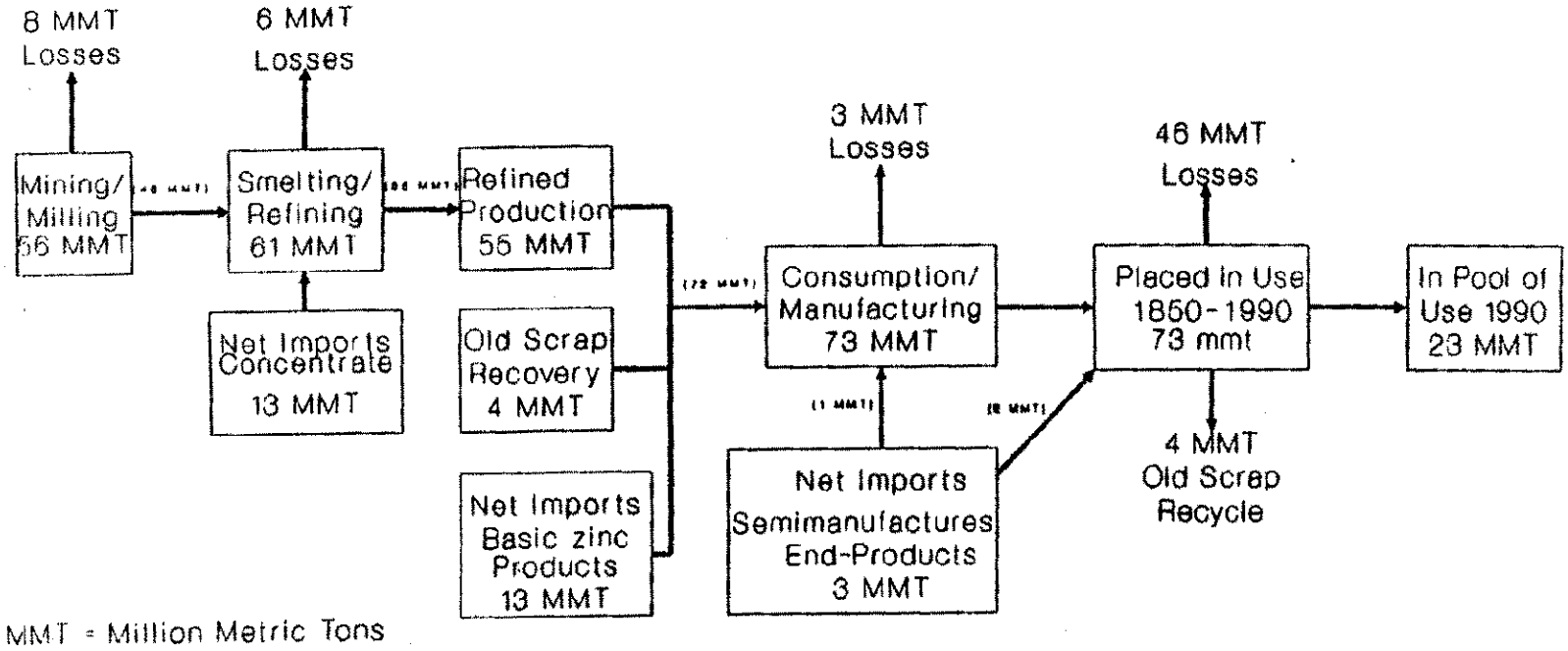


Figure 10.- Materials flow of zinc in the United States, 1850-1990

***SUMMARY

The United States was the world's largest producer and consumer of zinc in the 1850-1990 period. During that time, an estimated 41 million tons of recoverable zinc came from domestic ores, 59 million tons of refined zinc was produced by domestic smelting or processing, and 73 million tons of zinc entered the U.S. economy in the form of end products. Potential losses to the environment from the above zinc mining, processing, consumption, use and disposal were estimated to total 63 million tons (see figure 10).

It should be noted that the losses indicated represent only approximate maximum potential losses to the environment and are presented as a guide for further work. Mill tailings, for example, may have been reworked for zinc, used for mine backfill, or commercially used as fertilizers. Mine rock, tailings and smelter slags often have been used for construction and road building materials. Zinc-bearing slags are sometime used in fertilizers and animal feeds to provide trace constituents to the product. The zinc content typically is benign or beneficial to the environment in the above applications and for the most part, in most other instances in its end use and disposal.

Although actual zinc losses to the environment, especially in zinc mining and smelting, are thought to be substantially less than those indicated by this study, the data provide basic knowledge regarding anthropogenic loadings from production sources by State and from end-use disposal as it may relate to disposal near historically large population centers. On-site studies, however, will be necessary to determine the true extent of zinc loadings at specific mining, smelting, manufacturing and disposal sites.

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***APPENDIX A. -- U.S. SALIENT ZINC STATISTICS, 1850-1990

This section contains most of the basic statistical data upon which the U.S. historical materials flow study and the study for 1989 was based.

U.S. historical salient zinc statistics
(Metric tons)

Year	Slab zinc production		Mine1/ production (recoverable)	Imports for consumption		Exports		Consumption			Net import reliance (percent)7/	Price, cents per pound8/
	Primary	Secondary		Slab zinc	Ore (zinc content)2/	Slab zinc	Ore (zinc content)3/	Slab zinc4/	Consumed as ore5/	All classes6/		
1859	45	NA	245	NA	NA	NA	NA	NA	NA	NA	NA	NA
1860	725	NA	925	NA	NA	NA	NA	NA	NA	NA	NA	NA
1861	1,350	NA	1,650	NA	NA	NA	NA	NA	NA	NA	NA	NA
1862	1,350	NA	1,600	NA	NA	NA	NA	NA	NA	NA	NA	NA
1863	1,550	NA	1,800	NA	NA	NA	NA	NA	NA	NA	NA	NA
1864	1,630	NA	1,900	NA	NA	43	671	NA	NA	NA	NA	13.90
1865	1,900	NA	2,200	NA	NA	83	450	NA	NA	NA	NA	NA
1866	1,800	NA	2,000	NA	NA	63	203	NA	NA	NA	NA	NA
1867	2,900	NA	3,300	NA	NA	141	166	7,700	NA	9/7,700	NA	NA
1868	3,350	NA	3,800	NA	NA	463	378	8,731	NA	9/8,731	NA	NA
1869	3,900	NA	4,500	NA	NA	NA	NA	13,660	NA	9/13,660	NA	NA
1870	4,900	NA	5,400	NA	NA	49	693	13,362	NA	9/13,362	NA	NA
1871	6,250	NA	7,000	NA	NA	34	436	14,746	NA	9/14,746	NA	NA
1872	7,070	NA	8,200	NA	NA	28	167	17,251	NA	9/17,251	NA	NA
1873	6,661	NA	8,000	NA	NA	33	10	16,627	NA	9/16,627	NA	NA
1874	11,900	NA	13,500	NA	NA	19	115	16,240	NA	9/16,240	NA	NA
1875	14,363	NA	17,200	NA	NA	17	139	19,376	NA	9/19,376	NA	7.00
1876	15,400	NA	18,500	NA	NA	61	461	17,860	NA	9/17,860	NA	7.20
1877	14,150	NA	16,900	NA	NA	644	291	14,684	NA	9/14,684	NA	6.00
1878	17,800	NA	19,700	NA	NA	1,154	728	17,791	NA	9/17,791	NA	4.90
1879	19,300	NA	23,000	NA	NA	967	483	19,481	NA	9/19,481	NA	5.20
1880	21,082	NA	28,400	NA	NA	620	590	27,646	7,335	10/34,981	NA	5.50
1881	27,450	NA	34,800	NA	NA	676	516	29,308	7,257	10/36,565	NA	5.20
1882	30,631	NA	38,000	NA	NA	675	494	40,306	7,257	10/47,563	NA	5.30
1883	33,451	NA	42,000	NA	NA	386	138	42,315	8,709	10/51,024	NA	4.50
1884	34,967	NA	44,000	NA	NA	57	216	38,004	9,435	10/47,439	NA	4.40
1885	36,911	NA	47,000	NA	NA	46	310	39,294	10,886	10/50,180	NA	4.30
1886	38,683	NA	52,000	NA	NA	349	396	40,445	13,063	10/53,508	NA	4.40
1887	45,667	NA	58,000	NA	NA	164	54	49,217	13,063	10/62,280	NA	4.60
1888	50,714	NA	65,000	NA	NA	28	206	52,555	14,515	10/67,070	NA	4.90
1889	53,397	NA	66,000	NA	NA	399	1,213	54,388	12,316	10/66,704	NA	5.00
1890	57,772	NA	75,000	NA	NA	1,494	3,508	57,538	17,200	10/57,538	NA	5.50
1891	73,367	NA	90,000	NA	NA	1,948	171	71,327	17,200	10/88,527	NA	5.00
1892	79,161	NA	99,000	NA	NA	5,667	41	73,465	19,958	10/93,423	NA	4.60
1893	71,515	NA	89,000	NA	NA	3,301	44	69,058	17,461	10/86,519	NA	4.00
1894	68,336	NA	82,000	NA	NA	1,636	--	64,028	14,506	10/78,534	NA	3.50
1895	81,361	NA	96,000	NA	NA	1,388	21	79,357	15,030	10/94,587	NA	3.60
1896	73,934	NA	88,000	NA	NA	9,189	1,882	63,609	14,515	10/78,124	NA	3.90
1897	90,700	NA	109,000	NA	NA	12,923	3,746	80,541	18,144	10/98,685	NA	4.10
1898	104,688	NA	129,000	NA	NA	9,524	4,771	98,157	23,950	10/122,107	NA	4.60
1899	117,073	NA	146,000	NA	NA	6,127	11,429	113,021	29,135	10/142,156	NA	5.80
1900	112,388	NA	150,546	NA	NA	20,322	19,079	90,173	35,446	10/125,619	NA	4.40
1901	127,752	NA	167,646	NA	NA	3,075	20,029	128,529	35,198	10/163,727	NA	4.10
1902	142,362	NA	192,922	406	NA	2,937	25,280	138,511	40,591	10/179,102	NA	4.80
1903	144,441	NA	180,194	183	NA	1,380	17,876	140,052	48,308	10/188,360	NA	5.40
1904	169,378	NA	201,951	309	727	9,205	16,289	164,120	49,343	10/213,463	NA	5.10
1905	184,929	NA	213,003	388	7,301	5,004	14,037	181,834	53,724	10/235,558	NA	5.90
1906	203,908	NA	201,147	926	17,816	4,237	12,574	200,289	58,915	10/259,204	NA	6.10
1907	226,669	6,396	235,824	1,550	33,168	511	9,234	205,903	59,944	272,538	NA	5.80
1908	190,893	6,495	212,758	704	17,614	1,119	11,842	194,289	43,549	244,104	NA	4.60
1909	232,022	8,412	277,075	8,545	37,356	303	5,650	245,602	49,114	310,094	NA	5.40
1910	244,200	11,597	297,295	897	23,078	3,388	8,941	223,062	45,896	296,733	NA	5.40

U.S. historical salient zinc statistics
(Metric tons)

Year	Slab zinc production: Primary	Slab zinc production: Secondary	Mine1/ production (recoverable)	Imports for consumption: Slab zinc	Imports for consumption: Ore (zinc content)2/	Exports: Slab zinc	Exports: Ore (zinc content)3/	Consumption: Slab zinc4/	Consumption: Consumed as ore5/	Consumption: All classes6/	Net import reliance (percent)7/	Price, cents per pound8/
1911	259,932	12,740	313,215	293	14,933	13,023	8,292	254,065	41,841	330,140	NA	5.70
1912	307,360	23,645	343,656	9,724	15,936	6,808	10,591	308,752	58,089	408,701	NA	6.90
1913	314,499	23,579	368,694	4,686	12,244	12,234	8,034	267,955	64,067	361,587	NA	5.60
1914	320,281	18,638	377,082	177	11,006	67,594	5,040	272,140	64,064	364,877	NA	5.10
1915	444,084	27,001	533,057	57	52,316	119,213	377	330,991	72,187	459,036	NA	14.20
1916	605,506	26,105	638,039	19	134,397	137,211	71	416,685	81,897	577,969	NA	13.60
1917	607,427	15,272	647,159	16	65,747	199,639	1,197	375,251	88,517	564,368	NA	8.90
1918	469,856	8,997	577,052	10	22,506	96,751	56	334,458	93,239	537,589	NA	8.00
1919	422,515	17,915	497,905	29	15,430	132,718	--	293,895	90,909	475,194	NA	7.00
1920	420,369	19,387	532,993	--	23,265	103,661	--	293,060	106,122	497,362	NA	7.80
1921	181,891	15,942	232,820	5,986	12,963	4,495	--	184,703	51,917	295,881	NA	4.70
1922	321,395	29,926	428,220	36	NA	31,571	1,538	338,462	86,104	513,990	NA	5.70
1923	463,058	35,774	554,009	1	788	29,885	2,544	405,071	106,633	609,178	NA	6.70
1924	469,322	32,192	578,763	10	5,489	69,165	334	406,652	99,207	602,735	NA	6.30
1925	519,768	35,544	644,870	--	18,566	69,264	62,551	453,680	100,698	647,160	NA	7.66
1926	561,023	37,012	702,672	--	12,508	38,936	86,411	505,326	117,934	723,867	NA	7.37
1927	537,522	38,813	651,850	35	5,572	41,454	42,380	468,446	110,677	679,990	NA	6.25
1928	546,652	44,149	630,648	--	3,951	22,942	4,099	568,351	112,491	788,199	NA	6.03
1929	567,396	42,953	657,236	205	1,705	13,073	64	575,427	125,192	808,952	NA	6.49
1930	451,819	31,614	540,161	255	23,264	4,203	--	409,050	95,254	582,693	NA	4.56
1931	264,894	19,618	372,234	249	706	583	12	335,658	68,039	470,783	NA	3.64
1932	187,922	13,352	258,757	281	1,727	5,870	--	234,961	49,895	339,731	NA	2.88
1933	278,671	27,294	348,618	1,715	1,935	1,039	734	317,787	65,317	453,193	NA	4.03
1934	329,843	17,868	398,006	1,565	12,952	4,631	3,285	326,496	68,946	458,948	NA	4.16
1935	381,593	25,991	469,834	4,032	9,544	1,467	418	429,099	78,018	581,967	NA	4.33
1936	446,455	38,291	522,152	10,578	156	34	222	527,982	87,090	709,871	NA	4.90
1937	505,215	46,769	568,226	33,755	3,035	226	285	553,383	101,605	758,104	NA	6.52
1938	404,914	28,679	468,745	6,559	4,409	--	122	381,925	62,596	522,944	NA	4.61
1939	460,157	45,748	529,621	28,086	30,393	4,096	275	567,898	77,111	798,679	NA	5.12
1940	612,599	44,377	603,340	9,204	40,494	71,750	406	665,018	87,090	907,883	NA	6.34
1941	745,724	53,980	679,595	36,549	140,171	81,020	--	750,637	122,470	1,086,368	NA	7.48
1942	809,093	48,258	696,741	32,978	256,885	121,507	--	660,584	104,326	1,031,676	NA	8.25
1943	854,849	43,740	675,123	50,943	468,694	88,395	1	740,968	104,326	1,157,226	NA	8.25
1944	788,618	44,486	651,941	57,721	376,485	19,578	--	806,148	128,820	1,223,677	NA	8.25
1945	693,598	44,672	557,336	87,779	300,762	7,060	--	773,204	118,841	1,191,969	NA	8.25
1946	660,668	40,384	521,680	94,406	151,396	42,841	81	735,039	121,563	1,101,486	24	8.73
1947	728,011	54,016	578,428	65,374	176,740	96,769	1,274	713,374	132,449	1,087,273	25	10.50
1948	714,648	56,536	571,506	83,910	121,394	59,454	3,218	741,837	120,656	1,114,419	E	13.58
1949	739,158	49,932	538,145	113,910	99,369	53,260	2,654	645,771	79,832	900,135	1	12.15
1950	765,181	60,754	565,516	140,915	215,514	11,718	1,034	877,369	121,563	1,247,865	39	13.88
1951	799,804	44,141	617,964	79,871	179,618	33,121	2,803	847,284	121,653	1,203,002	24	17.99
1952	820,530	49,996	604,186	102,560	491,979	52,357	3,057	773,632	99,134	1,099,189	39	16.21
1953	831,077	47,967	496,620	206,524	407,990	16,301	2,679	894,418	107,269	1,217,795	47	10.86
1954	727,948	61,700	429,526	145,277	436,282	22,674	--	802,223	90,035	1,071,106	49	10.69
1955	874,076	59,912	466,902	176,955	348,947	16,392	--	1,015,877	107,170	1,332,727	43	12.30
1956	892,316	65,433	492,803	222,012	419,463	7,995	775	915,159	102,864	1,200,226	45	13.49
1957	894,299	65,764	482,382	243,873	616,356	9,784	6	848,780	100,072	1,117,283	47	11.40
1958	708,735	42,279	373,765	168,458	487,792	1,881	--	787,733	86,126	1,036,155	56	10.31
1959	724,538	52,452	385,829	149,197	384,769	10,550	1	867,448	98,039	1,159,724	53	11.46
1960	725,309	62,352	395,013	109,701	347,396	68,170	12	796,403	80,082	1,051,371	46	12.95
1961	768,200	50,110	421,288	113,567	324,457	45,409	1,515	844,782	88,225	1,095,398	46	11.55
1962	797,774	53,415	458,574	123,373	351,372	32,751	123	936,053	92,154	1,209,560	47	11.63

U.S. historical salient zinc statistics
(Metric tons)

Year	Slab zinc production: Primary	Slab zinc production: Secondary	Mine1/ production (recoverable)	Imports for consumption: Slab zinc	Imports for consumption: Ore (zinc content)2/	Exports: Slab zinc	Exports: Ore (zinc content)3/	Consumption: Slab zinc4/	Consumption: Consumed as ore5/	Consumption: All classes6/	Net import reliance (percent)7/	Price, cents per pound8/
1963	809,739	54,706	480,181	120,050	337,399	30,711	15	1,002,542	94,987	1,282,956	49	12.01
1964	865,531	64,951	521,503	121,670	282,529	24,054	35	1,095,215	96,114	1,393,210	44	13.57
1965	902,107	75,858	554,429	139,667	365,537	5,388	NA	1,228,412	111,486	1,580,377	51	14.50
1966	929,924	75,535	519,416	254,290	359,585	1,276	NA	1,291,528	114,937	1,651,088	54	14.50
1967	851,692	66,683	498,419	201,397	391,286	15,249	NA	1,134,592	103,692	1,456,814	52	13.85
1968	926,137	72,452	480,305	276,407	439,806	29,947	NA	1,225,295	112,590	1,583,362	58	13.50
1969	944,014	64,005	501,736	296,616	512,772	8,435	NA	1,256,796	114,951	1,645,785	59	14.65
1970	796,337	69,995	484,560	235,988	408,932	261	NA	1,076,784	113,199	1,425,728	53	15.32
1971	695,297	73,412	455,899	294,159	423,989	12,107	NA	1,137,664	108,185	1,497,485	60	16.13
1972	574,411	66,876	433,922	468,691	157,907	8,923	NA	1,286,705	107,325	1,672,870	61	17.75
1973	529,323	75,466	434,406	535,920	139,864	13,214	NA	1,364,350	117,617	1,752,613	65	20.66
1974	503,658	71,246	453,476	493,333	121,321	17,293	NA	1,168,178	115,315	1,517,732	60	35.95
1975	397,394	52,513	425,792	340,124	388,769	6,257	NA	839,445	75,053	1,117,484	63	38.96
1976	452,554	62,192	439,543	630,612	141,342	3,187	NA	1,028,876	91,844	1,394,268	59	37.01
1977	408,364	45,913	407,889	503,621	109,277	215	NA	999,505	86,940	1,367,704	58	34.39
1978	406,698	34,774	302,669	622,470	106,315	723	10,973	1,050,585	89,959	1,441,810	67	30.97
1979	472,481	53,212	267,341	524,130	87,499	279	20,095	1,000,606	79,710	1,394,314	63	37.30
1980	340,456	29,396	317,103	410,163	182,370	302	54,457	811,146	58,986	1,142,409	60	37.43
1981	346,563	50,192	312,418	612,007	245,710	323	54,232	840,875	60,643	1,189,369	65	44.56
1982	228,176	74,288	303,160	456,233	66,809	341	77,289	795,000	35,515	1,038,600	58	38.47
1983	235,694	69,390	275,294	617,679	63,156	427	60,168	933,000	36,912	1,246,300	65	41.39
1984	253,432	78,113	252,768	639,228	86,172	760	30,579	980,000	45,487	1,344,000	68	48.60
1985	261,209	72,563	226,545	610,900	90,186	1,011	23,264	961,000	39,886	1,257,000	70	40.37
1986	253,369	62,912	202,983	665,126	75,786	1,938	3,269	999,000	19,236	1,274,000	73	38.00
1987	261,345	82,589	216,327	705,985	46,464	1,082	16,921	1,052,000	2,536	1,383,000	69	41.92
1988	241,294	88,492	244,314	749,130	62,966	482	33,590	1,092,000	2,412	1,340,000	70	60.20
1989	260,305	97,904	275,883	711,554	40,974	5,532	78,877	1,060,000	2,107	1,311,000	61	82.02
1990	262,704	95,708	515,355	631,742	46,684	1,238	Z20,446	991,000	2,178	1,239,000	40	74.59

E Net exporter. NA Not available.

1/Recoverable mine production is estimated for 1859-1899.

2/Imports Ore: 1904-1909 were estimated (Minerals Yearbook 1926) and for 1910-1936 were zinc content of General Imports.

3/Exports Ore: 1897-1915 zinc content estimated at 50% of ore shipped; 1907-1915 virtually all willemite concentrate (50% zinc)

4/Data through 1981 are reported consumption of slab zinc; 1982 forward, data are apparent consumption of slab zinc.

5/1880-1900 data for zinc oxide from ore; 1901-1907 data for zinc oxide and zinc lead from ore; 1908-1918 data for pigments from ore; 1919-1924 data for pigments and salts from ore; 1925-1956 data for zinc oxide from ore; 1957-1988 includes ore directly to galvanizing.

6/Based on apparent consumption of slab zinc plus zinc content of ores and concentrates and secondary materials used to make zinc dust and chemicals.

7/Net import reliance is expressed as a percent of apparent consumption. Net import reliance is defined as exports (-) imports (+) adjustments for changes in industry and Government stocks. Apparent consumption in U.S. equals mine production (+) old scrap (+) net import reliance.

8/Source: Bureau of Mines. Nonferrous Metal Prices in the United States through 1988. Spec. Publ. 1989, pp. 125-130.

9/Data does not include ores and secondary consumed, data not available.

10/Data does not include secondary consumed, data not available.

***APPENDIX B. -- ZINC MATERIALS FLOW OF THE UNITED STATES, 1989

The following series of diagrams (figures B-1 thru B-11) show the sources and the potential and probable losses of zinc into the U.S. environment during 1989. The materials flow of zinc in 1989 was essentially that shown in figure 3 of the main report. The only exception was there was no ore-sourced zinc oxide production in 1989.

Figures B-1,2 and 3 show the sources of zinc losses to the environment owing to mining and primary zinc smelting. In addition to ores mined and smelted for zinc, other primary sources of zinc-loading of the environment are shown to illustrate their possible importance to a study of this kind. For example, in 1989 domestically-mined copper ores, coal burning, and other ore mining and processing were estimated to each contain from 20,000 to 30,000 metric tons of zinc, none of which was intended for recovery. Some of this zinc may have been recovered in smelter dust, however most was likely added to the environment in the form of tailings, fly ash and smelter waste products. These non-primary zinc sectors are areas for possible future study.

Figures B-4 and B-5 show the sources of U.S. supply of basic zinc products for 1989. The data include basic products made from new scrap and, therefore, double counting of zinc occurs in the apparent consumption total. Although this distorts the amount of zinc consumed overall, it permits better represention of the basic quantities required to produce end products as well as associated zinc losses and quantities of new scrap generation.

Figures B-6 through B-10 provide estimates of use sector consumption and losses associated with that consumption. Most of the "losses" indicated are new scrap and in essence, most of this material is recycled.

Figure B-11 summarizes the materials flow of zinc in the United States in 1989 in terms of losses to the environment from zinc-related production, consumption, use, and end-use disposal. Losses associated with 1989 zinc production and use were about 164,000 tons; however when the use and disposal of zinc products from previous years is considered, about 900,000 tons of zinc likely entered the U.S. environment from these antropogenic sources in 1989.

Figure B - 1. Sources of Zinc in the Environment from Mining and Primary Smelting

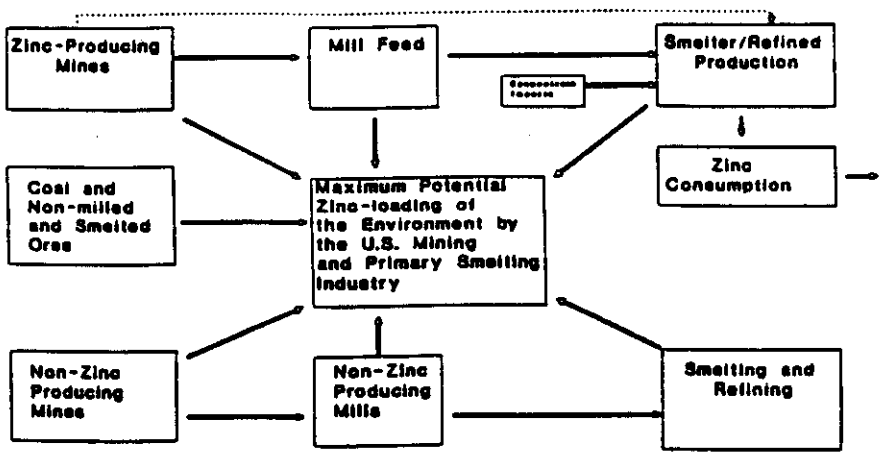


Figure B - 2. Zinc Production and Losses in Mining & Milling in 1989

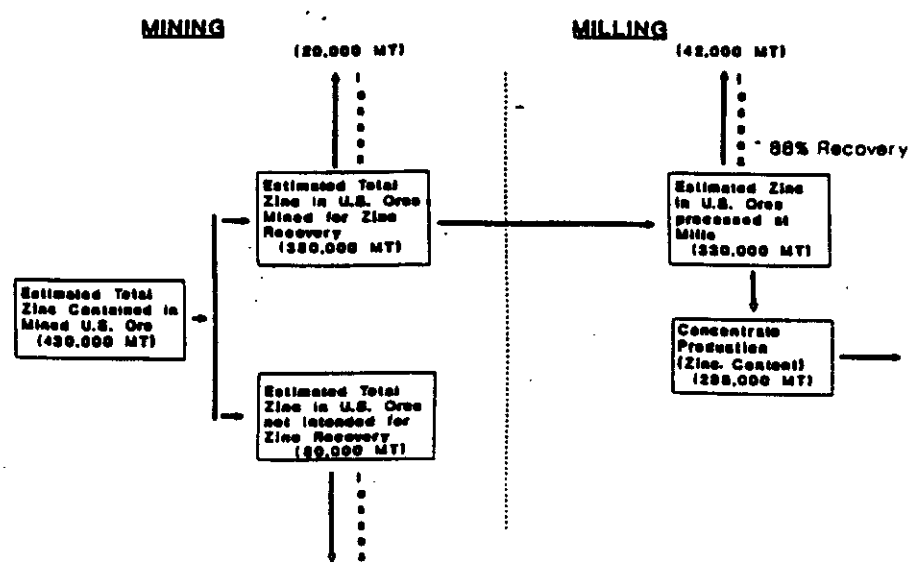


Figure B - 3. Feed and Production at Primary Zinc Smelters in 1989

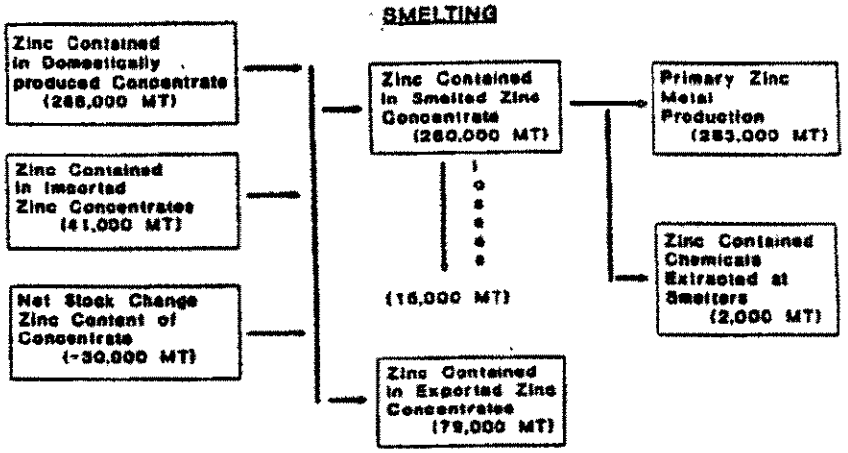


Figure B - 4. Estimated Total Domestic Production of Zinc in Basic Products in 1989

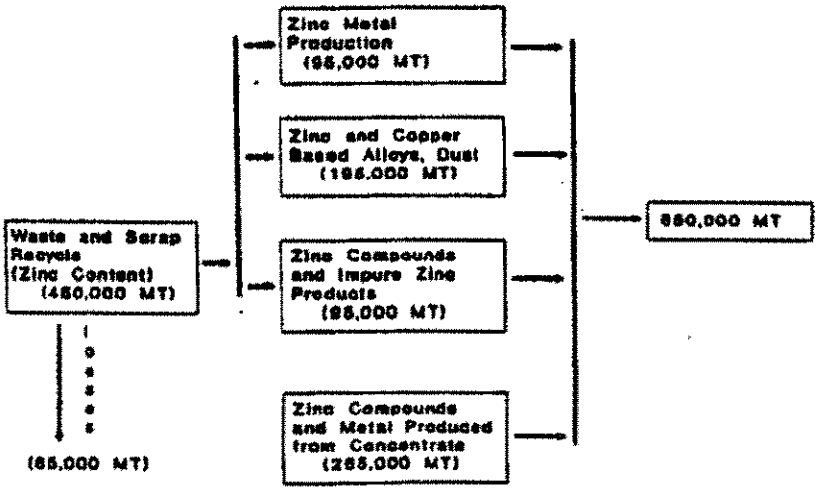


Figure B - 5. Distribution of Zinc by Major End-Use Categories in 1989

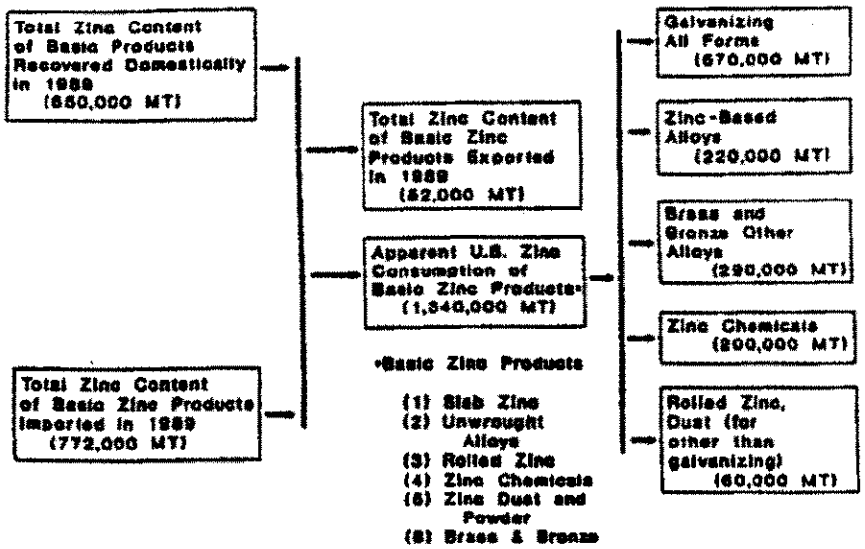


Figure B - 6. Galvanizing End Uses in 1989

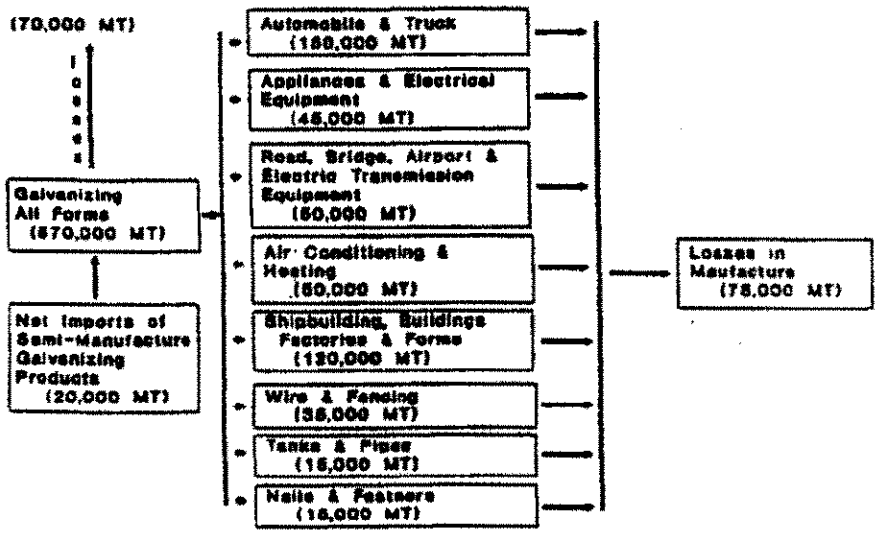


Figure B - 7. Brass, Bronze and other Non-Zinc-Based in 1989

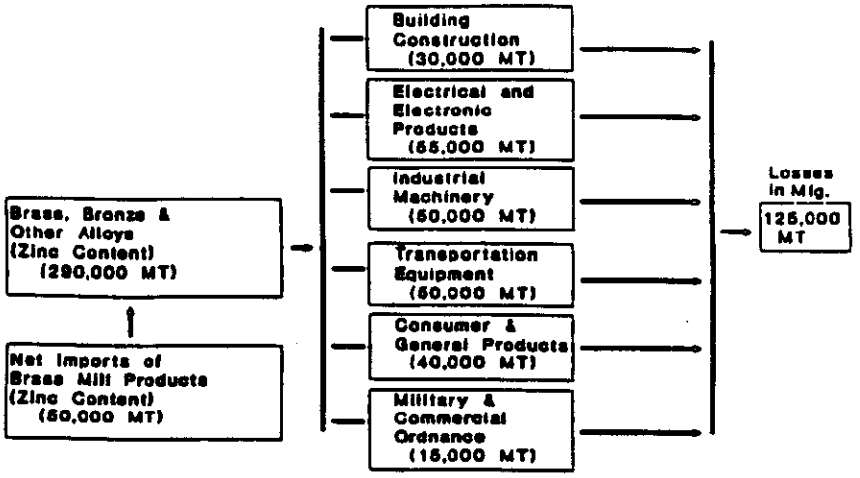


Figure B - 8. Zinc-Based Alloy Uses in 1989

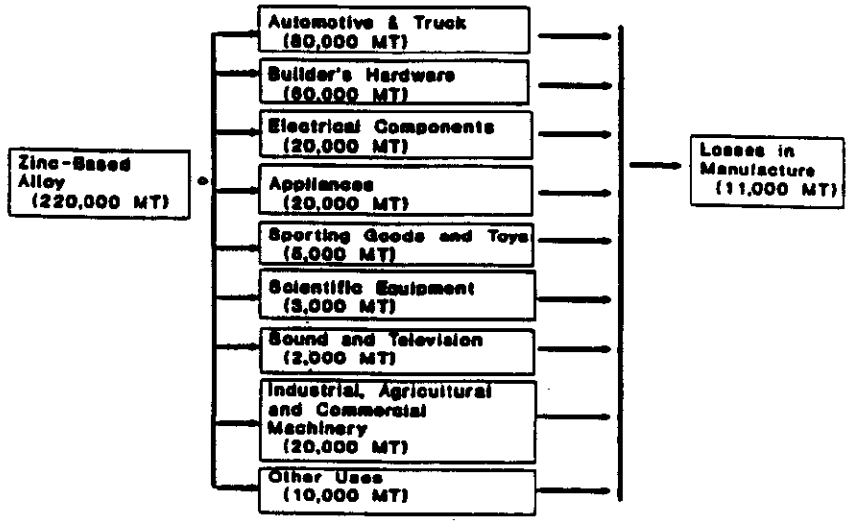


Figure B - 9. Rolled Zinc and Dust Uses in 1989

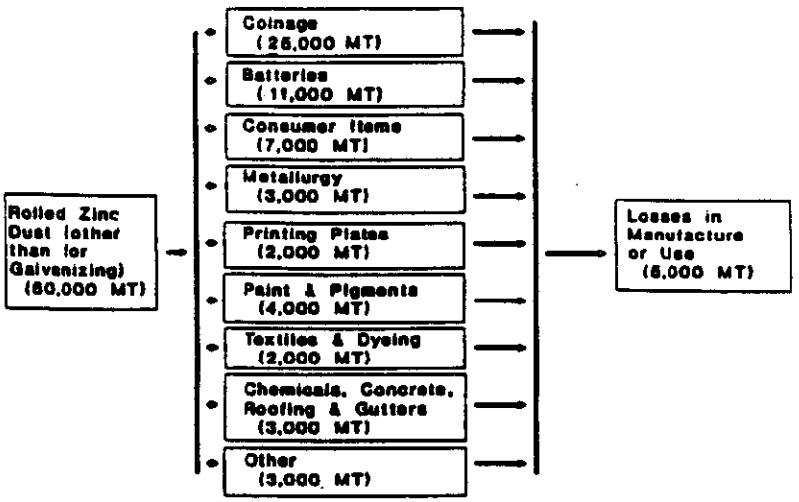


Figure B - 10. Zinc Chemical Uses in 1989

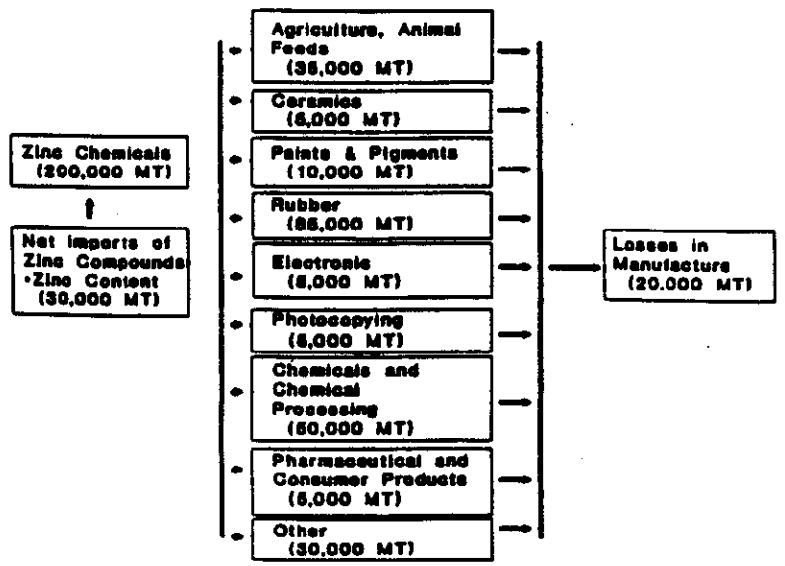
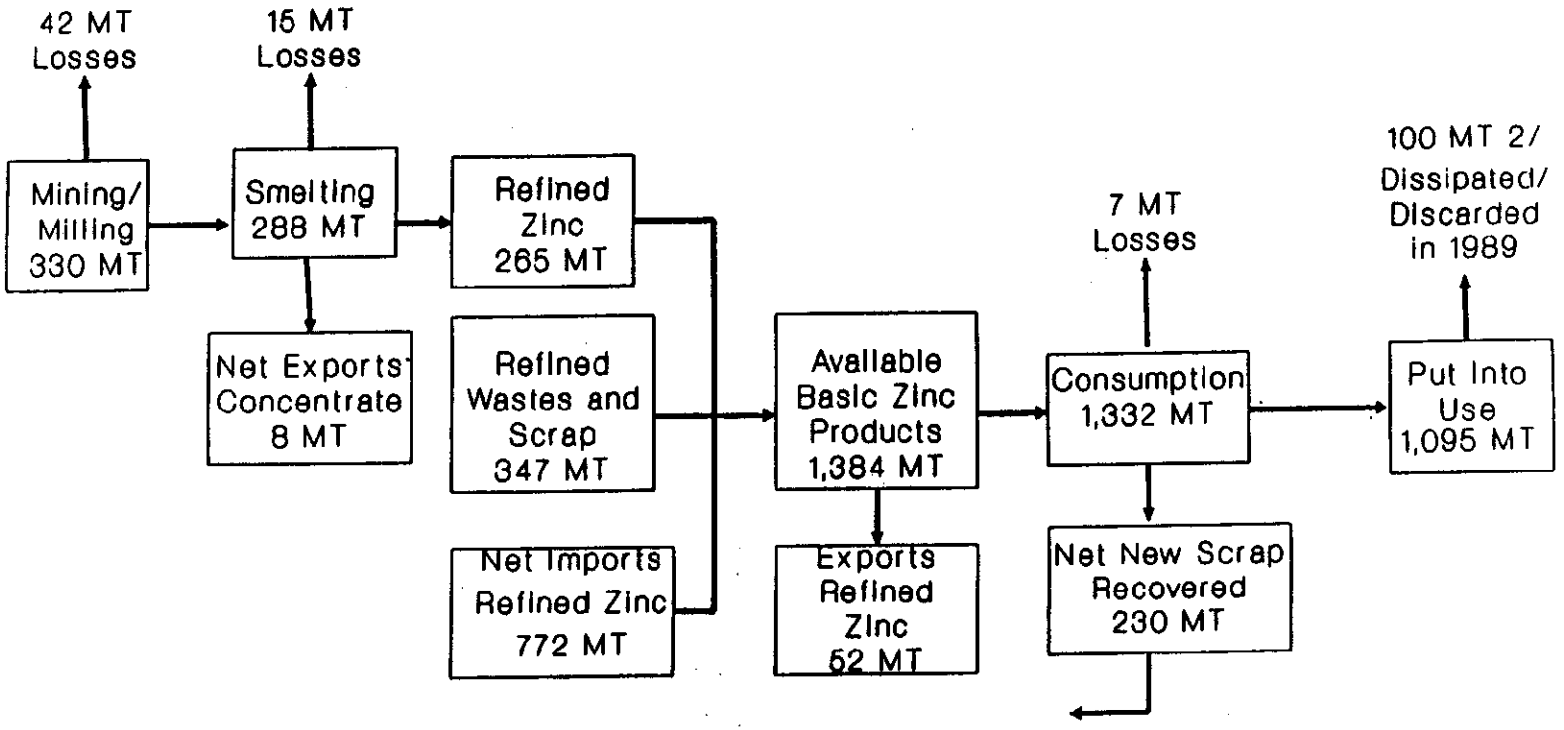


Figure B-11.- Materials flow of zinc in the United States in 1989. 1/

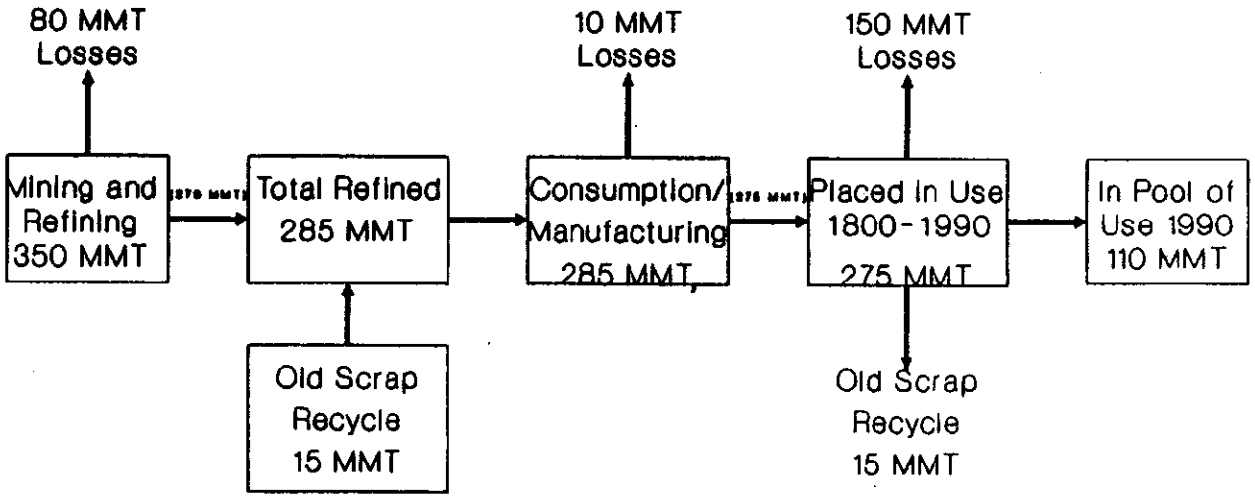


MT - Thousand metric tons zinc
1/Data includes new scrap
2/An additional 740,000 tons of zinc from end products madeprior to 1989 was estimated to have been discarded or dissipated in 1989.

***APPENDIX C.--MATERIALS FLOW OF ZINC FOR THE WORLD 1800-1990

This section contains the historical materials flow of zinc for the world for the 1800-1990 period. The historical world zinc mine and/or smelter production formed the basis for the diagram; it was assummed that production was equal to consumption. Most other sectors in the diagram are estimated based on the U.S. experience in the main study. Refined zinc production and consumption were assummed to be smelter production (slab zinc) plus estimates for ore-sourced zinc compounds and old scrap recycle. Losses of zinc to the environment from production and consumption activities were estimated to be less, percentage wise, for the world as a whole than for the U.S. industry because most of the world's production and consumption occurred outside the United States after World War II. The post World War II period was characterized by increased zinc recoveries at mines and smelters, construction of new, more efficient production facilities, and improved, less wasteful manufacturing technologies. The amount of zinc remaining in the world's pool of use was an estimate based on the fact that 70% of the total world zinc production and consumption has occurred in the past 40 years.

Figure C-1 shows that a maximum 240 million tons of zinc can be considered to have re-entered the Earth's environment from zinc mining, smelting, consumption, use and disposal activities since 1800. Dissipative use and land- fill disposal accounted for 63% of the zinc returned, followed by mining and smelting, 33%,and consumption and manufacturing, 4%.



MMT = Million Metric Tons

Figure C-1. Historical materials flow of zinc for the world, 1800-1990.