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COPPER

A Materials Survey

By A. D. McMahon

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

1965

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OFFICE OF THE DIRECTOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
WASHINGTON, D.C. 20240

January 11, 1965

Hon. Edward A. McDermott
Director
Office of Emergency Planning
Washington, D. C.

Dear Mr. McDermott:

In accordance with the agreement of April 15, 1955, between the Department of the Interior and the Office of Civil and Defense Mobilization, which assigned responsibility to Interior for preparation and revision of Surveys covering 45 mineral commodities, the Bureau of Mines with the cooperation of the Geological Survey has prepared and herewith transmits to you the revision of Copper, A Materials Survey.

Sincerely yours,

Acting Director

Foreword

The Materials Survey series being prepared by the Bureau of Mines, Department of the Interior, under the sponsorship of the Office of Emergency Planning, is designed to present in separate documents a compilation of comprehensive fundamental information for those metals and minerals essential to National Security. These Surveys summarize the demand-supply position in the United States and include information on production, consumption, imports, exports, capacities, substitutes, and pertinent history, usually in some detail back to 1925. The properties and uses of the commodity and its principal alloys and compounds are described. Exploration, mining, metallurgical, and fabrication methods are discussed. Domestic and foreign primary and secondary resources and reserves are covered. An extended presentation of the structure of the industry, employment and productivity, research and development, legislation, taxes, and Government wartime controls is included. Other special data are presented for particular commodities.

This Copper Materials Survey was prepared in the Division of Minerals under the direct supervision of Paul F. Yopes, Chief, Branch of Nonferrous Metals, and Donald R. Irving, Assistant to the Chief, Division of Minerals. The manuscript was reviewed, in whole or in part, by specialists in the Bureau of Mines, Geological Survey, and various segments of the copper industry.

CHARLES W. MERRILL,
Chief, Division of Minerals.

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COPPER

A Materials Survey

By

A. D. McMahon [1]

Introduction

This survey is one of a series of Bureau of Mines publications designed to serve the needs of Government and industry for comprehensive information on mineral commodities and activities.

Copper, a versatile metal, has been vital to all civilizations from prehistoric times to the present. Its essential value in antiquity and until the nineteenth century arose from its malleability and ease of working, its corrosion resistance and durability, its attractive colors in alloyed and unalloyed forms, and, of course, its availability. The principal uses were for tools, utensils, vessels, weapons, pipe, statuary and other objects of art, and for building and architectural purposes where formability, permanence, and beauty were necessary qualities. Utilization of copper based on these physical and mechanical properties has grown tremendously for commercial, structural, mechanical, architectural, and art items; and its capacity for forming numerous alloys has led to a myriad of applications from miniature copper and brass eyelets to huge bronze battleship propellers. The early nineteenth century marks the epoch of the greatest use of copper, transmitting electrical energy. This particular property of copper is fundamental to the spectacular growth of the electrical industry and all associated industries relying on electricity for power, light, and heat. More than half of all copper produced is used for transmission of electricity.

The copper industry has been able to expand along with the mounting demand because of the ever increasing discovery of resources in the world and advances in mining, metallurgical, and fabricating technologies. World production and consumption rose progressively from about 18,000 tons in 1800 to more than 4.5 million tons in 1960. The estimated world reserve of primary copper has more than doubled since 1935, being 212 million tons in 1960. Ninety percent of this reserve is credited to eight countries—the United States, Canada, Chile, Peru, the Soviet Union, Poland, Northern Rhodesia, and the Republic of the Congo. The United States share is 32.5 million tons of copper in ore, averaging approximately 0.9 percent.

Another reserve being accumulated in the industrial countries of the world is copper products now in use that will eventually be discarded as scrap and become available for recovering secondary copper. In the United States this resource of more than 30 million tons, provides about one-fourth of the annual supply.

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Work on manuscript completed July 1963.

The ores of copper are classified as sulfide or oxidized ores. They are further distinguished by copper content, type of copper-bearing mineral, mode of occurrence, and associated minerals; and they may be designated as high grade or low grade, primary or secondary, or disseminated, replacement, vein, massive sulfide, native copper, and complex. Although many copper minerals are known, relatively few are commercially significant. The predominant copper sulfide minerals found in the sulfide ore deposits of the world are chalcopyrite, chalcocite, bornite, enargite, and covellite; the principal oxidized minerals are chrysocolla, malachite, and azurite. Antlerite, atacamite, and brochantite are important oxidized ore minerals of some deposits in Chile. The copper-bearing ores of many deposits contain significant values in minerals of other metals that are recovered as byproducts or coproducts in concentrating, smelting, and refining processes. Metals recovered from copper ores as byproducts include iron, lead, zinc, molybdenum, nickel, cobalt, gold, silver, the platinum group metals, selenium, tellurium, and arsenic.

Most copper ores are mined from large low-grade deposits, which are the source of about 80 percent of the annual world production of primary copper. The economical recovery of copper from such ores requires mass extraction and treatment processes. Deposits near the surface are worked by open-pit mining; caving or other large-scale mining methods (cut and fill, shrinkage stoping, room and pillar) are used for underground mining of deep ore bodies. The metallurgical processes for recovering copper metal from its ores are concentrating, smelting, and refining for sulfide ores and leaching followed by chemical precipitation or electrowinning for oxidized ores. The final refinery product is almost pure copper (99.9+ percent) in refinery shapes (wirebars, billets, cakes, slabs, ingots, and ingot bars), which are used for producing copper wire and copper and copper-base alloy, semifabricated products such as strip, sheet, plate, tube, rod, and shapes. Figure 1 illustrates the sequence of operations followed to obtain copper products from copper ore.

The largest copper producer and consumer in the world throughout the 1925–62 period was the United States. Before World War II mine production and the recovery of secondary copper were adequate for domestic requirements and provided substantial quantities for export. When the United States entered World War II, however, large supplies of copper were required from abroad and the United States became a net importing nation. This situation continued through 1960.

Approximately one-half of the total United States supply of copper is derived from domestic mine production; a little more than one-fourth is obtained from imports; and about a fourth is secondary copper recovered from old scrap. Mine productive capacity in the United States has not changed substantially since World War I, according to peak production years associated with the wars and other times of increased industrial activity. Beginning with 1916 the mines produced about 1 million tons of copper annually in 1916, 1929, 1942–43, 1955–57, and 1960–63. However, because of the development of more efficient mass mining techniques and equipment, mine productivity, in output of copper per man hour, has increased almost fivefold.

Secondary copper is produced from new and old scrap, the two general classes of scrap copper. Old scrap consists of metal articles that have been discarded because of wear, damage, or obsolescence, usually after serving a useful purpose. New scrap is generated in manufacturing items for consumption and reenters the processing and fabrication cycle as run-around copper which does not contribute to new supply. Only copper from old scrap, whether in unalloyed or alloyed form, is a real addition to supply. There has been no sustained increase in the supply of secondary copper for many years. Since 1941 the recovery of copper from old scrap has fluctuated mostly between 400,000 and 500,000 tons a year, reaching a maximum of 515,000 tons in 1955—a period of high prices for copper.

Imports have come largely from properties owned by U.S. investors in Mexico, Chile, and Peru and from Canada. Chile has been the principal source, followed in order by Canada, Peru, and Mexico. In recent years significant quantities were furnished by Northern Rhodesia, the Republic of South Africa, and the Philippines. The United States exports refined copper to many countries—most of it destined for the United Kingdom, West Germany, Italy, France, and Japan.

Consumption of copper in the United States was at its highest during World War II. Since then, except for a few years, it has followed a declining trend caused to a marked degree by the substitution of aluminum, steel, plastics, and copper-clad materials for large-use items. The predominant users of copper are the electrical industry, the building construction and automotive industries, and manufacturers of industrial equipment and supplies. Wire mills and brass mills usually account for more than 95 percent of total consumption, wire mills having 50 percent or more in most years.

World consumption of copper increased almost 50 percent from 1954 through 1962, principally because of the flourishing industrial activity in Europe and Japan. The resultant new demand was met by a similar growth in world production, largely from expanded output in Canada, Chile, Peru, Northern Rhodesia, the Republic of the Congo, U.S.S.R., China, Australia, and the Philippines.

In the United States approximately 200 firms are engaged in producing and selling primary copper. Principal segments of the industry are mining, smelting, refining, fabricating, and marketing. The million tons of primary copper produced annually comes from large operations. Of 196 copper mines reporting production in 1962, the 25 largest mines accounted for 97 percent of the total output; the first 10 produced 74 percent, and the first 5, 48 percent.

A total smelting capacity of 8,800,000 tons is provided by 20 smelters and the total refining capacity consists of 1,963,500 tons at 12 electrolytic refineries and 371,000 tons at 6 fire refineries. About 35 companies in the United States are recognized as the important fabricators and users of primary copper; this they process into copper and copper alloy forms of sheet, strip, rod, tube, wire, and extruded and rolled shapes. Some of the larger fabricators are affiliated with the major copper producers who thus have facilities for processing ores from the mines to the finished copper and brass products.

Recovery of scrap copper constitutes an important branch of the copper industry in the United States. Old scrap collected by hundreds of scrap dealers is processed into secondary copper by primary smelters and refineries, secondary smelters (brass and bronze ingot makers), and copper mills.

Government legislation and programs involving segments of the copper industry usually comprise regulation, taxation, or aid to promote economic stability or to maintain national security. Some examples are the mining laws that regulate title, exploration, development, and extraction of ores from deposits on Government or Indian lands; import taxes levied for protection from foreign competition and reduction or suspension of such taxes for trade considerations; tax concessions granted mining enterprises for depletion in the Internal Revenue Code; laws regulating malpractices in securities and financial markets and prohibiting activities restraining trade, monopolies, and unfair trade practices. In emergency periods, such as World War II and the Korean War, price, export, import, distribution, and use controls were established for copper. Public Law 520, July 23, 1946, authorized acquisition of strategic and critical materials (including copper) for the Strategic Stockpile, and the Defense Production Act of 1950 provided for Government assistance in exploration of copper deposits, development and production loans, and guaranteed price contracts.

The copper supply outlook for the near future in the United States is encouraging. This view is based on an estimated ore reserve containing 32½ million tons of copper, an annual availability from secondary sources (old scrap only) of 450,000 tons, and a reserve of 1,142,000 tons of copper in the national stockpile. Also, the increased ore reserves and expanded copper production in Canada, Chile, and Peru provide ample sources of imports in the Western Hemisphere.

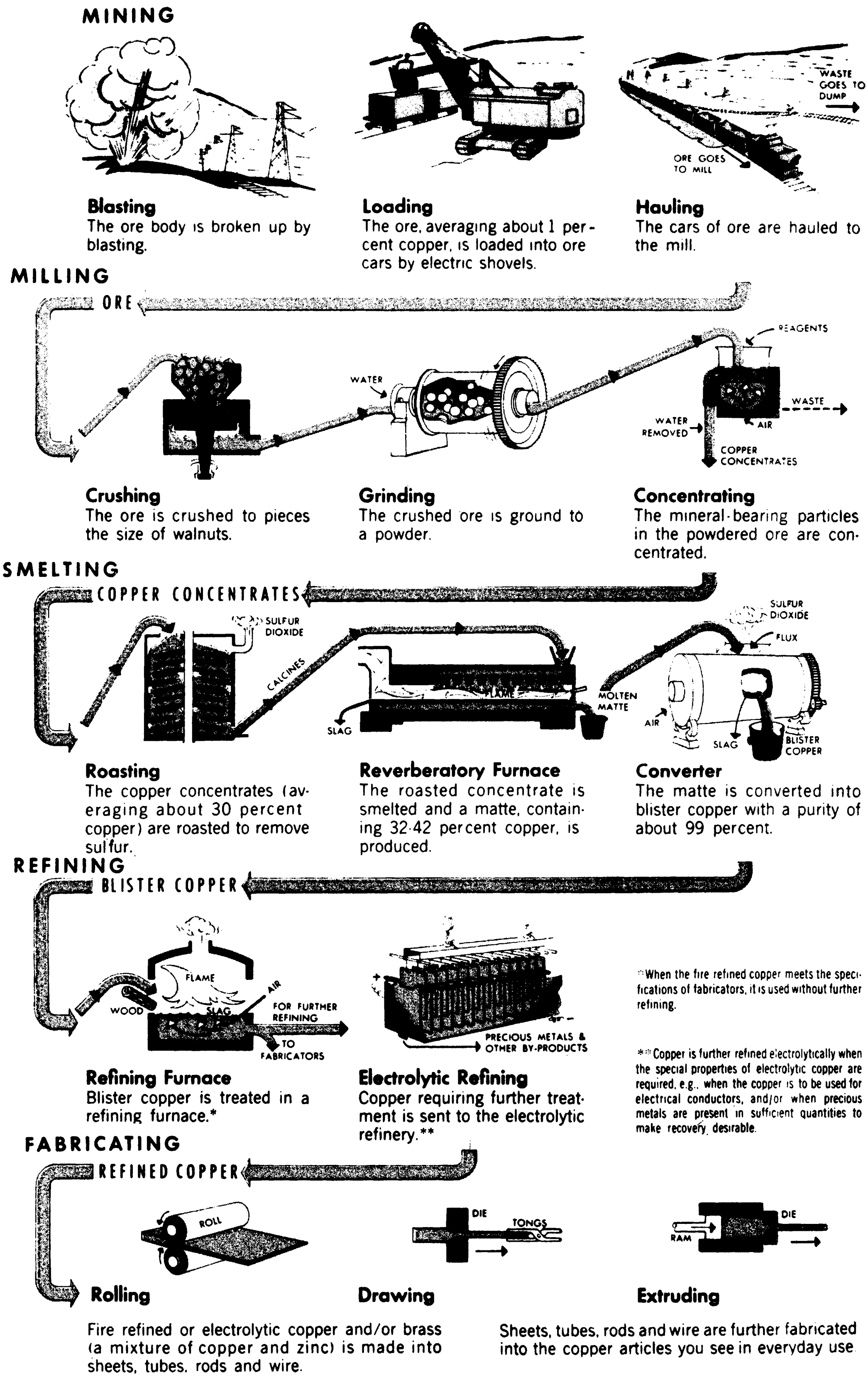

FIGURE 1.—Basic Steps—Copper Ore to Finished Product.

(Courtesy, Kennecot Copper Corp.)

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CHAPTER 1.—PROPERTIES, COMMERCIAL CLASSIFICATIONS, AND USES OF COPPER AND COPPER BASE ALLOYS

NATURE OF THE METAL

Copper is one of the few common metals that finds its greatest application in the commercially pure rather than the alloyed form, principally because of its superior performance as a conductor of electricity. However, metals such as zinc, tin, and others readily alloy with copper to form the widely used brasses and bronzes. Copper is an important alloying element in a large number of alloys having metals other than copper as the principal component and copper and copper-base alloy powders are formed into structural parts. This versatility and the exceptional service qualities inherent in the metal are responsible for its important role in the industrial economy.

PROPERTIES OF COPPER

The properties of copper having major significance are its high-electrical and thermal conductivities, corrosion resistance, good ductility and malleability, and high strength. In addition, copper has a pleasing color, is nonmagnetic, and is easily finished by plating or lacquering; it can be welded, brazed, and soldered satisfactorily. Certain of these basic properties can be improved for many applications by alloying with other metals. As a consequence the popular commercial brasses, bronzes, copper-nickel alloys, and nickel silvers have been developed.

Physical constants of copper:

Chemical symbol	Cu
Atomic number	29
Atomic weight	63.54
Valence	1 & 2
Crystal structure	Face-centered cubic.
Density, annealed, 20° C	8.89
Hardness, Moh	2.5–3
Melting point, ° C	1083
Boiling point, ° C	2595
Electrical resistivity, 20° C, microhm-cm., annealed	1.71

Physical.—Copper is the only metallic element besides gold having a rich natural color other than some shade of gray. The distinctive red color of metallic copper is best seen on a fresh or polished surface. Copper precipitated from solution is brownish red and the colloidal metal ranges from crimson or scarlet to various shades of blue and brown. Thin films of copper appear greenish-blue by transmitted light; molten copper has a golden color; and copper vapor is green. The compact metal has a bright metallic luster and takes a bright polish, which soon tarnishes when exposed to air. Old surfaces often have an orange tinge due to a film of cuprous oxide (Cu_2O). Full oxidation of a surface causes formation of a film of the black cupric oxide (CuO). Extended exposure to weathering produces a green (patina) surface deposit which varies depending on the atmosphere but the principal constituent is basic copper sulfate with traces of basic copper carbonate (malachite) for most atmospheres. Near salt water the amount of sulfate may be sharply reduced, with the carbonate increased substantially, and large amounts of basic copper chloride (atacamite) are included. In rare instances, basic copper nitrate has been reported where copper is exposed near power stations.

Grain size, fabricating method, and mechanical surface treatments (polishing, buffing, and vapor blasting) also affect the finished color. Combinations of alloy and mechanical treatments provide an unusual range of natural color finishes for copper; chemical treatments provide additional colors and finishes.

The density of commercial coppers ranges from 8.4 to 8.94 grams per cubic centimeter. Cast tough-pitch copper contains about 3 to 5 percent voids or gas holes, by volume, and such copper will have an apparent density of 8.4 to 8.7. The voids close during rolling; after working and annealing the density of tough-pitch copper is 8.89 to 8.94, depending on the residual oxygen content. Copper containing 0.03 percent oxygen has a maximum density of 8.92, and values as high as 8.9592 have been obtained for pure copper. The density of liquid copper is 8.22 near the freezing point. The shrinkage of copper on solidification is 4.96 percent.

Electrical.—The high electrical conductivity of copper, more than anything else, accounts for its widespread use in the electrical field. Only one metal, silver, is a better conductor in cross-section. Since aluminum has higher conductivity by weight, it is the principal rival of copper for certain types of electrical installations.

The conductivity of copper is expressed in percentages, thus providing a convenient measure of quality for electrical purposes and for comparison with other metals. The basis for rating is a mass conductivity standard adopted in 1913 by the International Electrotechnical Commission and subsequently by the American Standards Association, American Society for Testing Materials, and other bodies. The standard mass resistivity is 0.15328 ohm (meter, gram) at 20° C; that is, a copper wire 1 meter long, weighing 1 gram, and having a resistance of 0.15328 ohm at 20° C. The value of 100 is assigned to the reciprocal of this standard resistivity, and conductivities of other specimens are stated in percentages of this conductivity. This standard conductivity is designated the International Annealed Copper Standard (IACS). A standard density of 8.89 grams per cubic centimeter was also adopted to permit expression of the standard in terms of both mass and volume units as in the following equivalents:

0.15328 ohm (meter, gram), 875.20 ohms (mile, pound); 0.017241 ohm (meter, sq. mm), 1.8241 microhm (cm, cm^2); 0.67879 microhm (in, in^2), 10.371 ohms (ft, mil)—all at 20° C.

ASTM specifications require all copper intended for electrical use to meet a 100-percent conductivity minimum. Commercial coppers designated for electrical purposes have conductivities between 100.5 and 101.8 percent. Very high purity copper prepared for research use has a conductivity of 102.3 percent.

The electrical resistivity of metals increases with temperature, the average change for copper between 0° and 100° C. being 0.42 percent for each degree. At extremely low temperature the electrical resistance almost vanishes for copper (and other metals). Some resistivity values at temperatures from almost absolute zero (−273° C) to that of molten copper are:

Temperatures, °C:	*Resistivity, microhm-cm*
−258.6	0. 014
−206.6	. 163
−150	. 567
−100	. 904
+20	1. 7241
+100	2. 28
+200	2. 96
+500	5. 08
+1,000	9. 42
+1,500 (liquid)	24. 62

Source: Handbook of Chemistry and Physics, 1960–61, The Chemical Rubber Publishing Co., Cleveand, Ohio, 42 ed., 1960, p. 2590.

Copper may be cold worked to great extremes with but a slight loss of electrical conductivity, compared to losses in brasses and other alloys. The most severe cold working does not reduce the conductivity more than 3 percent.

The conductivity of copper by weight is surpassed by several light metals, notably aluminum. Relative conductivity values for silver, copper, and aluminum by volume and weight are:

Metal:	*Conductivity percent by— Volume*	*Weight*
Silver	100	44
Copper	94	50
Aluminum	57	100
Iron	16	---

Thermal.—Copper is the second best heat conductor of all metals, again being surpassed only by silver. Comparative values for thermal conductivity for different metals at room temperature (18° C) are as follows:

Heat Conductivity, cal/cm/cm^2/sec/° C:	
Silver	1. 006
Copper	. 934
Gold	. 705
Aluminum	. 480
Iron	. 161

Important thermal constants of copper are:

Melting point	1083.0° C (1981.4° F)
Boiling point	2595° C (4703° F)
Latent heat of fusion	48.9 cal/gram (89.8 Btu/lb)
Heat capacity	.0919 cal/gram/° C
Linear coefficient of expansion.	16.42 x 10^{-6}/° C
Thermal conductivity, 18° C.	.934 cal/cm/cm^2/sec/° C

Mechanical.—One or more of the qualities of strength, hardness, ductility, malleability, and ease of joining usually are desired with the other physical and chemical properties of copper. The properties denoting plastic deformation are rated highest, and those referring to strength are rated lowest in fully annealed metal.

Pure copper is not particularly strong or hard in the annealed condition, but both strength and hardness are increased considerably by cold working. Commercial coppers in the annealed state have tensile strengths from 32,000 to 35,000 pounds per square inch. Values to 75,000 psi have been obtained for severely cold worked copper. Annealed copper has a Brinell hardness of about 42, which can be increased to more than 100 by cold working. Copper is little hardened by quenching or other heat treatment. The tensile strength and elongation values obtained by cold working the three basic commercial types (tough pitch, deoxidized, oxygen free) are identical from a practical standpoint. This equivalence in mechanical properties is responsible largely for continuance of the historical tendency to consider both oxygen- and phosphorus-bearing coppers as commercial forms of the metal, and to reserve alloy designation for products having more pronounced alteration of physical characteristics.

Annealed or hot-rolled electrolytic tough-pitch copper is very ductile. High purity copper is so ductile that it is difficult to determine the existence of a finite limit beyond which it cannot be cold worked. (No evidence of such a limit has been observed in wires drawn 99.4 percent, which had developed a tensile strength of 75,000 psi.) Copper is very malleable which allows the rolling or hammering of the fully annealed metal into very thin sheets without cracking. Although there are apparently no quantitative criteria for measuring malleability, copper compares favorably with gold and silver in acceptance of plastic deformation without rupture.

Soft copper has very little elasticity or resilience, but cold working increases values for both properties. Soft copper has an elastic limit or yield point of 3,000 to 17,000 psi, depending on the convention used in defining these terms; there is little true elasticity, and even small loads may produce some permanent deformation. Cold-rolled copper has a yield point of 40,000 to 55,000 psi, and the Young modulus for hard copper is about 16 million psi.

The endurance limit, which is the maximum stress a metal will withstand without failure during numerous cycles of stress, is 11,000 psi for annealed copper. This can be increased by work hardening to 15,000 psi for tough-pitch copper and to 19,000 psi for deoxidized copper.

Copper and many of its alloys may be joined by welding, brazing, and soldering. The welding of oxygen-bearing copper requires special techniques because the high temperature of the heated zone may cause rejection of the cuprous oxide to grain boundaries, weakening the area. Success has been reported with fast welding processes when the welding time is so short that virtually no oxide segregates, or when the segregation is so minor that the strength of the joint is not seriously impaired. Such processes are helium- or argon-shielded arc welding, a resistance in air method, and use of a gas torch with a slightly oxidizing flame. Deoxidized and oxygen-free coppers are readily joined by arc- and gas-welding processes and brazing. Properly welded joints in oxygen-free copper will have strength and ductility about 90 percent of the annealed strength of the base metal. The properties of the weld may be greatly improved by cold working.

The oxygen-bearing, deoxidized, and oxygen-free coppers are readily joined by torch, furnace, dip, and twin-carbon-arc brazing processes, using either copper-phosphorus or silver-alloy types of brazing filler metals. (ASTM B260-56T and AWS A5.8-56T specifications for brazing filler metal.) By proper selection of the brazing process and filler metal it is possible to braze oxygen-bearing copper without loss of strength due to copper oxide segregation.

Soldering with the common types of tin-lead solders is an effective and simple way of joining sections of copper. Selection of a particular solder will usually depend upon the operating temperature and other working conditions of the required service as well as economic considerations.

Copper may be clad on other metals or may be clad with other metals, in each instance to achieve some special purpose. Copper cladding on steel is used to reduce the overall cost or to increase the strength while maintaining the high conductivity of copper. Copper cladding of aluminum combines the lightness of that metal and the conductivity of copper. Copper is clad with certain silver brazing alloys to facilitate the brazing of special types of tools and improve their performance.

Chemical.—Copper has an atomic number of 29 and an atomic weight of 63.54. It is the first member of subgroup IB of the periodic table, being followed by silver and gold. Each of these three metals form a univalent series of salts, but copper also forms a bivalent series and gold a trivalent series that are more stable than the corresponding univalent compounds. The electronic configuration of copper is 2:8:18:1. Loss of the outermost electron produces the cuprous ion Cu^{+}, and a second electron may be lost in the formation of the cupric ion Cu^{++}. The formation of these two ions is an important factor in considering the corrosion behavior of copper. There are two stable isotopes of copper, Cu^{63}, consisting of 29 protons and 34 neutrons, and Cu^{65}, with 29 protons and 36 neutrons. There are also known to be at least eight unstable (radioactive) isotopes having the mass numbers 58, 59, 60, 61, 62, 64, 66, and 67.

Some of the characteristic features of the metals in this group are:

1. They occur as native metal and may be separated from compounds with relative ease.
2. They are not very active chemically. As the atomic weight increases, the chemical activity decreases.
3. Copper and silver oxidize very slowly in air at ordinary temperatures.
4. Their oxides and hydroxides are slightly basic.
5. They form insoluble chlorides, for example, CuCl.

6. Complex ions are readily formed, for example, $[Cu(CN)_2]^-$.

7. Complex cations are formed with ammonia, for example, $[Cu(NH_3)_4]^{++}$.

One of the main reasons for the wide use of copper and copper-base alloys is the excellent resistance to corrosion displayed in a wide range of environments. Copper possesses very high resistance to the atmosphere; to naturally occurring waters, both fresh and salt; and to alkaline solutions, except those which are distinctly ammoniacal. Behavior of copper in acids is greatly dependent upon oxidizing conditions which affect it adversely. It has good resistance to many saline solutions. However, copper offers low resistance to sulfur and sulfur compounds, producing a corrosion product of copper sulfide. It may be seriously damaged by solutions such as sea water and brine when these move against it at high velocities.

Copper rarely corrodes through galvanic action as a result of contact with other metals. In the electromotive series of elements, copper is near the noble end and normally will not displace hydrogen from acid solutions. Copper is cathodic to the commonly encountered metals—tin, lead, nickel, iron, zinc, aluminum, and magnesium—that can be used to displace copper from solutions of its salts. Mercury, silver, palladium, platinum, and gold—being below copper—can be displaced from their salt solutions by metallic copper. There are many conditions, however, in which displacement does not proceed in accordance with the common electromotive series. The potential differences between dissimilar metals vary, depending upon the nature of the corrosive environment.

The crystal structure of copper is face-centered cubic, the cube side being 3.6078 A at 18° C; the closest distance of approach of atoms, 2.551 A. This is a close-packed structure, being one of two possible structures formed by the closest possible packing of uniform spheres. Each atom has 12 equidistant nearest neighbors. The structure has the highest degree of atomic concentration and symmetry to be found in any crystal structure.

Common gases such as O_2, CO, SO_2, and H_2 dissolve in molten copper. Some of these gases undoubtedly react with the copper or with other compounds; thus dissolved oxygen is probably in equilibrium with Cu_2O:

$$4Cu + O_2 \rightleftharpoons 2Cu_2O,$$

and reducing gases such as CO and H_2 react with Cu_2O to form copper, CO_2, and H_2O. The nature and amount of gas remaining in copper just before it solidifies markedly affects the properties of solid copper.

Copper will dissolve in most acids when aided by oxidizing action to form soluble copper salts. Copper also forms complex salts with ammonium compounds and with cyanides. In the complex copper-ammonium salts the copper is in the form of a cuprammonium ion which has a deep-blue color. Cupric ions impart a greenish-blue color to the solution; cuprous ions are colorless.

Examples of complex cyanides are the soluble sodium and potassium salts $NaCu(CN)_2$ and $KCu(CN)_2$. In these salts the copper is present in the negative ion $[Cu(CN)_2]$; these complex cyanides are used in electrolytes for electroplating copper.

Cupric chloride forms a soluble double chloride with ammonium chloride—$CuCl_2.2NH_4Cl.2H_2O$. The insoluble cuprous chloride forms a similar compound with ferrous chloride, and this makes possible the dissolving of cuprous chloride in brines of ferrous chloride.

Copper is fungitoxic and is used more in preparing agricultural fungicides than any other metal. Compounds of other metals (silver, mercury, cadmium, and others) may be more effective fungicides but the popularity of copper compounds is largely due to a fairly high degree of fungitoxicity, a low toxicity for most higher plants and animals, and a lower price than most other metals of comparable effectiveness in disease control.

Effects of Impurities.—The conductivity, tensile strength, and other properties of copper are affected to varying degrees by the presence of impurities which may either (1) be dissolved in the copper in solid solution or (2) be insoluble in solid copper. The most important of those in the first class are nickel, iron, arsenic, antimony, and phosphorus. The second group includes bismuth, lead, selenium, tellurium, sulfur, oxygen, and oxides.

Oxygen is present in all commercial copper, except in the deoxidized and oxygen-free grades. Its effect on the mechanical properties is not great, slightly increasing the tensile strength and reducing the ductility as the oxygen content increases. In small amounts oxygen increases the electrical conductivity of commercial copper, very likely by oxidizing other impurities and thus removing them from solid solution. Large amounts of oxygen, however, reduce the conductivity by forming copper oxide, reducing the effective cross section of the metal.

Sulfur, selenium, and tellurium, in general, affect the mechanical properties of copper adversely. In amounts to 1 percent, selenium and tellurium may be used for increasing machinability.

Bismuth also has a harmful effect on the mechanical properties of copper; it interferes seriously with hot rolling and slightly with cold rolling. Its effect may be partly neutralized by additions of oxygen, arsenic, and antimony. It is almost completely insoluble in copper.

On the whole, antimony is another harmful metal, although it is sometimes added to copper when high recrystallization temperatures are desired. In amounts of 0.5 percent and higher it hardens copper, decreases its ductility, and lowers its electrical conductivity. Antimony is similar in effect to phosphorus and arsenic and is intentionally added in small amounts (0.02–0.10 percent) to some high-brasses for increasing resistance to dezincification.

Arsenic is added intentionally to 0.6 percent because of its slight hardening and strengthening effect, especially in the cold-worked condition. It raises the recrystallization temperature but has little effect on the ductility and malleability. It decreases the electrical conductivity considerably. Arsenic is an excellent inhibitor of corrosion by dezincification in leaded muntz metal, admiralty brass, naval brass, and aluminum brass; 0.02 to 0.10 percent is added to these alloys for that purpose. It is not useful in the alpha-beta brasses because it does not inhibit dezincification of the beta phase.

Next to oxygen, silver is the most common element in commercial copper. It has negligible effect on the mechanical properties and electrical conductivity but significantly increases the recrystallization temperature and prevents softening of cold-worked material by short time exposure to heat.

The small amount of iron normally present in commercial copper has very little effect on its mechanical properties. In larger amounts, to 2 percent, it hardens and strengthens copper slightly without destroying ductility, but it reduces the electrical conductivity, especially in the absence of oxygen.

Lead is sometimes added in small amounts to copper to increase its machinability, but it should not exceed 0.005 percent if the copper is to be hot rolled; otherwise it will cause "hot shortness." If operations are conducted at room temperature, still larger amounts have little effect on the ductility of copper. It can be rendered somewhat less harmful by introducing oxygen.

Gases have a great effect on the physical properties of copper, especially in castings. Hydrogen is very soluble in liquid copper but will not cause unsoundness in copper castings, in the absence of oxygen, unless the solubility in the solid state, which is high, is exceeded. Carbon monoxide is probably soluble in solid and liquid copper to about the same extent and in the absence of oxygen is not harmful. Both carbon dioxide and nitrogen behave as if they were insoluble in copper. The influence of gases in copper is a complex problem of great importance to producers of copper castings. On the whole, the amount of gas evolved in casting should exactly neutralize the natural shrinkage of the metal on passing from the liquid to the solid state.

PROPERTIES OF COPPER POWDERS

The quality of metal-powder parts depends upon properties of the powders used. The most important of these properties are:

Purity.—Clean particle surfaces insure good contact between particles (needed for optimum mechanical properties). The presence of foreign particles must be held to a minimum, usually specified.

Apparent Density.—Apparent density (sometimes bulk density) is the weight of the unit volume of powder and is of particular importance in the pressing operation. The lower the value, the greater the volume needed for a part of given size.

Compressibility.—Compressibility (ratio of volume of loose powder to volume of compact) is important for both fabrication and end properties and is affected by physical characteristics of powder particles and distribution of particle size. Particle-size distribution affects press feed, dimensional changes during sintering, porosity of the compact, and final attainable density and strength.

Flow Rate.—The ease with which a metal powder can be fed into the die is determined by its flow rate. Low flow rates retard automatic pressing and may require the use of vibrating equipment.

Sintering Properties.—Sintering is usually done either in an inert, reducing, or neutral atmosphere or in a vacuum. The sintering temperature of metal powder is critical; when metal-powder compacts are sintered, either in the solid state or in the presence of a minor portion of a liquid phase, suitable physical and mechanical properties must be obtained within predictable and reproducible dimensions.

Green Strength.—This is the property of the powder to be handled without breakage after compacting and before sintering.

Mechanical and physical properties of sintered parts are closely related to the final density that can be achieved. As the density of a metal powder part increases, strength also increases, and at a density of 100 percent the properties theoretically will be at least equal to those of solid stock.

COMMERCIAL CLASSIFICATION

By Method of Refining

The broadest commercial classification of copper is related to the method by which it is refined. Thus, copper is described as electrolytic or fire refined:

Electrolytic Copper.—Copper which has been refined by electrolytic deposition, including cathodes which are the direct product of the refining operation; refinery shapes cast from metal cathodes; and products of fabricators made therefrom. Usually when this term is used alone, it refers to electrolytic tough-pitch copper without elements other than oxygen being present in significant amounts.

Fire-Refined Copper.—Copper that has been refined by a furnace process only, including refinery shapes and products of fabricators made therefrom. Usually when this term is used alone, it refers to fire-refined, tough-pitch copper without elements other than oxygen being present in significant amounts.

By Method of Casting or Processing

There are three basic classes of commercial copper. They are known as tough-pitch copper, oxygen-free copper, and deoxidized copper; there are several types of each available in refinery shapes and wrought and cast products. Seventeen types are recognized by the American Society for Testing Materials in its "Classification of Coppers" which bears the designation B 224–58. This classification is shown in table 1.

Tough-Pitch Copper.—Copper, that is, either electrolytically refined or fire refined, cast in the form of refinery shapes, and that contains a controlled amount of oxygen for obtaining a level set in the casting. The term is also applicable to the products of fabricators' products made therefrom.

The types of tough-pitch copper designated by the American Society for Testing Materials are: Electrolytic tough-pitch (ETP); fire-refined, high-conductivity tough-pitch (FRHC); fire-refined, tough-pitch (FRTP); arsenical tough-pitch (ATP); silver-bearing, tough-pitch (STP); silver-bearing, arsenical tough-pitch (SATP); and casting (CAST). ETP, FRHC, and STP are high conductivity coppers and the only types used for casting wire bars (table 1).

Tough-pitch copper can be cast with a level, set by adjusting the oxygen content between normal limits of 0.02 to 0.05 percent. Because of its adaptability to high-tonnage melting and casting techniques it is the least expensive kind to produce and has long been the standard variety for producing wire, rod, plate, sheet, and strip. The presence of oxygen affects the mechanical properties to some degree, while rendering certain impurities insoluble by converting them to oxides. The scavenging effect is beneficial both to high conductivity and to low-annealing temperature.

Oxygen-Free Copper.—Electrolytic copper that is free from cuprous oxide, produced without using metallic or metalloidal deoxidizers. By extension, the term is also applicable to fabricated products. The types of oxygen-free copper are as follows: Oxygen-free without residual deoxidants (OF), oxygen-free phosphorus bearing (OFP), oxygen-free phosphorus and tellurium bearing (OFPTE), oxygen-free silver bearing (OFS), oxygen-free tellurium bearing (OFTE). The OF and OFS types are high-conductivity coppers.

Oxygen-free copper is produced either by melting selected cathodes in the presence of carbon or carbonaceous gases and then casting in a reducing atmosphere or by coalesence of specially prepared and treated cathodes under heat and pressure. In the former method, the impurities are alloyed by the melting operation, resulting in higher annealing temperatures than are encountered with the tough-pitch variety. The net change in conductivity is negligible, however, since the tendency for loss caused by increased solubility of impurities can be offset by gains from elimination of cuprous oxide and regulation to allow partial oxidation of some of the impurities, notably iron. It can also be modified during production by additions of silver, phosphorus, and so forth.

Coalesced copper (PDCP) is made by compressing specially prepared granular cathodes in a reducing atmosphere while hot and then without previous melting by extruding through a die into commercial shapes. The impurities mechanically trapped in the original cathodes are physically dispersed in unalloyed form in the extruded products. As a result, oxygen-free copper produced by this method has a conductivity advantage of several tenths of a percent, and a low-annealing temperature. It is extruded to sizes for mill finishing and thus is not available in many of the standard dimensions associated with refinery shapes produced by casting. Alloying additions are also precluded by the nature of operations. The extrusion operation provides an excellent surface, free from laps and slivers which may act as points of weakness in insulated coatings. Consequently, a large proportion of coalesced copper is used for manufacturing conductors into wire, flatwire, bar, and strip. The products are also characterized by high-residual ductility, resistance to hydrogen embrittlement, and suitability for metal to glass seals.

Deoxidized Copper.—Copper cast into refinery shapes, freed from cuprous oxide by

TABLE 1.—*Classification of copper*

Class and type	ASTM designation	Forms in which available							
		From refiners				From fabricators			
		Wire bars	Billets	Cakes	Ingots and ingot bars	Flat products	Pipe and tube	Rod and wire	Shapes
Tough pitch:									
Electrolytic	ETP	X	X	X	X	X	X	X	X
Fire refined, high conductivity	FRHC	X	X	X	X	X	X	X	X
Fire refined	FRTP	------	X	X	X	X	X	------	X
Arsenical	ATP	------	X	X	------	X	X	X	------
Silver bearing	STP	X	X	X	X	X	X	X	X
Silver-bearing arsenical	SATP	------	X	X	------	X	X	------	------
Casting	CAST	------	------	------	X	------	------	------	------
Oxygen free:									
Without residual deoxidants	OF	X	X	X	------	X	X	X	X
Phosphorus bearing	OFP	X	X	X	------	X	X	X	------
Phosphorus and tellurium bearing	OFPTE	------	X	------	------	------	------	X	X
Silver bearing	OFS	X	X	X	------	X	------	X	X
Tellurium bearing	OFTE	------	X	------	------	------	------	X	X
Deoxidized, phosphorized:									
High-residual phosphorus	DHP	X	X	X	------	X	X	X	X
Low-residual phosphorus	DLP	------	X	X	------	X	X	X	X
Silver bearing	DPS	------	X	X	------	X	X	------	X
Arsenical	DPA	------	X	------	------	X	X	------	------
Tellurium bearing	DPTE	------	X	------	------	------	------	X	X

Source: ASTM Standards 1961, pt. 2, Non-Ferrous Metals, p. 261.

using metallic or metalloidal deoxidizers. The term is also applicable to fabricated products. The types of deoxidized copper are: Phosphorized, high-residual phosphorus (DHP), phosphorized, low-residual phosphorus (DLP). phosphorized, silver bearing (DPS), phosphorized arsenical (DPA), and phosphorized, tellurium bearing (DPTE).

Deoxidized coppers (DLP and DHP) are produced by deoxidizing with sufficient phosphorus to insure combination with all of the available oxygen. The high-conductivity type, DLP, must contain very little residual phosphorus, and the total content rarely exceeds 0.011 percent of phosphorus. Greater amounts are intentionally added to produce type DHP which may contain 0.015 to 0.040 percent phosphorus, resulting in a conductivity range of 80 to 90 percent I.A.C.S. A significant increase in annealing temperature is also obtained which permits soldering of hard-drawn products with minimum softening. The residual phosphorus is most beneficial in preventing absorption of oxygen by the copper during hot-working and annealing operations, thus avoiding embrittlement during those subsequent processes which require heating in a reducing atmosphere. It is especially important to provide a residual deoxidixer in material to be welded by gas, carbon-arc, or metal-arc methods where both embrittlement and porosity would result from oxidation. Consequently, the quantity of phosphorized copper used for tube manufacture alone exceeds that of all other oxygen-free or deoxidized types combined.

TERMS RELATING TO SPECIFIC KINDS OF COPPERS

The American Society for Testing Materials (ASTM Standards 1961) has adopted descriptive terms for identifying the principal types of cast and processed coppers:

High-Conductivity Copper.—Copper which, in the annealed condition, has a minimum electrical conductivity of 100 per cent I.A.C.S. as determined in accordance with ASTM methods of test.

Casting Copper.—Fire-refined, tough-pitch copper usually cast from melted secondary metal into ingot and ingot bars only, and used for making foundry castings, but not wrought products.

Phosphorized Copper.—General term applied to copper deoxidized with phosphorus. The most commonly used deoxidized copper.

High Residual Phosphorus Copper.—Deoxidized copper with residual phosphorus present in amounts (usually 0.013 to 0.040 percent) generally sufficient to decrease appreciably the conductivity of the copper.

Low Residual Phosphorus Copper.—Deoxidized copper with residual phosphorus present in amounts (usually 0.004 to 0.012 percent) generally too small to decrease appreciably the conductivity of the copper.

Arsenical Copper, Phosphorous Bearing Copper, Silver Bearing Copper, Tellurium Bearing Copper.—Copper containing the designated element in amounts as agreed upon between the supplier and the consumer.

Any of these alloyed coppers can be produced as tough-pitch, oxygen-free, or deoxidized varieties.

The most important classification for wrought forms of commercial copper and copper alloys is based on composition, the forms being designated by long established names. Commonly accepted trade terms for the different kinds of copper, and their nominal chemical compositions, are as follows:

Accepted trade term:	*Co position, Percent*
Electrolytic tough pitch (ETP).	99.90 Cu–0.04 O
Phosphorized, high-residual phosphorus (DHP).	99.90 Cu–0.02 P
Phosphorized, low-residual phosphorus (DLP).	99.90 Cu–0.005 P
Lake	Cu–8 oz./ton Ag
Silver bearing (10–15)	Cu–10 to 15 oz./ton Ag
Silver bearing (25–30)	Cu–25 to 30 oz./ton Ag
Oxygen free (OF), no residual deoxidants.	99.92 Cu (min.)
Free cutting, lead bearing	99.0 Cu–1 Pb
Free cutting, tellurium bearing.	99.5 Cu–0.5 Te
Free cutting, selenium bearing.	99.4 Cu–0.6 Se
Cadmium copper	99.0 Cu–1 Cd
Chromium copper	Cu–0.4 to 1.2 Cr
Beryllium copper	Cu–1.8 to 2.05 Be

FORMS

ASTM defines refinery shapes and fabricators' products as follows:

Refinery Shapes

Wire Bar.—Refinery shape for rolling into rod (and subsequent drawing into wire), strip or shape.

Approximately 3½ to 5 in. square in cross-section, usually from 38 to 54 in. in length and weighing from 135 to 420 lb. Tapered at both ends when used for rolling into rod for subsequent wire drawing and may be unpointed when used for rolling into strip. Cast either horizontally or vertically.

Cake.—Refinery shape for rolling into plate, sheet, strip, or shape. Rectangular in cross section of various sizes. Cast either horizontally or vertically, with range of weights from 140 to 4000 lb or more.

Billet.—Refinery shape primarily for tube manufacture. Circular in cross-section, usually 3 to 10 in. in diameter and in lengths up to 52 in.; weight from 100 to 1500 lb.

Ingot and Ingot Bar.—Refinery shapes employed for alloy production (not fabrication).

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

Cathode.—Unmelted flat plate produced by electrolytic refining. The customary size is about 3 ft. square and about ½ to ⅞ in. thick, weighing up to 280 lbs.

Copper Powder.—Finely divided copper particles produced by electrodeposition.

Fabricator Products

Wire.—A solid section, including rectangular flat wire but excluding other flat products, furnished in coils or on spools, reels, or bucks. Flat wire may also be furnished in straight lengths.

Tube.—A hollow product of round or any other cross-section, having a continuous periphery.

Pipe.—Seamless tube conforming to the particular dimensions, commercially known as "Standard Pipe Sizes."

Shape.—A solid section, other than rectangular, square or standard rod and wire sections, furnished in straight lengths.

Shapes are usually made by extrusion but may also be fabricated by drawing.

Flat Products.—A rectangular or square solid section of relatively great length in proportion to thickness.

Included in the designation "flat product" depending on the width and thickness, are plate, sheet, strip, and bar. Also included is the product known as "flat wire."

Rod.—A round, hexagonal, or octagonal solid section. Round rod for further processing into wire (known as "hot-rolled rod," "wire-rod," or "redraw wire") is furnished coiled. Rod for other uses is furnished in straight lengths.

Copper Powder.—Finely divided copper particles produced by (1) high velocity atomization of molten copper with stream of compressed gas, steam, or water; (2) gaseous reduction of finely divided oxides; and (3) precipitation from solutions.

Grades and Specifications

The various types of copper are graded by the American Society for Testing Materials principally according to their chemical composition. Specifications adopted for these coppers are as follows:

ASTM Designation:

B4–42—Lake copper wire bars, cakes, slabs, billets, ingots, and ingot bars (must originate on the northern peninsula of Michigan).

(a) *Low Resistance Lake Copper.*—minimum purity of 99.900 percent, silver being counted as copper.

	Resistivity, max., international ohm (meter, gram)
Wire bars	0. 15328
Cakes, slabs, and billets:	
for electrical use	. 15328
for other uses	. 15694
Ingots and ingot bars	. 15694

(b) *High Resistance Lake Copper.*—minimum purity of 99.900 percent, silver and arsenic being counted as copper; resistivity greater than 0.15694 international ohm (meter, gram) at 20° C.

B5–43—Electrolytic-copper wire bars, cakes, slabs, billets, ingots, and ingot bars—minimum purity 99.900 percent, silver being counted as copper.

	Resistivity, max., international ohm (meter, gram)
Wire bars	0. 15328
Cakes, slabs, and billets:	
for electrical use	. 15328
for other uses	. 15694
Ingots and ingot bars	. 15694

B115–43—Electrolytic cathode copper—minimum purity of 99.90 percent, silver being counted as copper. The copper shall have a resistivity not to exceed 0.15328 ohms (meter, gram) at 20° C (annealed).

B170–59—Oxygen-free electrolytic copper wire-bars, billets, and cakes—minimum purity of 99.95 percent, silver being counted as copper. Resistivity not to exceed 0.15328 ohms (meter, gram) at 20° C (annealed). Test samples shall be free from cuprous oxide as determined by microscopic examination at 75 X magnification. Prepared wire samples, annealed at 800° to 875° C for 20 min in hydrogen, shall withstand four 90° bends (2 each in opposite directions) without fracture.

B72–60—Fire-refined casting copper—must conform to the following requirements as to chemical composition:

	Grade A, percent	*Grade B, percent*
Copper plus silver minimum	99.75	99.50
Arsenic ......maximum..	0.0075	0.10
Antimony........do....	.012	.012
Bismuth..........do....	.003	.003
Iron.............do....	.010	.010
Lead.............do....	.100	.30
Nickel...........do....	.10	.10
Oxygen...........do....	.10	.10
Selenium.........do....	.040	.040
Sulfur...........do....	.01	.01
Tellurium........do....	.014	.014
Tin..............do....	.025	.05

B216–49—Fire-refined copper for wrought products and alloys—must conform to the following requirements as to chemical composition:

	Percent
Copper plus silver......minimum..	99.88
Arsenic...............maximum..	.012
Antimony.................do....	.003
Selenium plus tellurium......do....	.025
Nickel...................do....	.05
Bismuth..................do....	.003
Lead.....................do....	.004

COPPER BASE ALLOYS

Nature

Copper-base alloys comprise a series of alloys having at least 40 percent copper with the amount of copper not less than that of any other constituent. Theoretically, adding another element to copper makes the mixture an alloy, however small the addition. But, in practice, copper is considered commercially pure if it is not less than 99.88 percent, silver being counted as copper. When other elements are included with copper in small enough amounts so that they produce certain desired qualities without changing the basic characteristics of the copper, the result is a modified copper with a copper content of neither less than 99.3 percent nor more than 99.88 percent, silver again being counted as copper. All other combinations in which copper is the chief constituent are copper-base alloys.

There are four traditional copper-base alloys, namely, brass, bronze, nickel-silver, and cupro-nickel. Nomenclature for many compositions may be confusing under the original concept that brasses are copper-zinc alloys and bronzes are principally copper and tin. Modern metallurgical developments, however, have resulted in important new alloys and necessitated revision and elaboration of many of the original simple definitions.

Properties

WROUGHT ALLOYS

Brass.—The most widely used and best known copper-base alloys are the brasses. Copper and zinc together form a complete series of solid solutions. As zinc is added to copper, tensile properties increase, electrical and thermal conductivities decrease, and there is some diminishing of corrosion resistance. Brasses are commonly used in applications where it is desired to improve some specific characteristic of copper while sacrificing only those qualities that are unimportant to the particular application. In general, the brasses offer mechanical properties superior to those of copper with some loss in the electrical and thermal conductivities. For certain mill products and manufactures, brasses are selected instead of copper because of the lower cost.

There are two broad classifications of wrought copper-zinc alloys, one containing 64 to 99 percent copper, consisting of a single phase and known as alpha brasses; the other containing 55 to 64 percent copper, containing two phases and known as alpha-beta brasses. The alloys of copper and zinc containing less than 55 percent copper, owing to predominance of the beta phase, are brittle and of no commercial significance.

Alpha brasses are exceptionally ductile and malleable at room temperature and can be cold worked by any of the commercial methods such as deep drawing, spinning, stamping, forming, cold rolling, cold heading, flaring, and upsetting. Their hardness is increased by cold work, the degree of hardness being dependent on the amount of cold work and the copper content of the alloy. Alpha brasses containing more than 85 percent copper have work-hardening properties similar to those of copper, and because of this property these brasses are used extensively for applications requiring successive drawing operations without intermediate anneals. After cold-working operations, the brasses can be rendered malleable or ductile again by heat treatment at temperatures ranging from 700° to 1,400° F, depending upon the properties desired. Alpha brasses are single-phase alloys; they are not susceptible of hardening by heat treatment.

Those alpha brasses containing between 64 and 80 percent copper possess relatively poor hot-working properties. In order to hot roll or hot forge these alloys successfully the utmost care must be taken to keep lead, a natural impurity of most zinc, to a trace. Brasses of this group are best hot worked at temperatures in excess of 1,350° F; the best results are obtained if all hot working is done within the range of 1,350° to 1,550° F. The alpha brasses containing 80 percent or more of copper have hot-working properties comparable to those of copper, which is extremely plastic through a wide temperature range. As in the case of copper, however, care must be exercised to control the lead within very close limits. As a general rule, if these brasses do not contain in excess of 0.01 percent lead, they can be hot forged, hot rolled, or otherwise hot worked without any difficulty.

In the alpha range, tensile properties increase with increasing zinc content, which is also accompanied by a change of color from red through gold to the green yellows and a progressive decline of electrical and thermal conductivities.

The corrosion resistance of alpha brasses is adversely affected by the same substances and conditions as those affecting the resistance of copper. In some instances they may be corroded by substances, particularly those which might be called active chemical reagents, that do not affect copper to any appreciable extent. An exception to this generality is that in resisting corrosive attack of sulfides the brasses, on the whole, are better than copper; and their superiority in that respect becomes more marked as the zinc content increases. It is of particular interest that in combating the corrosion of sea water, certain of the brasses—for example, 85–15 brass (known as rich low or red brass)—withstand corrosion better than copper.

Brasses containing less than 85 percent copper when exposed to certain media frequently fail in a characteristic manner known as dezincification. Failures of this kind are identified by the spongy areas of copper in the form of layers or so-called plugs on the affected surface. This spongy copper results from the solution of fractions of the alloy in the media and a redeposition of copper by chemical displacement. Arsenic, antimony, and phosphorus are effective dezincification inhibitors in alpha brasses.

Brass that contains less than 85 percent copper may under certain conditions fail by stress-corrosion cracking or, as it is more commonly called, season cracking. Conditions promoting this form of failure are the presence of internal stress, produced by cold-working operations, and exposure to mild atmospheric corrosion. Traces of ammonia in the atmosphere accelerate this type of corrosion. Season cracking can be prevented effectively by relief annealing below the recrystallization temperature.

The following are the more important alpha brasses:

Name:	*Copper, percent*	*Zinc, percent*
Gilding metal	95	5
Commercial bronze	90	10
Red brass	85	15
Low brass	80	20
Cartridge brass	70	30

Gilding metal and commercial bronze are extremely easy to cold work, have hot-working properties comparable to copper and can be readily spun, drawn, forged, and upset. These alloys have slightly higher tensile properties and about the same ductility as copper but lower thermal and electrical conductivities.

Red brass and low brass have excellent corrosion-resisting and cold-working properties, frequently being superior to those of copper. Cartridge brass, yellow brass, and intermediates are known generally as the high brasses. These alloys possess the optimum combination of strength and ductility. High brasses all have excellent cold-working properties and can be readily spun, drawn, forged, and upset.

The alpha-beta brasses—that is, those containing from 64 to 55 percent copper—are much easier to hot work than those in the alpha range, the ease of hot working increasing as the copper content decreases. These brasses become increasingly difficult to cold work as the copper content decreases, and those containing less than 58 percent copper are unsuited for any cold-working operations. Like the alpha brasses, the alpha-beta brasses can be rendered soft after cold-working operations by annealing within the temperature range from 700° to 1,400° F, depending upon the properties required. The alpha-beta brasses, however, can be hardened slightly by quenching from the annealing temperature. The hardening is produced by formation of a greater amount of beta in the alloy than would be produced by slower cooling.

The alpha-beta brasses possess the highest tensile properties and the lowest ductility of any of the copper-zinc alloys. Both of these properties are affected by the ratio of the beta phase to the alpha phase. Alloys of the lowest copper content, because of the greater percentage of beta phase, are the strongest and least ductile. The alpha-beta brasses with the higher copper content approach the alpha brasses containing 64 percent copper in ductility and strength.

Lead is added to brass primarily to improve its machineability; it also definitely improves shearing, blanking, and piercing operations. Lead is virtually insoluble in alloys of copper and zinc and, when present, occurs as finely divided and distributed metallic particles. This uniform dispersion throughout a brass alloy causes the chips to break off, and very little heat is transmitted to the edge of the cutting tool during machining. With leaded brasses, friction between the chip and the tool is reduced to a minimum while, with copper-zinc alloys, the chips are long and tough, tool wear is high, and lubrication problems are difficult.

The presence of lead in brasses does not appreciably influence the mechanical strength or corrosion resistance of the parent alloy, but it drastically reduces the ease of flaring, upsetting, cold heading, and bending operations. Lead in alpha brasses renders them hot-short and unsuitable for fabricating by hot-working methods. The alpha-beta brasses containing between 55 and 60 percent copper can be hot rolled if the lead does not exceed 1 percent and can be successfully hot forged with up to 2 percent lead. If greater amounts of lead are present, cracking in forging may occur. As the copper content increases beyond 60 percent, less lead can be tolerated. When the limit of the beta phase is reached, between 63 and 64 percent copper, lead must be kept to a trace if hot-working properties are to be retained.

Bronze.—Tin is the essential alloying element in the phosphor bronze group of alloys. The maximum limit for tin is about 10 percent in alloys that are to be cold worked, and up to this amount the copper-tin alloys are of alpha grain structure. Addition of tin to copper increases the strength and hardness at a rapid rate and reduces the melting point, density, and electrical and thermal conductivities. Tin is added to some of the brasses in amounts of about 1 percent for improving resistance to corrosion by dezincification in sea water, as in admiralty brass, naval brass, and manganese bronze. Tin is particularly beneficial in providing the high-elastic limit, resilience, and endurance strength characteristics of springs made from phosphor bronze.

The copper-silicon alloys or silicon bronzes are essentially alloys of copper and silicon containing a third constituent usually from 0.25 to 1.25 percent of one of four elements—tin, manganese, zinc, or iron. These alloys are divided into two general types, grades A and B. Grade A silicon bronzes are those containing the maximum of silicon (2.25–3.25 percent) and of the third constituent and are used in those applications requiring the highest tensile properties in combination with a resistance to corrosion equal to or better than that of copper. Grade A alloys possess welding characteristics similar to those of the mild steels. Grade B silicon bronzes contain smaller amounts of silicon (0.90–2.25 percent) and of the third constituent and are characterized by unusually good cold-working properties in combination with tensile properties comparable to 70–30 brass, corrosion resistance similar to that of copper, and weldability almost equal to that of grade A alloys.

Aluminum bronzes are high-copper alloys containing between 4 and 10 percent aluminum. Small amounts of iron, nickel, silicon, and manganese are frequently added to the alloys of higher aluminum content to increase strength and hardness. Industrial aluminum bronzes are of two general types: The alpha or single phase alloys—often referred to as homogeneous alloys; and the alpha-beta or two-phase alloys—known commercially as duplex bronzes. Under equilibrium conditions, 9.8 percent of aluminum is soluble in copper before the beta phase appears, but in commercial practice equilibrium conditions are practically never reached, and alloys containing more than 7.5 percent aluminum usually exhibit two phases.

The alpha aluminum bronzes possess excellent cold-working properties. They also have good hot-working properties and can be readily hot forged, rolled, and extruded. They are most plastic within a temperature range of 1,450° to 1,650° F. Their hot plasticity increases as the aluminum content increases and, conversely, their cold-working properties decrease with a corresponding increase in sensitivity to work hardening. The annealing characteristics are similar to those of the alpha brasses, and softening of work-hardened alloys can be accomplished by annealing between 800° and 1,400° F, depending upon the properties required.

The duplex (two-phase, alpha-beta) aluminum bronzes have excellent hot-working properties through a much wider range than the alpha bronzes. They can be extruded and hot forged into very intricate shapes. Their hot-working properties compare favorably with those of the alpha-beta brasses but they can be cold worked only lightly.

All aluminum bronzes possess good resistance to scaling or oxidation at elevated temperatures, being better in this respect than any of the other copper-base alloys. The resistance to scaling or oxidation increases with the aluminum content. The corrosion resistance of these alloys is due to formation of aluminum oxide (Al_2O_3) on exposed surfaces. This film is very resistant to attack by mineral acids, but it is soluble in alkalies. Thus, aluminum bronzes have been widely used in acid environments, but offer only moderate resistance to the attack of strong alkalies. In general the wrought aluminum bronzes are selected for those applications requiring high-tensile properties, good corrosion resistance, strength, and wear-resisting qualities.

Cupronickels.—Nickel is the major alloying element in the cupronickels. The most evident effect is the change in color of the alloy as the nickel content increases. The color of cupronickel is almost nickel white. The addition of nickel to copper increases the strength, hardness, and modulus of elasticity but lowers the electrical and thermal conductivities substantially. Although nickel and copper are mutually soluble in all proportions in the solid state, 30 percent nickel is usually the maximum content permissable for alloys to be manufactured with brassmill equipment. At more than 30 percent nickel the melting points and annealing temperatures reach values that are too high for the furnaces, and the resistance to cold work becomes too great for customary brassmill reduction schedules. Cupronickels are particularly suitable for service at elevated temperatures.

Minor Additions.—Manganese is added to some of the wrought copper alloys, principally as a minor or secondary alloying element. In manganese, aluminum, and silicon bronzes, it improves the grain structure. In cupronickels and nickel-silvers, small amounts are added to improve the metal quality of mill shapes for working operations where its presence is permitted in the finished products.

Phosphorus is confined almost entirely to the phosphor-bronzes, where it is present in amounts to 0.50 percent. It serves as a deoxidizer, and the residual phosphorus content increases the mechanical properties. In admiralty and aluminum brass, phosphorus is used as one of the inhibitors of dezincification. It reduces electrical conductivity substantially, but when used in combination with a small amount of nickel to form nickel phosphide, the phosphide can be precipitated by heat treatment to increase strength, and because it is not in solid solution, the phosphorus ceases to affect conductivity appreciably.

Iron used as a minor alloying element in manganese, aluminum, and silicon bronzes adds strength and makes a finer-grained alloy. Small amounts added to cupronickels improve resistance to corrosion by sea water.

Arsenic is added to the extent of a few hundredths of a percent as an inhibitor of dezincification corrosion in admiralty and aluminum brass.

Cadmium in amounts to 1 percent is added to copper to increase strength and wearing qualities with less sacrifice of electrical conductivity than when other alloying elements are used to obtain the same strength. This combination of properties makes copper-cadmium alloys especially suitable for trolley wires, long-span power lines, and similar applications.

Beryllium is added to copper in amounts to about 2 percent to obtain precipitation-hardening alloys of strength and hardness far beyond any of the other copper alloys. The commercial copper-beryllium alloys after a 2- or 3-hour heat-treatment at 1,450° to 1,500° F, followed by a water quench to return the alpha structure, are malleable and can be drawn, stamped, or cold worked. After such working or cold working, and in order to establish phase equilibrium with attendant high mechanical properties, parts are subjected to an aging anneal at 525° to 575° F for varying periods of time, dependent upon the physical dimensions of the part and the properties required. It is common practice to add a third constituent; cobalt is frequently added to obtain high-temperature stability, and nickel is introduced as a minor constituent to retard grain growth.

CASTING ALLOYS

The properties of brass and bronze castings are dependent on the composition of the alloy, the cleanliness of the metal, and the methods of casting. The properties may vary, as the percentages of the major constituents are at or near the minimum or maximum limits permitted in the specifications for the alloy. They may be affected because of the tolerance specified for other elements. The techniques of sand casting, permanent-mold casting, die casting, investment casting, plaster-mold casting, centrifugal castings, and other methods may account for variations found in castings of the same alloy. Test bars cut from a casting produced by one method can have different properties from those obtained from a casting produced by another method.

Strength, ductility, hardness, etc., are subject to variation due to grain size. In general, the coarser the grain the lower will be the tensile strength, elongation, reduction in area, hardness, and impact strength. Grain size is dependent chiefly upon the rate of cooling of the casting, which is influenced by many variables.

Commercial Classification

Copper-base alloys are grouped in two classes according to specifications required in the processes of fabrication. These two classes are wrought alloys and casting or foundry alloys.

WROUGHT ALLOYS

These are made by alloying the various components and casting the alloy into slabs, cakes, or billets for hot or cold working by rolling, drawing, extrusion, or forging. Depending on the alloy, the wrought products comprise such diverse shapes as plate, sheet, strip, bar, rod, wire, and seamless tube. The chief elements alloyed with copper are zinc, tin, lead, nickel, silicon, and aluminum and to a lesser extent, manganese, cadmium, iron, phosphorus, arsenic, chromium, beryllium, selenium, and tellurium. The range of chemical compositions for the wrought alloys of copper is narrower than for casting alloys. Many compositions that can be poured successfully into either sand or permanent molds are entirely unfit for working operations. In rolling, drawing, forging, extrusion, or tube-billet piercing, a high degree of ductility or malleability, either hot or cold, is a prime requisite. Compositions of wrought alloys referred to as standard in the copper- and brass-mill products industry are shown in table 2.

Brass.—This is any copper-base alloy containing zinc as the principal alloying component, with or without smaller quantities of other elements. There are alloys that are definitely brasses by definition, yet they have names that include the word bronze; for example, commercial bronze (90 percent Cu–10 percent Zn). Although it is recognized that these alloys technically are not bronzes, they do resemble bronze in appearance and, because of long usage, terms such as "commercial bronze" have widespread acceptance.

Bronze.—This is a copper-base alloy having tin as the principal alloying constituent. However, the term "bronze" is seldom used alone and the copper-tin alloys have come to be known as phosphor bronze because of the small residual phosphorus content. With a suitable modifier use of the term "bronze" also extends to a variety of copper-base alloy systems, having the principal alloying element other than tin or zinc. These systems include the aluminum bronzes, the beryllium bronzes, and the silicon bronzes.

Nickel-Silver.—Formerly known as German silver, this is a copper alloy containing both nickel and zinc. Its name derives from its predominantly silvery color. Depending on the composition, the color may vary from yellowish white to silvery white.

Cupronickels.—Essentially, these are copper and nickel, the nickel content usually being 10, 20, or 30 percent. Small amounts of iron and manganese may be and usually are added.

Special Alloys.—There are many special and proprietary alloys that are essentially defined by their names; included are aluminum-tin bronze, aluminum-silicon bronze, cadmium bronze, chromium copper, beryllium copper, leaded copper, selenium copper, and others.

CASTING ALLOYS

Mostly brasses and bronzes, these are made essentially from a complex assortment of industrial nonferrous scrap by scientific selection, smelting, and refining processes for sand and permanent-mold castings. The quantities of alloying metals, such as lead, tin, iron, and aluminum are usually greater than in wrought alloys and are a necessary part of the composition. Elements present as impurities are greater in amount than they are in wrought metals but are not considered harmful within the limits of the specifications. Casting alloys are produced by firms known as ingot makers or manufacturers, and most all casting alloys are marketed and consumed in ingot form. In 1945, the American Society for Testing Materials adopted a standard classification of different types of cast copper-base alloys. There are many hundreds of these alloys, and the classification simplifies the terminology of the various types; each class shown generally covers many alloys. This classification bearing the ASTM designation B119–45 and endorsed by the American Foundrymen's Association is reproduced here as table 3.

USES OF COPPER AND COPPER-BASE ALLOYS

The use of copper and its alloys is universal. They are practically synonymous with all things electrical and have a myriad of uses in construction, autos, aircraft, missiles, railroad equipment, marine equipment, appliances, machinery and equipment, scientific instruments, utensils, jewelry, cladding, and many other applications.

Approximately half of all copper consumed is for electrical applications, including power transmission, electronics, and electrical equipment, transportation, and complex weapons systems. The greatest use is for construction (homes, plants, office buildings) and power generation and transmission. Virtually all building wiring is copper. The transmission of power continues to be a major market for copper, even though aluminum is now used for most high-voltage overhead lines; copper still

TABLE 2.—*Composition and forms of wrought copper-base alloys*

Name	Nominal composition, percent						Typical forms [1]
	Copper	Zinc	Lead	Tin	Other: Element	Other: Percent	
Brasses-nonleaded:							
Guilding, 95 percent	95.00	5.00					S,W.
Commercial bronze, 90 percent	90.00	10.00					S,R,W,T.
Red brass, 85 percent	85.00	15.00					S,R,W,T.
Low brass, 80 percent	80.00	20.00					S,R,W.
Cartridge brass, 70 percent	70.00	30.00					S,R,W,T.
Yellow brass, 66 percent	66.00	34.00					S,W.
Yellow brass, 63 percent	63.00	37.00					R,W.
Muntz metal	60.00	40.00					S,T.
Leaded brasses:							
Leaded commercial bronze	89.00	9.25	1.75				R.
Leaded tube brass	66.50	33.00	.50				T.
High-leaded tube brass	66.50	31.90	1.60				T.
Low-leaded brass	64.50	35.00	.50				S.
Medium-leaded brass	64.50	34.50	1.00				S,R,W.
High-leaded brass	64.00	34.00	2.00				S,R.
Free-cutting brass	61.50	35.25	3.25				R.
Leaded muntz metal	60.00	39.40	.60				P.
Free-cutting muntz metal	60.00	39.00	1.00				T.
Forging brass	60.00	38.00	2.00				R,F.
Architectural bronze	56.00	41.50	2.50				ES.
Tin and aluminum brasses:							
Inhibited admiralty [2]	71.00	28.00		1.00			P,T.
Naval brass	60.00	39.25		.75			P,S,R,W,T,F.
Leaded naval brass	60.00	37.50	1.75	.75			R,F.
Manganese bronze	58.50	39.20		1.00	Mn Fe	0.30 1.00	P,R,F.
Aluminum brass [2]	77.00	21.00			Al	2.00	T.
Phosphor bronzes:							
Phosphor bronze	94.75			5.00	P	.25	S,R,W,T.
Do	91.75			8.00	P	.25	S,R,W.
Do	89.75			10.00	P	.25	S,R,W.
Do	98.70			1.25	P	.05	S.
Leaded	93.70		1.00	5.00	P	.10	S,R.
Free-cutting	87.90	4.00	4.00	4.00	P	.10	R.
Cupronickels:							
Cupronickel	88.35				Ni Fe Mn	10.00 1.25 .40	P,T.
Do	68.90				Ni Mn Fe	30.00 .60 .50	P,R,T.
Nickel-silvers:							
Nickel silver	65.00	17.00			Ni	18.00	S,R,W.
Do	55.00	27.00			Ni	18.00	S,R,W.
Do	65.00	23.00			Ni	12.00	S,W.
Do	65.00	25.00			Ni	10.00	S,W.
Silicon bronzes (Copper-silicon alloys):							
High-silicon bronze	95.80				Si [3] Mn	3.10 1.10	S,R,W,T,F.
Low-silicon bronze	98.25				Si [3] Mn	1.50 .25	S,R,W,T.
Aluminum bronzes:							
Aluminum bronze	95.00				Al	5.00	S,R,T.
Do	92.00				Al	8.00	S,R.
Do	90.25				Al Fe	7.00 2.75	P,S.
Do	82.00				Al Ni Fe Mn	9.50 5.00 2.50 1.00	P,R.
Aluminum-silicon bronze	90.75				Al Si	7.25 2.00	R,F.

See footnotes at end of table.

TABLE 2.—*Composition and forms of wrought copper-base alloys*—Continued

Name	Nominal composition, percent						Typical forms [1]
	Copper	Zinc	Lead	Tin	Other		
					Element	Percent	
Other copper alloys:							
Cadmium bronze	99.00				Cd	1.00	W.
Chromium copper	99.14				Cr Si	.85 .01	R.
Beryllium copper	[4] 97.70				Be	1.90	S,R,W.
Leaded copper	99.00				Pb	1.00	R.
Selenium copper	99.40				Se	.60	R.

[1] S=sheet and strip; R=rod; W=wire; T=tube; P=plate; F=forgings; and ES=extruded shapes.
[2] Arsenic, antimony, or phosphorus: 0.02 to 0.10.
[3] In place of manganese, iron or zinc are also used in comparable amount.
[4] Ni+Co+Fe=0.40.

Source: Butts, Allison B. Copper, The Metal, Its Alloys, and Compounds. Reinhold Pub. Corp., 1954, p. 537.

TABLE 3.—*Cast copper-base alloys*

Class	Addition elements	Remarks
	Copper	
Copper	Not more than 2 percent total of arsenic, zinc, cadmium, silicon, chromium, silver, or other elements.	Conductivity copper castings, pure copper, deoxidized copper, and slightly alloyed copper.
	Brasses	
Red	2 to 8 percent zinc. Tin less than zinc. Lead less than 0.5 percent.	Alloys in this class without lead seldom used in foundry work.
Leaded red	2 to 8 percent zinc. Tin less than 6 percent, usually less than zinc. Lead more than 0.5 percent.	Commonly used foundry alloys. May be further modified by addition of nickel. See ASTM Specifications B62 and B145.
Semired	8 to 17 percent zinc. Tin less than 6 percent. Lead less than 0.5 percent.	Alloys in this class without lead seldom used in foundry work.
Leaded semired	8 to 17 percent zinc. Tin less than 6 percent. Lead over 0.5 percent.	Commonly used foundry alloys. May be further modified by addition of nickel. See ASTM Specification B145.
Yellow	More than 17 percent zinc. Tin less than 6 percent. Less than 2 percent total aluminum, manganese, nickel, iron, or silicon. Lead less than 0.5 percent.	Commonly used foundry alloy.
Leaded yellow	More than 17 percent zinc. Tin less than 6 percent. Less than 2 percent total aluminum, manganese, nickel, or iron. Lead more than 0.5 percent.	Commonly used foundry alloy. See ASTM Specification B146.
High-strength yellow, manganese bronze.	More than 17 percent zinc. More than 2 percent total of aluminum, manganese, tin, nickel, and iron. Silicon less than 0.5 percent. Lead less than 0.5 percent. Tin less than 6 percent.	Commonly used foundry alloys under name of "manganese bronze", and various trade names. See ASTM Specification B147.
Leaded high-strength yellow, leaded manganese bronze.	More than 17 percent zinc. More than 2 percent total of aluminum, manganese, tin, nickel, and iron. Lead more than 0.5 percent. Tin less than 6 percent.	Commonly used foundry alloys. See ASTM Specifications B132 and B147.
Silicon	More than 0.5 percent silicon. More than 5 percent zinc.	Commonly used foundry alloys. See ASTM Specification B198.

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TABLE 3.—*Cast copper-base alloys*—Continued

Class	Addition elements	Remarks
	Brasses—Continued	
Tin	More than 6 percent tin. Zinc more than tin.	Alloys in this class seldom used in foundry work.
Tin-nickel	More than 6 percent tin. More than 4 percent nickel. Zinc more than tin.	Alloys in this class seldom used in foundry work.
Nickel, nickel silver	More than 10 percent zinc. Nickel in amounts sufficient to give white color. Lead less than 0.5 percent.	Commonly used foundry alloys, sometimes called German silver.
Leaded nickel, leaded nickel-silver.	More than 10 percent zinc. Nickel in amounts sufficient to give white color. Lead more than 0.5 percent.	Commonly used foundry alloys, sometimes called "German silver." See ASTM Specification B149.
	Bronzes	
Tin	2 to 20 percent tin. Zinc less than tin. Lead less than 0.5 percent.	Commonly used foundry alloys. May be further modified by addition of some nickel or phosphorus, or both. See ASTM Specifications B22 and B143.
Leaded tin	To 20 percent tin. Zinc less than tin. Lead more than 0.5 percent, less than 6 percent.	Commonly used foundry alloys. May be further modified by addition of some nickel or phosphorus, or both. See ASTM Specifications B61 and B143.
High-leaded tin	To 20 percent tin. Zinc less than tin. Lead more than 6 percent.	Commonly used foundry alloys. May be further modified by addition of some nickel or phosphorus, or both. See ASTM Specifications B22, B66, B67, and B144.
Lead	Lead more than 30 percent. Zinc less than tin. Tin more than 10 percent.	Used for special bearing applications.
Nickel	More than 10 percent nickel. Zinc less than nickel. Less than 10 percent tin. Less than 0.5 percent lead.	Commonly used foundry alloys. Sometimes called German silver or nickel-silver.
Leaded nickel	More than 10 percent nickel. Zinc less than nickel. Less than 10 percent tin. More than 0.5 percent lead.	Commonly used foundry alloys. Sometimes called German silver or nickel-silver. See ASTM Specification B149.
Aluminum	5 to 15 percent aluminum. To 10 percent iron, with or without manganese or nickel. Less than 0.5 percent silicon.	Commonly used foundry alloys. Some may be heat-treated. May be further modified by addition of some nickel or tin, or both. See ASTM Specification B148.
Silicon	More than 0.5 percent silicon. Not over 5 percent zinc. Not over 98 percent copper.	Commonly used foundry alloys. Some are readily heat-treated. See ASTM Specification B198.
Beryllium	More than 2 percent beryllium or beryllium plus metals other than copper.	Most of these alloys are heat treatable.

Source: American Society for Testing Materials. ASTM Standards. Pt 2 Non-Ferrous Metals (Specifications) Electronic Materials. Philadelphia Pa., 1958, pp. 186–188.

dominates in high-voltage underground lines. Generation and utilization of electrical energy requires extremely large quantities of copper. Examples are heat exchangers, windings in motors, generators and transformers, magnet wire in control apparatus, and bus bars.

For communications, telephone and telegraph wire and cable are the two greatest uses. Numerous components in radio and television sets and telegraph receiving and sending equipment are made of copper or its alloys, and coaxial cables employ a substantial amount of copper. The excellent electrical conductivity of copper has made it the major metal used in expanding applications of printed circuits.

The noncorrosive quality of copper and its alloys accounts for many uses in construction for roofing products, plumbing goods, builders hardware, and functional decorative applications. Sheet roofing, gutters, downspouts and heads, flashing, fittings, and accessories consume a large amount of copper. Copper and red brass are found frequently in plumbing items such as tank-lever lift arms, toilet tank trim, lavatory fittings, tub fittings, faucets, traps and drains, flush valves, piping and tubing, and other fixtures. Brass and bronze are popular for builders hardware because they are decorative, noncorrosive, and easy to fabricate for such items as locks, door knobs and knockers, door stops, hinges, bolts, latches, and safety hasps.

The automotive industry accounts for about 9 percent of the copper consumed in the United States, using about 30 to 40 pounds per vehicle. Volume use is in radiators, heaters and defrosters, air conditioning units, bearings, bushings, carburetors, oil lines, strainers, wiring, switches, and plating. Major uses take strip, tube, plates, and wire; secondary uses take rods, bars, and foundry products.

More copper is required for the maze of wiring in electrical systems of airplanes than for any other use in the aircraft industry. Some of the larger planes use as much as 3,000 pounds of copper in electrical systems and mechanical components.

Use of copper is minor, though essential, in missiles. As in aircraft, the major use is in wiring systems.

Railroads use a large quantity of copper in diesel locomotives, passenger cars, and switching and signal devices. The average Pullman car uses almost 2,000 pounds of copper tube in the water supply system, air brakes, heating system, air conditioning unit, condensers, evaporator, and heating coils.

Tankers, cargo ships, pleasure craft, passenger liners, and naval vessels use copper and its alloys in a great variety of marine equipment. Naval brass is used for propeller shafting (because of its strength, torque resistance, machinability, and corrosion resistance); manganese bronze for struts and rudders (high strength and corrosion resistance); silicon bronze for fastenings and water tanks; soft and hard drawn copper for exhaust yokes; fuel lines, water lines, and piping (resistance to corrosion and leaks, workability, long life). The USN nuclear submarine *Skipjack* uses brass in capstans, torpedo tubes, diving gear, and valves; more than 48,000 feet of copper tube in hydraulic, air, and lubricating oil lines; and more than 6,000 feet of cupronickel tube in auxiliary cooling lines, heat exchangers, lavatories, bilge pumps, and salt water service lines.

Manufacturers of appliances such as washing machines, air conditioning units, refrigerators, radio and television sets, and other units specify copper and its alloys for many components requiring materials that are electrically or thermally conductive, corrosion resistant, and durable. Radio and television sets provide the largest market for printed circuits, but there is great potential for their use in appliances, automobile instrument panels, and electronic computers.

Large machinery and equipment, turbines, and heat exchangers use copper or its alloys in many ways. Specific uses are copper for motors, other electrical equipment and tubing; bronze for worm wheels, oil baffles, check valves, and levers; cupronickel for tubing; naval brass, muntz metal, and aluminum bronze for plates, sheets, bars, and weld wire.

Copper is used extensively in watches, clocks, microscopes, projectors, and many types of gages.

Solid copper, brass, and bronze are popular materials in utensils, jewelry, furnishings, and decorative items. They are used in manufacturing such items as: Brass and bronze medallions; solid brass furnishings—towel bars, curtain rods, wall hooks, and soap dishes; copper, brass, and bronze jewelry; cookware; tableware; and bronze and brass plaques and signs.

From data contained in the 1958 Census of Manufactures by the Bureau of the Census, a table compiled by the Copper Division of BDSA, U.S. Department of Commerce reproduced here in table 4 shows end uses of copper and copperbase alloys in the form of bare wire, insulated wire and cable, and other mill shapes and forms. The percentage of total metal consumed by various fabricating industries is of particular interest. The importance of the electrical industry is apparent, as almost 35 percent of total consumption was accounted for by electrical machinery. Consumption by the military, the automotive industry, and for refrigeration equipment is also significant.

Products of the powder-metallurgy process have found wide usage in machine components. Compacted structural parts are used in automotive, railroad, farm, aircraft, marine, and communications equipment and in household appliances, such as washers, dryers, ironers, electric fans, and refrigerators. Metal powder of single elements, or in combination with other metals or nonmetals are processed to make oil-impregnated porous bearings; cams, gears, motor brushes, clutch facings; contact points, filters, filaments, lock assemblies; and many other various shapes.

The number of automotive applications for powder-metal parts has doubled since 1950. Chrysler Corp. and General Motors Corp. now use about 100 different powder-metal parts in their cars; the Ford Co. uses slightly less. Iron powder mixed with copper, or copper and carbon, is used for transmission and engine parts that receive high impact and fatigue loads. Many new applications are believed feasible as powders and processing methods are designed for strength properties.

TABLE 4.—*End-uses of copper, 1958*

(In thousands of pounds)

Consuming industry	Bare wire (electrical conductor)	Insulated wire and cable	Other mill products	Castings [1]	Total	Percent of total consumption
Metal fabricating industries, etc.[2]	197,280	257,563	1,132,013	214,656	1,801,512	-
Ordnance and accessories	(3)	[3] 4,885	40,438	63	45,386	2.5
Fabricated metal products	6,876	2,838	473,975	90,684	574,368	31.88
Cutlery	-	-	3,279	109	3,388	0.18
Hand and edge tools, except machine tools, and hand saws	118	177	1,809	364	2,468	.13
Hardware, n.e.c.	1,480	325	56,802	9,246	67,853	3.7
Plumbing fixtures	-	-	3,545	[4] 126	3,671	.2
Plumbing fixture fittings and trim (brass goods)	-	-	55,765	19,906	75,671	4.2
Heating equipment, except electric	708	1,077	13,222	[4] 1,232	16,239	.9
Fabricated structural iron and steel	(5)	(6)	[5] 1,275	272	1,547	.086
Metal doors, sash and trim	-	17	1,165	153	1,335	.074
Boiler shop products	123	95	22,920	1,574	24,712	1.31
Sheet-metal work	545	(7)	9,350	207	10,102	.55
Screw-machine products	-	176	70,437	647	71,260	3.9
Bolts, nuts, screws, rivets and washers	-	-	43,792	(7)	43,792	2.4
Metal stampings	2,565	188	70,303	509	73,565	4.08
Miscellaneous fabricated wire products	1,050	201	11,363	-	12,614	.67
Valves and pipe fittings (except plumbers brass goods)	287	582	108,948	56,334	166,151	9.2
Machinery, except electrical	7,469	16,902	142,711	71,681	238,763	13.25
Steam engines and turbines	(6)	(6)	(6)	7,397	7,397	.41
Internal combustion engines	(3)	[3] 572	4,432	2,516	7,520	.42
Farm machinery and equipment	40	283	3,979	2,003	6,305	.35
Construction machinery	342	1,959	7,040	[4] 4,368	13,709	.76
Mining machinery and equipment	459	445	810	1,429	3,143	.17
Oil field machines and equipment	(3)	[3] 89	1,393	1,377	2,859	.16
Elevators and moving stairways	(3)	[3] 2,109	585	214	2,908	.16
Hoists, cranes, and monorails	76	711	102	716	1,605	.09
Metal-cutting machine tools	-	403	576	1,558	2,537	.14
Metal-forming machine tools	-	47	151	1,589	1,787	.10
Special dies and tools	155	(8)	2,041	743	2,939	.16
Metalworking machinery, n.e.c.	1,258	1,858	4,565	2,723	10,404	.58
Food products machinery	(3)	[3] 1,995	1,314	2,900	6,209	.35
Woodworking machinery	94	2,118	95	101	2,408	.13
Paper-industries machinery	-	-	3,436	978	4,414	.24
Printing-trades machinery	-	-	1,511	1,005	2,516	.14
Special-industry machinery, n.e.c.	82	276	4,022	2,152	6,532	.36
Pumps and compressors	595	1,801	8,126	19,550	30,072	1.67
Ball and roller bearings	(6)	(6)	3,075	1,475	4,550	.25
Blowers and fans	(6)	206	1,899	319	2,424	.13
Power transmission equipment	161	101	1,141	5,538	6,941	.39
General industrial machinery, n.e.c.	373	113	5,098	1,554	7,138	.40
Refrigeration machinery	3,253	946	55,058	2,446	64,703	3.59
Measuring and dispensing pumps	-	27	846	558	1,431	.08
Service industry machines, n.e.c.	109	111	620	1,218	2,058	.11
Machine shops	472	732	27,796	5,254	34,254	1.90
Electrical equipment	176,597	205,395	224,134	22,712	628,838	34.91
Electrical measuring instruments	1,880	3,890	4,378	572	10,720	.60
Transformers	45,002	32,111	21,478	544	99,135	5.50
Switchgears and switchboards	5,431	5,961	41,740	8,250	61,382	3.41
Motors and generators	59,817	62,746	29,972	1,184	151,719	8.42
Industrial controls	2,133	3,102	7,780	377	13,392	.74
Welding apparatus	1,764	3,306	3,853	2,779	11,702	.65
Electrical industrial goods, n.e.c.	6,652	6,575	3,370	-	16,597	.92
Household refrigerators	(5)	1,318	[5] 8,801	-	10,119	.56
Household laundry equipment	(5)	3,004	[5] 610	-	3,614	.21
Electrical housewares and fans	982	4,014	3,495	-	8,491	.47
Household vacuum cleaners	1,432	145	-	-	1,577	.09
Household appliances, n.e.c.	286	815	4,387	1,204	6,692	.37
Lighting fixtures	566	4,409	9,161	699	14,835	.82
Current-carrying devices	3,490	3,938	28,289	3,050	38,767	2.15
Noncurrent-carrying devices	(6)	(8)	4,450	994	5,444	.30
Radio and TV receiving sets	4,438	4,802	758	-	9,998	.56
Telephone and telegraph apparatus	5,267	17,461	25,164	31	47,923	2.66
Radio and TV communications equipment	951	9,224	2,415	2,453	15,043	.84
Electronic components, n.e.c.	14,585	10,047	10,024	321	34,977	1.94
Engine electrical equipment	21,921	28,527	14,009	254	64,711	3.59
Transportation equipment	4,350	20,769	189,306	13,184	227,609	12.63
Motor vehicles and parts	1,560	4,628	167,955	4,037	178,180	9.89
Aircraft	374	4,008	659	126	5,167	.29
Aircraft engines and parts	(5)	341	[5] 730	1,049	2,120	.12
Aircraft equipment, n.e.c.	329	558	4,187	718	5,792	.32
Shipbuilding and repairing	(3)	[3] 3,186	7,268	5,980	16,434	.91
Boatbuilding and repairing	-	-	1,487	681	2,168	.12
Locomotives and parts	2,087	4,491	6,014	593	13,185	.73
Trailer coaches	(5)	3,557	[5] 1,006	-	4,563	.25
Instruments and related products	1,988	6,774	27,279	15,542	51,583	2.86
Scientific instruments	(6)	3,810	1,279	596	5,685	.32
Mechanical measuring devices	974	1,473	11,974	12,411	26,832	1.49
Automatic temperature controls	1,014	1,491	14,026	2,535	19,066	1.06
Miscellaneous manufactures	-	-	36,170	795	36,965	2.05
Silverware and plated ware	-	-	8,341	795	9,136	.51
Needles, pins, and fasteners	-	-	27,829	-	27,829	1.54

[1] Excludes castings produced and consumed in same establishment.
[2] Metal fabricating industries include establishments whose primary activity is manufacturing products fabricated beyond metal mill or foundry level.
[3] Bare wire included with insulated wire and cable.
[4] Data not available for castings produced and consumed in same establishment.
[5] Bare wire included with other mill products.
[6] Not available.
[7] Not applicable.
[8] Between 1 and 1.5 million pounds of insulated wire and cable were consumed.

Source: Copper Division, BDSA, Department of Commerce.

Copper As an Alloying Element

In addition to its role in copper-base alloys, copper is an important constituent of a large number of alloys having a metal other than copper as the principal component.

Aluminum Alloys.—In 1911, the German metallurgist, Wilm, announced development of Duralumin, a series of alloys containing about 4 percent copper, 0.5 percent magnesium, and 0.5 percent manganese. This development marked the real beginning of wrought aluminum alloys. Pure (99.9$^+$ percent) aluminum, as cast, has tensile and yield strengths of only 9,000 psi and 3,000 psi, respectively. Addition of copper to and beyond the limit of solid solubility strengthens aluminum rapidly. Aluminum will dissolve 5.65 percent of copper at 548° C (1,018° F), the eutectic temperature, but will hold only 0.45 percent at equilibrium at 300° C (572° F). The hardening effect of copper added to aluminum is due to age hardening or precipitation hardening caused by precipitation of very fine particles of $CuAl_2$. The precipitation of this compound to form a two-phase structure was found to produce a stronger alloy than the solid solution, while retaining high ductility.

Although the newest wrought alloys contain copper, it is no longer the principal hardening element. The new alloys are widely used in aircraft construction, but the aluminum-copper-base alloys still dominate the light alloy field.

Ferrous Alloys.—Pure copper and pure iron are miscible in the liquid phase in all proportions. Introducing carbon affects the miscibility, however, so that a molten eutectic iron containing 4.3 percent carbon can dissolve only about 3 percent copper. Ductile alloys can be produced throughout the entire composition range, but copper in commercially important iron-base alloys is limited to approximately 2.5 percent, and is usually lower. About 0.25 percent copper in copper-bearing steel will roughly double the corrosion resistance of the steel in air. Copper increases the depth of hardening after quenching any steel, but its relative effect is much greater in the high-carbon than the low-carbon steels. In cast iron, copper reduced the tendency toward chilling in light sections and at the same time promoted soundness in heavy sections. In addition, copper in cast iron tends to increase strength, improve machinability, and improve resistance to wear, galling, impact, and shock.

Gold-Copper-Silver Alloys.—Copper hardens gold principally by forming solid solutions. Other elements are added to impart certain properties or characteristics. The gold-copper-silver alloys are more commonly used than gold-copper alloys. An 18-carat alloy of 75-percent gold with about equal parts of silver and copper has a yellow color; replacing more of the silver with copper produces a red gold. The 14-carat alloy of 58.35-percent gold, 2.5 to 5 percent copper, and balance of silver is green. Increasing the copper to 20 to 30 percent makes yellow golds, and higher copper gives a reddish color. The 10-carat golds are largely high-copper alloys with various additions to control color. White gold is a series of gold-nickel-copper-zinc alloys containing the requisite amount of gold to make 10-, 12-, and 14-carat alloys. The copper varies from 51.5 to 31.0 percent.

Nickel-Copper Alloys.—Copper is soluble in nickel in both the liquid and solid states in all proportions, and all the alloys have homogenous structures—regardless of the heat treatment. Although all of the alloys are ductile, only Monel and constantan have much commercial utilization. A third alloy, 70 Ni–30 Cu, has a special use in the form of wire or ribbon for magnetic temperature compensation in electrical meters which depend on the flux produced by a constant voltage or by a certain load current for their actuation.

Monel is the most important nickel-copper alloy. It is available in both cast and wrought form. This alloy—67 percent nickel, 30 percent copper, and the balance iron and manganese—is a strong, ductile alloy that can be formed into rod, wire, plate, sheet, strip, and tubing. Ingots are cast of this alloy that weigh as much as 14,000 pounds. The tensile strength varies from 70,000 psi in the annealed state to 120,000 to 140,000 psi in the full-hard condition. The mechanical properties are quite stable with temperatures to 400° C (750° F). Monel is widely used in chemical, pharmaceutical, and marine equipment, laundries, and kitchens because of its pleasing appearance, strength, and resistance to sea water, dilute sulfuric acid, and strong caustics.

Constantan is an alloy of about 45 percent nickel and 55 percent copper [2] that is distinguished by its high electrical resistance and unusually constant temperature coefficient of electrical resistivity. Extensive use is made of this property in electrical instruments.

Silver-Copper Alloys.—The silver-copper system is relatively simple, with a eutectic at 28.1 percent copper which solidifies at 779.4° C (1,435° F). The maximum solid solubility of copper in silver at this temperature is 8.8 percent, decreasing to about 0.1 percent in equilibrium at room temperature. The high-silver, silver-copper alloys can be age hardened. They have been considered to be the classical

[2] Although more than 50 percent copper, constantan is listed by the National Bureau of Standards and by the American Society of Metals as a nickel-base alloy.

examples of age hardening by precipitation of finely divided particles with simultaneous changes in physical properties. All of the alloys of silver and copper are ductile. Of the high-silver alloys, the most important is the 92.5 silver-7.5 copper alloy known as sterling silver. The alloy is universally prized for making flatware and objects of art. It can be hardened with a considerable gain in yield strength. Another important alloy is 90 silver-10 copper, or coin silver. It is used for silver coinage in the United States and for electrical contacts when a harder material than pure silver is desired. The eutectic silver-copper alloy (28 percent Cu) is used to some extent as a brazing metal.

Platinum-Copper and Palladium-Copper Alloys.—Both platinum and palladium form continuous series of solid solutions with copper. Although the alloys are potentially useful, little actual demand exists for the binary alloys. The 60 palladium-40 percent copper alloy has some use as electrical contacts. The ternary palladium-silver copper alloys with more than 5 percent copper and not more than 65 percent palladium are age hardenable and are used in dentistry.

Zinc-Copper Alloys.—The binary high-zinc, Zn–Cu alloys are of no great importance commercially. More important are the ternary zinc-copper-aluminum diecasting alloys that are so widely used in the automotive, electrical and other industries, The tendency toward expansion is an important property of these alloys, causing them to fill molds completely.

Other Alloys.—The high-tin, ternary tin-antimony-copper alloys include all of the high-tin babbitt metals. The fatigue strength and the indentation hardness of these alloys increase with increasing antimony and copper. However, the maximum resistance to cracking in service is obtained with about 3 to 7 percent antimony and 2 to 4 percent copper. The bond strength of babbitt metals cast on steel decreases as the copper content is increased from 3½ to 7 percent. It has been shown that the decreased bond strength is associated with precipitation of Cu_6Sn_5 at the interface of the babbitt and the steel, where the compound concentrates during freezing by normal segregation. Tin-lead-antimony-copper alloys are also used for bearings, but are considered inferior to the high-tin alloys. Lead-base bearing alloys often contain copper ranging from 0.2 to 7.4 percent. Pewter may also contain a little copper as a hardener. Copper in amounts up to 4.7 percent may be used in type metals. The zinc-tin bearing metals, britannia metal, and various white casting alloys usually contain from 2 to 11 percent copper.

Copper is added to manganese alloys in amounts from 3.5 to 35 percent to increase elongation. The silver-copper-zinc alloys in which the copper ranges from 0 to 40 percent are widely used as silver solders.

The properties of several binary and more complex alloy systems based on copper have been investigated. Studies were made of the precipitation hardening of copper containing 2.2 and 4.5 percent cobalt, with and without adding 6 to 12 percent manganese. Precipitation hardening is greater in the alloys containing manganese.

Copper-titanium and copper-zirconium alloys were investigated by Dies, who reported that an alloy containing 0.25 percent zirconium retained work-hardness at moderately elevated temperatures better than the conventional silver-bearing copper and had high-electrical conductivity. Copper alloys containing as much as 2 percent titanium with 0.3 to 1.2 percent aluminum were found by Gruhl and Cordier to give considerable response to precipitation hardening, together with comparatively high ductility and good workability, both hot and cold.

A Japanese patent covers a dental alloy of golden color containing 51 to 60 percent copper, 35 to 43 percent zinc, 0.3 to 2 percent silicon, and 0.5 to 5 percent of either iron or cobalt. Another patented material for special applications—namely, for control rods in nuclear reactors—consists of copper containing 5 to 20 percent boron and 25 to 79 percent nickel or chromium.

Copper Compounds

Of the many known copper compounds only a few are manufactured industrially and used on a large scale. In point of tonnage, copper sulfate ($CuSO_4$) is the most important to industry. Anhydrous copper sulfate is a white crystalline substance, but the usual commercial form is the pentahydrate ($CuSO_4.5H_2O$), called blue vitriol, which contains about 26 percent copper. It is highly valued as a fungicide and as a source of minerals for plant and animal life. Copper sulfate is used extensively to activate sphalerite and other sulfide minerals in metallurgical flotation, as a print toner in photography, in dyes, galvanic cells, and antiseptics, and as the raw material for producing the complex copper ammonium compound necessary for making crayon. Other copper compounds and their uses are given in table 5.

TABLE 5.—*Copper compounds and their uses*

Name	Formula	Crystal color	Soluble in—	Typical uses
Basic cupric acetate	$Cu(C_2H_3O_2)\cdot CuO\cdot 6H_2O$.	Blue	Water, ammonium, hydroxide acid.	Catalyst for making organic compounds.
Basic cupric carbonate	$CuCO_3\cdot Cu(OH)_2$	Dark green	Slightly in water and acid.	Raw material for production of other copper compounds, pigments for paints and ceramics, fungicides, pyrotechnics.
Bordeaux mixture	$3Cu(OH)_2\cdot CuSO_4$	Blue	Water, ammonium hydroxide, acid.	Fungicide.
Cuprous chloride	$CuCl$	White	Hydrochloric acid, ammonium hydroxide.	Catalyst in chemical manufacturing, condensing agent for soaps, fats, and oils.
Cuprous cyanide	$CuCN$	White	Hydrochloric acid, ammonium hydroxide.	Electroplating, catalyst, insecticide, antifouling paints.
Cupric chloride	$CuCl_2$	Yellow brown.	Water, alcohol, ammonium chloride.	Mordant, refining of gold and silver, recovery of mercury from ores, pyrotechnics, photography.
Cupric nitrate	$Cu(NO_3)_2$	Blue	Water, alcohol	Electroplating solutions, burnishing iron, preparation of metal catalysts.
Cuprous oxide	Cu_2O	Dark red	Hydrochloric acid	Production of copper salts, ceramics, electroplating, fungicides, antifouling paints.
Cupric oxide	CuO	Brownish black.	Acids	Rayon and ceramic industries, electrical depolarizer, chemical analysis, catalyst.

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CHAPTER 2—HISTORY

PREHISTORY AND EARLY HISTORY OF COPPER

The industrial history of mankind is divisible into two major epochs—a stone age and a metal age. Between these two epochs there was a transition period, when metals were found in their native state and fashioned by hammering into useful implements including weapons and objects of art. Gold and silver were of no industrial value to primitive man, and the use of copper became the link between the ages of stone and metal. Copper was the second metal used by man, gold being the first. The oldest known relics of copper are not necessarily the first that were made, but hammered copper is found among Chaldean remains that go back to 4500 B.C.; and in the Badarian graves of Fayoum in Egypt there is native copper that may be even more ancient. Some writers believe that two millenniums separated the first use of hammered copper from the beginning of true metal culture, about 3500 B.C., when copper was smelted from its ores and cast in a mold. This dates the first knowledge of copper at about 6000 B.C.

The prehistory and early history of copper is traced through archeological, philological, technical, historical, and classical writings concerning the role of copper in changing and advancing civilizations. The sequence of cultural development as divided into the well-defined neolithic, copper, bronze, and iron ages is not confirmed by the study of the early use of the metals. Such a progression was probably true over different spans of time in the ancient Near East, Egypt, and parts of prehistoric Europe, but a definite and uniform succession of metal cultures all over the world cannot be substantiated. The North and South American Indians had not entered the metal age until many centuries after the Egyptians, and as the mineral resources of North America yielded no tin, there was no bronze age there. Southern India and southern and central Africa also skipped the bronze period. Australia, New Zealand, Japan, and the islands of the Pacific passed directly from the use of stone to that of iron.

Mining

Little is known about ancient copper mining although it is certain that both open-pit and underground mining was practiced in antiquity. The most important copper-ore deposits were in Sinai, Syria, Baluchistan and Afghanistan, Caucasia and Transcaucasia, the Taurus region, Cyprus, Macedonia, Iberia, and Central Europe. The copper in use among the Sumerians of southern Mesopotamia (3500–3000 B.C.) was obtained from Asia Minor which was also the source for supplying the Assyrians much later. The peaks of production in this region fell between 2400–2000 B.C. and 1500–1200 B.C.

Copper was worked in Egypt beginning from Dynasty III (2600 B.C.). It is estimated that about 10,000 tons was produced over 1,500 years. Some copper mines were in the Arabian Desert, but by far the greatest quantity of copper came from mines of the Sinai peninsula. Although these mines were first worked for turquoise, remains of crucibles, slag, and copper objects prove that smelting of ore was practiced in predynastic times. Production at the oldest mines in Wādi Maghara continued (with a break between Dynasties V and XI) to 1750 B.C. From 1600 B.C. onwards, mining was concentrated in the neighboring region of Jabal Serābīt al Khādim, until it ceased about 1200 B.C. when Egypt had come to depend upon imports from Cyprus and Armenia.

Another important copper-mining center was in the Wādī al ʻArab between the Dead Sea and the Gulf of Aqaba. Here mines were worked from the early to the middle bronze age, and again between 1800 and 1300 B.C. by the Edomites. Mining was by the room-and-pillar method; some of the pillars still show thin veins of ore.

In Cyprus copper mining began about 2500 B.C. Both oxide and sulfide ores found here were used in supplying Egypt during Dynasty XVIII (1580–1350 B.C.). The mines were operated successively under the dominion of the Egyptians, Assyrians, Phoenicians, Greeks, Persians and Romans. The English word, copper, was derived from the Greek name of the island of Cyprus, Kypros, through the Latin cuprum. The same deposit is still being exploited, supplying 39,000 tons of copper in 1960.

Copper was used in China as early as 2500 B.C., according to the Shu Ching epics, but no mention is made of the source or the mining of this copper.

In Europe, copper mines belonging to the bronze age are known in Austria, Germany, France, Spain, Portugal, Greece, and Tirol.

In Tirol the mines of Mitterberg seem to have been worked from about 1600 B.C. in the bronze age to the Hallstatt period of the iron age, about 800 B.C. Probably the most important copper deposits in Europe were those of Spain and Portugal, including the outstanding Rio Tinto ore body which is still being exploited. In Britain copper deposits found in Anglesey, Cornwall, Devon, and Shropshire are of historical interest, having been developed by the Romans after the great invasion of A.D. 43.

In North America evidence, discovered by archeologists in pits found on the Upper Peninsula of Michigan and on Isle Royale in Lake Superior, reveals that copper mining and the forming and use of copper implements and weapons was carried on during a prehistoric period extending from about 5000 to 1000 B.C. There are many of these pits in the area, estimates of those on Isle Royale alone are into the thousands. A section of charred log found in one pit and subjected to carbon-dating methods was determined to be 3,000 years old, plus or minus 350 years; another piece from the same pit was tested and found to be 3,800 years old, plus or minus 500 years.

When copper was first mined in Central Africa is not known. Early Portuguese explorers noted production of copper and iron from Katanga in their 18th-century reports. Several of the Rhodesian copper belt and Katanga ore bodies had been mined extensively and mining operations had ceased long before the Europeans arrived. These ancient copper workings and outcrops pointed out by the Africans undoubtedly led to extensive exploration campaigns which resulted in development of the presently known copper deposits.

Metallurgy

Copper metallurgy started when primitive man discovered that certain stones after being hammered looked like gold. This new natural material was worked by the same processes used when working bone, stone, or fibers—hammering, cutting, bending, grinding, and polishing. This is considered the introductory phase to copper metallurgy.

Annealing native copper was the initial phase of true metallurgy. When it was found that copper when hot was much more malleable and easy to shape, tempering or annealing followed by hammering became common practice. Brittle forms of native copper which had resisted shaping could be worked with good results after heating. This discovery must have been made around 5000 B.C., for the technique was common knowledge of the peasant culture that had spread over Southwestern Asia and North Africa by the fourth millennium before Christ.

Reducing oxide ores and melting copper is linked with development of the pottery kiln. It is believed that only a civilization that made well-baked pottery requiring a high-baking temperature would possess the technical equipment that made the reduction of ores possible. With the knowledge of melting copper came the new way of fashioning metal objects by casting. This art also required a knowledge and ability to manufacture crucibles, tongs, and means of developing blast air (blowpipe, bellows). Archeological studies find that both stages had been reached in Near Eastern prehistory. The date of discovery is roughly estimated about 4000–3500 B.C.

The last phase, reduction of sulfide ores, certainly falls in historic times, though its exact beginning is still obscure. The two stages of roasting the sulfide ores, then smelting with charcoal, in different types of furnaces, each suited to one of the stages, was known to the ancient metallurgists. Finds of such specialized furnaces and lumps of semirefined and pure copper both in the Near East and such European metallurgical centers as Mitterberg prove this. The working of pyrites is connected with the invention of bellows, which is dated around 1580 B.C.

Bronze

Use of bronze dates from remote antiquity. Its first use was probably for celts and dagger blades of the second city of Troy, about 2500 B.C. It was known in Crete around 2000 B.C. and by the late Aegean civilization between 1600 and 1000 B.C. Significant styles of utensils, weapons, implements, tools, and engraved ornaments which have been found reflect the levels of art development in particular areas in certain periods. With the invention of hollow casting about the middle of the 6th century before Christ bronze became the most important material of monumental sculpture. The advancement of the art of working bronze throughout the Hellenistic, Roman, Byzantine, and Medieval periods is reflected in bronze statuary, furniture, church doors, and other ornamental and useful articles made in those times and still in existence. Bell founding, an important industry in northern Europe, France, Germany, England, and the Netherlands, began in the early part of the Middle Ages.

Brass

The mention of brass in the Bible and by Homer, Hesiod, Aristotle, and others undoubtedly refers to copper or bronze, because brass was not known as such in ancient times. Some references claim that brass was known to the Romans and possibly to earlier cultures, indicating that brass may have been produced by the smelting of cupriferous zinc-ores which could have come from mines in Laurium, Sardinia, and Cyprus.

Brass was produced in the Low Countries beginning about A.D. 300 and it became an important article of commerce. This brass was made by the calamine process in which copper shots were heated with calamine and charcoal. In 1781 James Emerson patented the process for producing brass from copper and zinc metals. However, brass was produced by the calamine method as late as 1850.

GROWTH OF INDUSTRY IN UNITED STATES

The greatest use of copper developed from the phenomenon of transmitting electricity and the invention and progressive improvement of the electric generator. In 1831 Michael Faraday discovered that an electromotive force (voltage) is set up in a conducting wire when it is moved at right angles to or across a magnetic field. With this principle he developed the dish dynamo or electric generator. Development of the electrical industry was dependent upon parallel development of other industries, one of the major ones being the copper industry, which provided copper wire for transmitting electricity and for component parts of generators and motors.

Invention of the telegraph by Samuel F. B. Morse in 1840 was the beginning of the first public service of electricity. In 1850 the first international cable was laid between Dover, England, and Calais, France. Alexander Graham Bell demonstrated the principle of the electric speaking telephone in June 1875. Edison applied for the first incandescent lamp patent November 4, 1879. Many such inventions and discoveries were made—all involving electricity and requiring copper for its transmission.

The electrical industry began to receive public attention in 1885, and the many developments responsible for its progress until 1905 were made possible by expansion of copper production in the United States.

Copper was first produced in the Colonies in 1709 at Simsbury, Conn. In 1705 a vein of copper ore was discovered in Simsbury. In 1712 another vein was exposed in what is now Cheshire. Other undertakings were carried on for a short time in East Hartford, Bristol, and other points. At Cheshire the paying ore lay only in small pockets and the shafts were soon abandoned. More extensive operations were carried on at Simsbury. The oldest mining charter in the country was given in 1709 to the company that worked this mine. For 30 years after 1707 these operators were actively engaged. They reported that $15,000 had been expended by them. The legislature passed several bills designed to encourage the workers. But since the laws of England forbade smelting the ore here, the product of the mine was shipped to England, many consignments being made. Small amounts were smelted here, notwithstanding the prohibition. After 1737, the returns not being satisfactory, the energy of the operators flagged. The deposit has been worked but intermittently since. In 1760 a company was formed in England to procure copper from the Simsbury mine. Two ship loads of ore were sent from New York. One of these was captured by the French; the other sank in the English channel. This ended foreign interest in the deposit. Later, for a short time in 1837 and again in 1857 operations were carried on.

It was not until exploitation of rich ore deposits of the Northern Peninsula of Michigan in the early 1850's that production in the United States exceeded a few hundred tons a year. Thereafter, smelter production increased from 728 tons in 1850 to 8,064 in 1860, 14,112 in 1870, and 30,240 in 1880. In the early 1880's, U.S. industry was dominated by Calumet & Hecla Mining Co. in Michigan, which was producing half of the domestic output at a cost per pound that would be competitive today, because ore ran as high as 20 percent copper. All the Michigan copper, known as Lake copper, was marketed by Calumet & Hecla through a pooling agreement, and the preeminence of Michigan was considered unassailable, particularly by those who financed the Lake development.

The first discovery of copper in Montana was in the Parrot mine at Butte in August 1866, but throughout the seventies the Butte mines were exploited only for their silver output and their silver possibilities. The area became famous for copper production when mining of copper ore began at the Anaconda mine in the early 1880's. Later, the Anaconda Copper Mining Company gained control of most of the properties in the Butte area because of its affiliation with Amalgamated Copper Company.

Another great copper area was slowly being exploited in the Southwest at the same time. Development of the oxidized silver-copper ores of Arizona was financed by the New York metal traders, Phelps Dodge & Co. Thus the Bisbee operation was first acquired by Phelps Dodge and in 1885 was merged with the Copper Queen mine, forming the basis for great mining operations in Arizona. In addition, the Bingham, Utah, property was brought into operation by 1907, by Utah Copper Co., which was later taken over by Kennecott Copper Corp.

The Lake pool, headed by Calumet & Hecla, made a determined fight against this western competition. Prices were slashed to discourage Montana producers, and by 1886 copper was selling at 10 cents a pound, compared to an average price of more than 20 cents in the previous decade. Western production, however, was scarcely checked, and the Lake pool was forced to admit defeat before the increasing production of Butte copper. In 1887, Butte production alone exceeded that of all Michigan.

The price decline, following increased United States production, was accompanied by rapidly increased consumption by the growing electrical industry. One of the most spectacular corners in the history of market gamblers—the Secretan corner—occurred at this time. By 1887, Secretan, a French financier, had contracted for three-fourths of the world copper and had begun to raise prices. Consumption fell while supplies of newly mined copper and scrap flooded the market. As stocks increased, prices tumbled. Efforts to secure a reduction in the mounting contract deliveries of copper failed, and in March 1889 the market collapsed.

While the industry was recovering from the Secretan debacle and the price still hovered around 11 cents, the ground was laid for a new effort to corner the market—the Amalgamated pool, involving Standard Oil, National City Bank (New York), and the Anaconda Copper Mining Co. Their scheme was much the same as that used by Secretan, and although the new combine did not attain its goal, for much the same reason that Secretan failed, the precarious position in which the industry found itself was saved in part by quiet liquidation of the Amalgamated surplus copper stock holdings during the next 3 years by a London banking firm.

The industry had hardly recovered from the failure of Amalgamated Copper Co. before it embarked on another price-raising attempt. The pool of 1906–07 was helped materially by the rapid increase in consumption and the high level of speculative prosperity. Elimination of the influence of F. Augustus Heinze in 1906 strengthened the position of Amalgamated at Butte. Under Federal mining law, the owner of the apex of a vein had the right to mine the whole vein. In the complicated Butte vein structure, Anaconda and the Amalgamated found themselves facing the possibility of losing most of their ore in a legal battle with Heinze, who owned a number of fractional claims on which his lawyers and engineers found the apex of the chief Butte veins. In 1906 Heinze was bought out by Amalgamated for 10.5 million dollars; and Amalgamated, in an effort to recoup, curtailed production, forcing prices up. In 1907, with further restriction of production, the price reached 25 cents before the financial panic of that year. The price broke to about half the 1907 peak, and as production from the new porphyries expanded, the price remained near the 13-cent level until 1912.

Increased supplies from Arizona, New Mexico Utah, and Nevada, made possible by large-scale exploitation of the great porphyry deposits, would have broken the market if European consumption had not been at an abnormally high level. German demand in particular was almost insatiable and not only held the price around 13 cents but led to an increase to 18 cents in 1912–13.

The domestic copper industry received tremendous impetus during World War I. Domestic mines supplied 60 percent of the world primary copper during the war, and U.S.-controlled mines in other parts of the Western Hemisphere supplied almost 20 percent more. The United States was the clearing house for world copper during this period, importing nearly all the production of other Western Hemisphere sources and supplying most of the European demand.

The immediate postwar period brought many serious problems. To cope with oversupply, the industry organized the Copper Export Association to operate in the export market under the Webb-Pomerene Act. Huge war stocks were liquidated in an orderly fashion, and the industry was pulled through the acute depression of 1921, while the average price was maintained at slightly above the prewar average. Maintenance of the prewar price was far from satisfactory to an industry with inflated war costs; but, considering that primary consumption in 1919–23 was 8 percent below the 1909–13 period and that productive capacity in the Western Hemisphere had expanded 65 percent above the prewar figure, this was an accomplishment of note. This organization did not include foreign companies.

During the next 8 years, 1922–29, the swelling output of the mines of the Chile Copper Co., Braden Copper Co., and (after 1924) Union Minierè du Haut Katanga was more responsible than any other single factor for keeping copper prices below the prewar level during this period, bringing about the inactivation of the Copper Export Association in 1924. In 1926, Copper Exporters, Inc., was formed under provisions of the Webb-Pomerene Act. This organization included producers of more than 80 percent of the United States mine production, representing all the outstanding units. With them were associated foreign producers, which, together with the domestic members, controlled more than 90 percent of the world copper output.

The new organization was a means of increasing the dominance of U.S. producers. By eliminating the influence of speculators, who operated chiefly through the London Metal Market, prices could be dictated by New York, since most of the world production and consumption centered in the United States. Whereas the Copper Exporters, Inc., did succeed in fulfilling their first aim—reducing the power of middlemen and eliminating the London influence—they were not as successful in their second stated aim—stabilization of prices—for prices showed a strong tendency to rise.

This increase in prices was not at once apparent, for in 1927, the first full year of the Exporters activity, prices declined. At the same time, mine production decreased, and stocks increased. By 1928, however, the price of copper began to rise, bringing with it increased production of primary and secondary copper. This increase carried through 1929 with the price for that year averaging 18.23 cents per pound, 24 percent more than in 1928, and mine production was at the second highest point in the history of the industry.

The copper industry had just begun to benefit from rapid expansion of this era when the stock-market crash came late in 1929. Production dropped sharply in 1930 and 1931, and by 1932 refinery output was 75 percent below the 1929 level. Copper Exporters, Inc., disbanded in 1933.

Of the 10 copper refineries operating at 94 percent of their total capacity in 1929, 9 were active in 1932 but were using only 25 percent of their capacity because of the depression.

Anaconda, Kennecott, and Phelps Dodge in 1929 controlled 66 percent of the mine output of the United States and 31 percent of the output outside the United States, 48 percent of the total world production. By 1932, however, the combined share of these three companies had declined from 48 to 36 percent of the world total. United States production also declined from 47 percent to 23 percent of the world total.

Another event that had a far-reaching effect on the United States copper industry was passage in 1932 of a 4-cent excise tax on all foreign copper imports. This was equivalent to a 72-percent ad valorem duty based on the average price in 1932 and was practically an embargo. Most imports of ores, concentrates, and other unfinished forms of copper entered under bond for treatment and re-export without payment of the tax. A small portion was imported, the tax was paid, and the metal that was exported in manufactured form was eligible for a drawback of 99 percent of the tax. Only small quantities of tax-paid copper were retained in the United States for ultimate consumption.

Business activity revived a little by 1933, bringing with it relief for the copper producers. This trend of increased production continued for the next 5 years, except for a slight recession in 1938.

The copper industry broke all production records in the 1939–49 decade. Refinery output soared from 1,126,000 tons in 1940 to 1,502,000 tons in 1943, the peak for the period. Although output decreased quantitatively after 1943, the amount of capacity being utilized averaged approximately 75 percent, which when the excess capacity created by wartime requirements is considered, indicated that the metal-preparation segment of the industry was in a relatively sound economic condition. However, domestic mines were incapable of supplying the production demands of the economy, thereby forcing operators of smelters and refineries to rely more heavily on imports of unrefined copper.

In Arizona in the 1950's the Lavender Pit, San Manuel, Silver Bell, Copper Cities, Pima, and Esperanza mines started production; capacity at the Ray mine was substantially increased by conversion from block caving to open-pit mining; and the Mission and Christmas mine deposits were developed for production. The White Pine mine in Michigan, the Yerington mine in Nevada, and the Kelley and Berkeley mines in Montana were brought into production. United States mine production exceeded all previous records in 1956 (1,104,156 short tons) and almost reached this record in 1957 and 1960; 1958 and 1959 were low production years because of voluntary cutbacks in mine output and strikes.

Increasing demand in the United States and Europe beginning in the latter half of 1954 created a copper shortage, and the price of major producers in the United States rose continually, reaching 46 cents a pound on February 21, 1956, highest in 90 years. Prices quoted by custom smelters in the United States, the London Metal Exchange, and other European markets were even higher, attaining a peak of 55 cents per pound. (See chapter 6.)

A number of substantial copper properties in Canada began producing in the 1950's. Large reserves were developed at the Toquepala, Cuajone, and Quellaveco deposits in Peru and at the El Salvador, Rio Blanco, Mantos Blanco, La Africana, Chuquicamata, and Braden properties in Chile. Additional sources of ore were found in the copper belts of Northern Rhodesia and the Republic of the Congo. In Europe, large deposits were developed in Yugoslavia, at Majdanpek; the Glogów area of Poland; Ireland; Finland; Bulgaria; and the U.S.S.R. Substantial ore bodies were found in Australia and the Philippines. World mine production increased progressively each year, except for 1958, and in 1960 was 66 percent higher than in 1950.

TECHNOLOGICAL DEVELOPMENTS

Principal technological developments in the United States pertinent to the copper mining and smelting industry during the past 100 years include the following:

1. Application of square-set mining, first developed by Philip Deidesheimer in the early 1860's, which solved the problem of mining the large and fabulously rich, but soft and crumbling, silver sulfide ore body at the Comstock silver mines of Nevada. The system was immediately successful and has since found worldwide application for ground support in mining ores that could not be mined by any other known method.

2. Introduction of a block-caving system at the iron mines in Michigan and the use of slushers for mucking, the forerunner of modern mechanical loading in underground metal mines, both near the close of the 19th century. These two developments were not generally accorded a prominent place in mining history, but their significance appears when viewed from the perspective of later years.

3. Adaption of the Bessemer steel converter to the conversion of copper matte into metal in France in 1880 and in the United States in the late 1880's. This development eliminated the need for dead roasting copper sulfide ore as a prelude to blast-furnace smelting to black copper. Previously, emphasis had been on the treatment of oxide ores, and the worldwide practice was to convert sulfides to oxides by cumbersome methods of roasting; in some cases this was followed by leaching, in others, by blast-furnace smelting. The converter, with concomitant development of electrolytic refining to purify the resultant blister copper and to recover its precious metals and other byproducts, started electrolytic copper in the long, hard, competition to become accepted as equal, if not superior, to Lake copper. The converter also was a major factor in lowering costs so that lower-grade ores could be utilized.

4. The beginning of open-pit mining in 1907 permitted profitable exploitation of huge bodies of low-grade disseminated copper ores in the Southwest that previously had been considered economically unworkable. Advancements in mining technology effecting development of better mining methods, mining and transportation equipment, explosives, and engineering control contributed to increasing output by open-pit mining, accounting for 80 percent of the copper ore and 75 percent of the copper produced in 1960.

5. Rapid development of the flotation process introduced in copper concentrators between 1913 and 1916. This process improved the recovery of sulfide minerals from fine-grained ore fractions. Previously, the practice was to use gravity methods to concentrate the ore, but ore that required fine grinding to liberate minerals from gangue was not recoverable if the average tenor was below the economic limit of direct smelting.

About 1921, the discovery that certain flotation reagents could be used to effect separation of metallic sulfides from each other made available additional tonnages of copper and other minerals in selective mixed ores. Selective flotation can now make satisfactory separations of these minerals if the minerals themselves are not so intimately intergrown as to require excessive comminution to liberate them as discrete particles. With introduction of flotation at the Utah Copper Co. mill after 1914, recovery was increased from 75 percent in that year to more than 90 percent by 1935, despite a general decline in the grade of ore treated. At the Calumet & Hecla Consolidated Copper Co., Inc., mill, flotation was applied only to slime, and part of the indicated improvement in recovery was due to leaching of sand tailings. Up-to-date figures have not been compiled; however, it is safe to assume that since 1935 the percentage of recovery had decreased, owing to the complexities and lower grade of ores being treated. By no means does this detract from the effectiveness of this innovation, but it does point up its limitations.

6. With flotation came a marked change in copper-smelting methods. No longer was the blast-furnace converter cycle adequate, because most of the fine flotation concentrates were blown into the stack, and expensive recycling techniques were required to recover copper from the dust. Again the steel industry made an important contribution to copper metallurgy—the open-hearth steel furnace. This furnace metamorphosed into the copper reverberatory furnace to smelt copper concentrate into matte. To control the sulfur content, partial roasting of fine concentrates to a granular calcine before reverberatory smelting rather than sintering for blast-furnace smelting gained in importance. Later improvements in flotation now make it possible, in many cases, to control the sulfur and iron in concentrates at the mill to eliminate

roasting. And in 1960, Phelps Dodge Corp. initiated the use of reformed natural gas in place of green poles for reduction in the anode furnaces of their smelters in Arizona.

The following chronology indicates the major events important to development of the copper industry from 1850 to 1960, inclusive.

CHRONOLOGY

1850 Michigan mines became principal U.S. copper producers.
1855 First Atlantic cable was laid.
1857 Duty of 5 percent ad valorem, laid on copper ingots in 1846, was removed.
1861 Civil War began.
1861 Duty was placed on copper ingots, etc., 2 cents a pound; on ores, 5 percent; and other copper, 25 to 35 percent ad valorem.
1864 Duty on copper ingots was placed at 2.5 cents a pound until 1869.
1865 Civil War ended. "Greenback" inflation occurred.
1869 Duty on raw copper was raised to 5 cents a pound, 1869 to 1883; "Black Friday" occurred on Wall Street; first transcontinental railway was completed.
1871 Calumet & Hecla consolidated the Michigan mines.
1873 Panic of 1873 occurred.
1875 Rich copper deposits were discovered in Arizona and Montana.
1878 Edison invented incandescent lamp, marking beginning of electrical industry.
1879 Anaconda Silver Mining Co. was organized; copper mining began in Globe-Miami, Ariz.
1880 First electric lamps were installed in New York, December 20.
1883 United States became the leading world copper producer.
1884 Duty on raw copper was reduced to 4.5 cents per pound.
1887 Secretan acquired corner on copper; 85 percent of United States output was controlled.
1888 Montana became leading United States producer.
1889 Secretan corner was broken by flood of new and scrap copper.
1891 Baring Bros. failed because of copper corner, precipitating depression of nineties.
1892 General Electric Co. was formed. New York-Chicago copper telephone line was installed.
1894 Raw copper was placed on "free list." Serious labor troubles occurred.
1896 Business recovered.
1898 Spanish-American War occurred.
1899 Amalgamated Copper Co., capital $75 million, acquired Anaconda.
1900–1905 Was era of consolidations, mergers, and financial wars for control of rich Montana copper deposits. F. Augustus Heinze threatened Amalgamated-Anaconda mineral rights by securing control of key properties in Butte.
1906 Amalgamated bought out Heinze for $10.5 million, ending 5-year fight for control.
1907 "Rich man's panic" was experienced on Wall Street, October.
1909 Daniel C. Jackling proved economical his idea of mining and processing the low-grade copper ores of the western United States on a scale previously unknown, thereby revolutionizing copper mining in the United States and abroad and making available new and needed copper reserves to meet world requirements.
1912 Braden Copper Co. in Chile began production of low-cost copper.
1914 World War I began. Clayton Act was passed.
1915 Kennecott Copper Corp. was formed.
1916 Chile Copper Co. was in production.
1917 United States entered war; copper was placed under price control at 23.5 cents a pound.
1918 World War I ended. Webb-Pomerene Act was passed.
1919 Copper Export Association was formed.
1920 Postwar inflation affected industry.
1921 Deflation occurred; "buyers' strike" enforced; most copper mines were shut down. Copper Export Association pool removed 200,000 tons of copper from domestic market.
1924 Katanga, Belgian Congo, began volume production. Copper Export Association was disbanded.
1926 Copper Exporters, Inc., was organized as international copper cartel.
1927 Domestic copper production was curtailed, contrasting with upward trend in demand.
1928 Copper stocks were reduced to panic-buying levels.
1929 Panic buying of copper continued; stock-market panic occurred, October; copper prices were pegged at 18.3 cents for nearly a year; Canada became large copper producer.
1931 Copper Exporters, Inc., was dissolved; Rhodesian mines gained in volume production.

1932 Duty of 4 cents per pound was placed on raw copper June 21.
1933 NRA (National Recovery Act) Code for Copper and Brass Mill Products Industry was approved in November.
1934 NRA Code for Copper Industry price was set at 9 cents per pound.
1935 NRA was declared unconstitutional. International Copper Control was formed June 1.
1936 Copper production was curtailed by cartel—South America, Africa.
1937 Copper shortage brought panic buying and almost a 50-percent price increase.
1938 Business recession began.
1939 World War II began September 1. International copper cartel was abandoned.
1940 U.S. Government began buying copper through RFC (Reconstruction Finance Corp.) subsidiary.
1941 United States entered World War II December 8. Copper prices were part under voluntary control
1942 Copper prices were fixed at 12 cents, Connecticut Valley, with a Government subsidy for high-cost mines; Premium Price plan set, February 1.
1945 World War II ended.
1946 Price control was ended November 10. Rapid price increases made Premium Price Plan ineffective.
1947 Premium Price Plan was ended June 30.
1948 Geneva Trade Agreement was made. Excise tax was reduced from 4 cents to 2, pending ratification by Chile. (Tax was suspended during the war and suspension was continued to March 31, 1949).
1949 Chile ratified Geneva agreement in February. Tax was further suspended until June 30, 1950.
1950 Korean conflict began June 26. Defense Production Act was passed. Defense Minerals Administration in the Department of the Interior, National Production Authority in the Department of Commerce, and other agencies were created to carry out provisions of the act.
1951 National Production Authority reinstituted Controlled Materials Plan for copper, steel, and aluminum. Ceiling price on copper was established January 26 by the Office of Price Stabilization. World copper (free world countries) was placed under international allocation and quotas were set by the International Materials Conference.
1952 Chile embargoed copper exports to United States, resulting in dual prices in United States. Kelley mine at Butte, Mont., was started in production.
1953 Free trading resumed on London Metal Exchange August 5 after lapse of 14 years and on the New York Commodity Exchange after a recess of 2 years. Initial production came from Yerington mine in Nevada.
1954 Silver Bell, Lavender Pit, and Copper Cities mines in Arizona and the White Pine mine in Michigan reached production stage. U.S. Government purchased 100,000 tons of Chilean copper.
1955 San Manuel started production. Prices increased rapidly.
1956 Mine production and price of copper reached record high in the United States. Three-year labor contracts between principal producers and unions in United States were negotiated in June. Production was started at the Berkeley pit at Butte, Mont.
1957 San Manuel Copper Corp. and White Pine Copper Co. delivered copper to the Government under DMPA contracts negotiated in 1952. Export controls on copper were relaxed by Bureau of Foreign Commerce.
1958 Excise tax on copper imports was reimposed July 1 at 1.7 cents per pound pursuant to agreement at GATT meetings at Geneva, in 1956.
1959 Principal copper mines, smelters, and refineries were closed by longest strike in history. Operations began at the Esperanza mine in Arizona in March. Production was started in April at the El Salvador mine in Chile.
1960 World mine production reached new high. Scheduled production began at the Toquepala mine in Peru, January 1.

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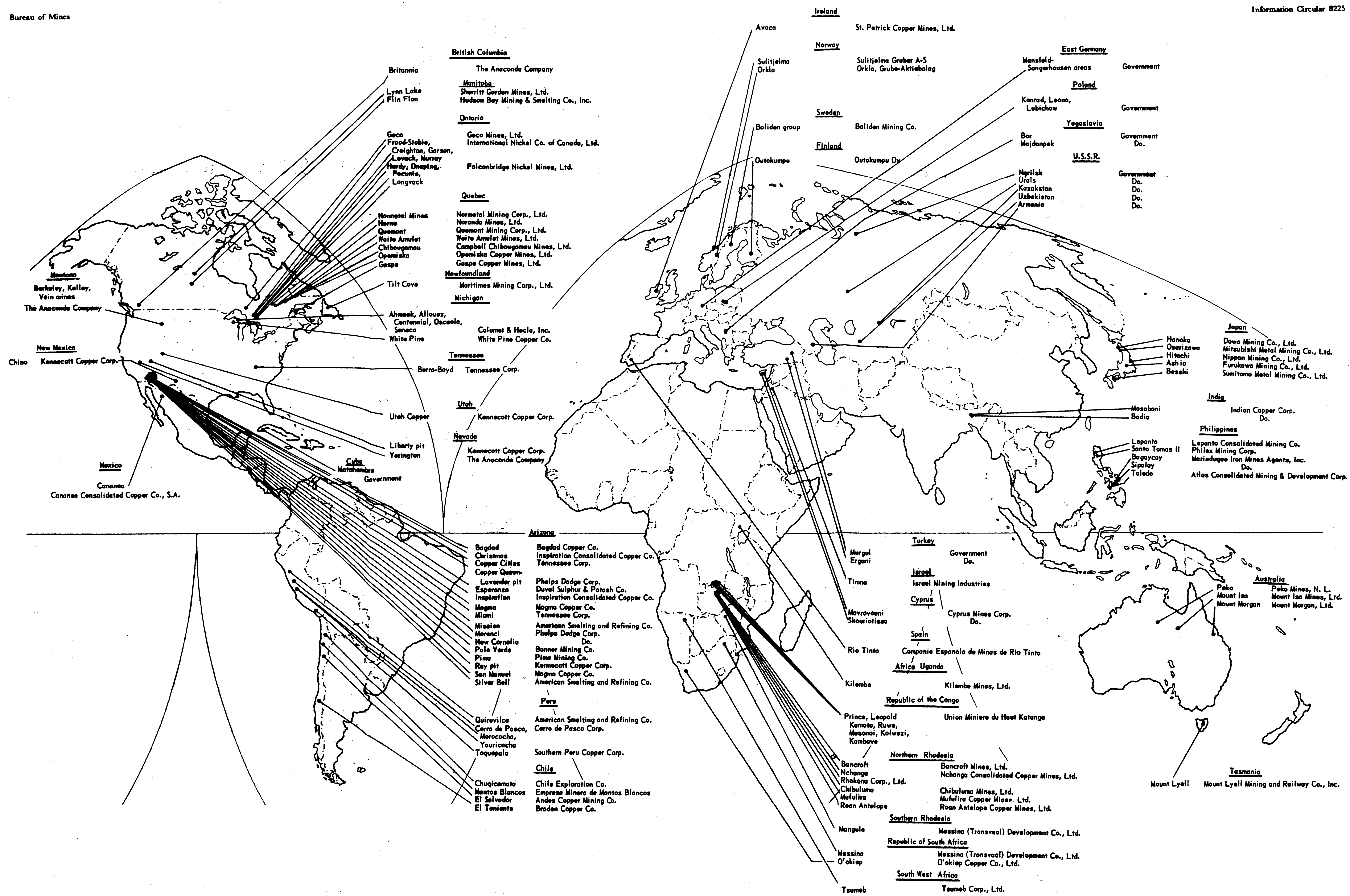

FIGURE 2.—Major Copper Mines of the World

733-740 O - 65 (Face p. 39)

CHAPTER 3.—PRIMARY COPPER RESOURCES

The world is plentifully endowed with sources of copper. Mines operating today are equipped and have the capacity to more than fulfill current demand. New discoveries coupled with extensions at mines in many copper provinces of the world during the 1950's greatly increased the known world copper resource. Important copper producing regions of the world are: (1) The western United States, (2) the western slope of the Andes in Peru and Chile, (3) the central African Copperbelt in Northern Rhodesia and the Republic of the Congo, (4) the Ural Mountains and the Kazakhstan region in U.S.S.R., (5) the Precambrian area of central Canada, and (6) the Keweenaw peninsula of northern Michigan. Figure 2 shows location of major copper mines in the world.

GEOLOGY

Deposits of copper are widely distributed, both geographically and geologically. Geologically such ore bodies are found in a variety of host rocks of all ages under greatly varied structural conditions. The periods of their formation range from Precambrian to Recent. Many are characteristically associated both in time and location with igneous activity, while a few occur in sandstones and shales.

Types of Deposits

Following is a general classification of types of copper deposits; it should be recognized that gradations will occur with gradual changes from one physical and chemical environment to another: (1) Lenticular deposits in schistose rocks; (2) Sudbury nickel-copper type; (3) native copper types; (4) bedded deposits in sedimentary rocks; and (5) vein, pipe, and disseminated deposits.

LENTICULAR DEPOSITS IN SCHISTOSE ROCKS

The primary mineralization of these deposits consists of sulfides of iron, copper, and zinc commonly as a replacement of schistose rocks. Schistosity may be the result of widespread metamorphism, but the deposits are along zones of shearing. Such deposits seem to have formed at some depth under conditions that favored deformation by shearing rather than by brecciation or shattering. The solutions that deposited the ores were closely confined to the channels and replaced the sheared rock almost completely to form massive sulfide lenses. The minerals are those of moderate temperature range of sulfide deposition, and the deposits may or may not contain precious metals and zinc or lead in important amounts. Such deposits usually are not closely associated with igneous stocks, and none is in stocks.

The deposits of the deeply eroded Appalachian region belong to this classification, as do some of the deposits on the border of the Sierra Nevada and Coast Range batholiths in California and British Columbia, respectively, where erosion has also been deep. The Tertiary deposits of the Rocky Mountain area, which have relatively shallow erosion, are not of this type.

The primary ores are generally a rather low-grade massive sulfide. Pyrrhotite is present in many of the ores, and iron-bearing sphalerite is in most of them. These minerals are notably absent in most of the Tertiary copper deposits, and depth of formation seems to be a factor in their formation.

Supergene alteration in many deposits has produced a zone of enriched sulfides, usually thin and rich as at Ducktown, Tenn., and Iron Mountain, Calif., but sometimes deep and rich as at Jerome, Ariz.

SUDBURY NICKEL-COPPER DEPOSITS

These are associated with the norite member of the Sudbury irruptive. Generally, the ore bodies occur associated with faults at or near the footwall contact between the norite and the underlying volcanics or in offsets of the norite within the volcanic series. Structurally, faulting appears to be the main ore-localizing feature, with ore bodies occurring in zones of shearing and brecciation close to the norite contact. Ore occurs as disseminated and heavy sulfide types containing pyrrhotite, pentlandite, and chalcopyrite as the principal minerals. Gold and silver occur as tellurides and in the native state. The platinum group metals appear as sperrylite, platinum arsenide, and other rare combinations.

NATIVE COPPER DEPOSITS

Included are those in which the copper occurs in shoots in tops of certain lava flows, in conglomerates interbedded with flows, and in sandstones. The rocks in which the copper occurs are characteristically red owing to the presence of ferric oxide. The latter may account for the copper being deposited as native metal rather than as sulfide.

Deposits of this type have been mined at vertical depths of more than 6,000 feet in veins and lodes with no notable change in mineralogy. The ores are generally low-grade concentrating ores, although large masses of copper are present.

The Lake Superior district of Michigan is the only large producing region having deposits of this type, although similar deposits occur in New Jersey, Pennsylvania, Maryland, Alaska, and Northern Canada. For many years native copper also accounted for much of the production at the Corocoro mine in Bolivia.

BEDDED DEPOSITS IN SEDIMENTARY ROCKS

These include contact or pyrometasomatic deposits and those formed by replacement of sedimentary rocks, commonly limestone, outward from fissures. The two classes are not sharply separated. The typical contact or pyrometasomatic deposits are replacements of limestone or dolomite by silicates, oxides, and sulfides. Many contact deposits contain large bodies of andradite (the ferric iron garnet) with which are associated other high-temperature silicates, iron oxides (magnetite and hematite), and sulfides of iron and copper. Many such deposits are in limestone at or near the contact of an intrusive body, usually a stock.

The silicates and oxides formed first and the sulfides later. The sulfides, including copper sulfide, are most abundant at many deposits between the silicate zone and the unreplaced limestone. In some deposits the silicate zone is largely lacking, and the sulfide zone is close to the igneous contact. Contact deposits grade into fissure-replacement and bedded deposits, in which certain beds of limestone are replaced by sulfides outward from fissures with or without the formation of silicates.

Deposits of the contact metamorphic type are widely distributed, especially in the eastern Cordilleran region, but with a few exceptions have yielded relatively little copper. Part of the great deposits at Bisbee, Ariz., and some of the limestone replacement deposits at Bingham, Utah, are examples of such occurrences, and many of less importance have been mined.

With such deposits may be grouped those in limestone far from known intrusive bodies; the chalcocite deposits of the Copper River district in Alaska are outstanding examples.

VEINS, PIPES, AND DISSEMINATIONS

These may be grouped as three types of deposits, each having distinctive features but showing such gradation that a definite separation is neither possible nor desirable. The deposits are similar in mineral composition and differ mainly in the character of the fracturing that has controlled deposition.

Vein Deposits.—Perhaps, the simplest type of deposit and the simplest veins are those that occupy a single fault or fissure. Large copper deposits of this character are uncommon but are approached in the Magma vein of Superior, Ariz., and the Old Dominion vein of Globe, Ariz.

Other districts, such as the Butte district in Montana and the Morenci district in Arizona have complex vein systems in which the larger veins can be mined as units, but in parts of these areas a mass of small veins are mined together.

In general, the veins tend to join and decrease in number in depth, and a complex system of veins may merge into only a few root channels.

Volcanic Pipe Deposits.—These are more or less cylindrical bodies formed by volcanic explosion. The rock within the pipe is usually brecciated, although in some a core of relatively unbrecciated rock is surrounded by an envelope of highly brecciated rock. The ore minerals cement and partly replace the brecciated rock. In some pipes, quartz has replaced most of the rock in a central channel, while in others replacement has been slight.

Volcanic pipes range in size from a few feet or tens of feet to hundreds of feet in diameter and in shape from nearly circular to elongated, resembling breccia veins. A few, like the Cactus pipe in Utah and the Colorado pipe at Cananea, Mexico, which have been followed to what seems to be their roots, show a decrease in area and less brecciation with depth. The pipe type of deposit has been particularly productive at Cananea and Nacozari, Mexico. Some of the disseminated deposits may be large pipes such as the Utah copper deposits of Bingham, Utah. In many of the pipes the ore minerals, disseminated as a breccia cement and replacement, comprise only a small part of the ore; in others, like the Colorado and Campbell pipes, parts of the ore bodies are massive sulfide. Most of the volcanic pipe deposits are in the Tertiary of the eastern Cordilleran region and were probably formed at shallow depth.

Replacement Pipelike Deposits.—These occur in limestone and have been productive at many places; the Campbell ore body at Bisbee, Ariz., is an example. These grade into the manto-type deposit common in limestones and are generally formed by solution along intersecting fractures.

The origin of pipelike ore deposits is still open to question. In some the start was doubtless due to faulting or jointing, which formed breccias. These permeable channels were enlarged by solution before the ore minerals were deposited. This has been referred to as mineralization stoping.

In other pipes the character of brecciation has suggested that volcanic explosive action has broken a more or less cylindrical body of rock. This permeable zone has later been traversed by mineralizing solutions which have cemented and partly replaced the breccia.

The importance of pipelike deposits depends on the distinction that is drawn between them and other types, but typical pipelike deposits of both types have produced much ore.

Disseminated (Porphyry) Deposits.—In North America this is confined to the eastern Cordilleran region. It occurs characteristically in and around the tops of intrusive bodies that probably are upward extensions of batholitic intrusions. The intrusive bodies may therefore be simple upward projections in the form of stocks or cupolas, or they may follow structural features and be modified forms of stocks or cupolas. Some of the disseminated deposits, such as those of the Bingham district, Utah, and the Ely district, Nev., are in such modified stocks.

Along the boundary of the stocks both the intruded and the intrusive rocks have been jointed and fractured. The fracture zones were subsequently mineralized, mainly with pyrite and chalcopyrite in variable amounts and proportions. In some deposits, such as those of Bingham, Utah, most of the mineralization is in the stock; but some extended into the intruded quartzite, while in others, such as those of Miami, Ariz., much of the mineralization is in the intruded schist. The primary mineralization is characteristically low in grade but with wide variations. The deposits have all undergone oxidation, which has affected them differently.

Effect of Oxidation on Copper Deposits

The effect of oxidation on the value of copper deposits is perhaps greater and more varied than for any other metal. Several factors influence oxidation:

1. Character of the sulfide, particularly the proportion of pyrite to copper sulfide or copper-iron sulfides.
2. Character of the gangue minerals or enclosing rock, whether reactive or nonreactive.
3. Type of the deposit, whether massive sulfide or disseminated sulfide.

CHARACTER OF SULFIDES

Pyrite (FeS_2) in oxidizing is first changed to ferrous sulfate and sulfuric acid. If the oxidizing process continues the ferrous sulfate will oxidize to ferric sulfate, which may break down to give limonite and sulfuric acid. Abundant pyrite gives abundant sulfuric acid. Pyrrhotite or more complex iron-copper sulfides may oxidize similarly but will yield less sulfuric acid than pyrite.

Formation of sulfuric acid and ferric sulfate promotes solubility of metals and is favorable to their movement in ground water. The presence of iron sulfide, especially pyrite, therefore favors leaching of copper.

CHARACTER OF GANGUE

Gangue minerals have been classed as reactive, intermediate, and inert.

The carbonates, calcite and dolomite, are most reactive; the micas, feldspars, and other silicates are intermediate; and quartz and barite are inert. An inert gangue, such as quartz, has no chemical influence on the oxidation products of sulfides and is favorable to their movement. Reactive gangues, such as calcite and dolomite, react with all the oxidation products of sulfides, neutralizing sulfuric acid, precipitating the metal sulfates as carbonates, and causing precipitation of limonite from ferric sulfate. The presence of calcite or dolomite is unfavorable to the movement of copper and tends to produce copper carbonate deposits in the upper parts of the oxidizing body rather than a zone from which copper has been leached. With an abundant carbonate gangue there will be little downward movement of copper. With a quartz or silicate gangue there may be much downward movement.

As the copper sulfate, other sulfates, and sulfuric acid move below the zone of oxidation they encounter fresh sulfides, and the copper is precipitated on these as copper sulfide. Precipitation may result from direct reaction between the copper sulfate and the sulfide or hydrogen sulfide may precipitate sulfides from the sulfate solutions.

TYPE OF DEPOSIT

In massive sulfide bodies, such as the lenses in schist, the copper is precipitated before the solutions have penetrated far into the sulfides, resulting in a shallow zone of supergene (secondary) sulfides which in some deposits is very rich. This precipitation is due to the abundance of fresh sulfides.

In disseminated deposits the sulfate solutions penetrate deep into the zone of scattered sulfide grains (mainly pyrite and chalcopyrite) before all the copper is precipitated, and a thick zone of secondary sulfide is produced which is usually not rich.

The zones migrate downward during weathering, and oxidation of the secondary sulfide zone may produce a relatively rich zone of carbonates and oxides. The water table practically limits the downward movement of oxidation.

The net result of oxidation is the formation of four zones, any one of which, except the lowest or primary zone, may be lacking:

1. An upper zone from which copper has been leached.
2. A zone in which copper has been fixed as a carbonate.
3. A zone in which copper leached from above has been deposited as secondary sulfide.
4. The zone of primary sulfides.

Mineralogy

COPPER MINERALS

Copper is found in nature in numerous minerals and in various combinations with other elements. Of 165 known copper minerals only about 12 are commercially important; about 6 minerals are the source of more than 95 percent of the copper mined. Principal copper minerals are listed in table 6.

There are three important groups of copper-bearing minerals. The first is that of the primary or hypogene minerals, those deposited at considerable depth in the earth by processes that may be related to igneous activity. Examples of these are bornite, chalcopyrite, and enargite. Some complex minerals are also primary, but minerals of this type are not abundant in economic deposits.

The second group is composed of the supergene copper minerals commonly formed by weathering of copper sulfides. Cuprite, malachite, azurite, and chrysocolla are the chief minerals of the supergene zones of copper deposits when a reactive gangue is present. Brochantite and atacamite are found in the upper portions of ore bodies in arid regions.

The third group, the simple sulfides, chalcocite, and covellite, are predominant in the zone of seconadry enrichment. These minerals may also be found as primary minerals in some deposits.

The copper minerals found most frequently at the surface are the green and blue copper carbonates and the green silicates. These colors are distinctive; however, a rock with a very small percentage of copper may be colored green. Cuprite, tenorite, native copper, atacamite, chalcanthite, and occasionally other rare copper minerals are found in outcrops; these minerals, together with the carbonates and silicate minerals, are formed by weathering of copper sulfides. Chalcopyrite and, to a smaller extent, bornite may exist in outcrops or in float, but when found at the surface in arid districts usually they are as kernels surrounded by alteration products. Copper sulfides are generally associated with pyrite and other iron sulfide minerals.

TABLE 6.—*Principal copper minerals*

Mineral	Composition	Specific gravity	Copper, percent
Native: Native copper	Cu	8.8 -8.9	100.0
Oxides:			
Cuprite	Cu_2O	6.0	88.8
Tenorite	CuO	5.8 -6.3	79.8
Malachite	$CuCO_3Cu(OH)_2$	3.9 -4.03	57.3
Azurite	$2CuCO_3Cu(OH)_2$	3.77	55.1
Chrysocolla	$CuSiO_32H_2O$	2.0 -2.4	36.0
Antlerite	$Cu_3SO_4(OH)_4$	3.39	54.0
Brochantite	$Cu_4SO_4(OH)_6$	3.39	56.2
Atacamite	$CuCl_{2.3}Cu(OH)_2$	3.75-3.77	59.4
Sulfides:			
Chalcopyrite	$CuFeS_2$	4.2 -4.3	34.5
Bornite	Cu_5FeS_4	4.9 -5.4	63.3
Chalcocite	Cu_2S	5.5 -5.8	79.8
Covellite	CuS	4.9 -5.0	66.4
Enargite	$Cu_3As_5S_4$	4.43-4.45	48.3
Tetrahedrite	$Cu_8Sb_2S_7$	4.7 -5.0	52.1
Tennantite	$Cu_8As_2S_7$	4.7 -5.0	57.0

COPPER ORES

Copper ores vary in type (whether sulfide or oxide), in the valuable metals occurring in them, in tenor, and in the kind of associated gangue present. They are commonly distinguished as oxidized ores or sulfide ores and may range between high grade and low grade, the grade roughly expressing copper content.

A sulfide ore is a natural mixture containing copper-bearing sulfide minerals and associated gangue minerals that are either valueless, as regards their metal content, or of subordinate importance for some other purpose. The gangue may consist simply of the minerals making up the host rock, or it may be composed of various other minerals developed during the general ore-forming process, or it may occur as a combination of these two groups. Thus the gangue might consist of a sulfide, such as pyrite, along with quartz, sericite, calcite, barite, etc. From an ore like this, in addition to the principal value in copper, pyrite might be reclaimed as a byproduct for its sulfur, and barite might be recovered to be used in well-drilling muds.

An oxidized copper ore is similarly a natural mixture of oxidized copper minerals and gangue. Examples would be malachite and azurite in dolomite stained by iron oxide, or brochantite and crysocolla deposited among silicates.

Although there are many ores in which copper is dominant and is the principal metal recovered, for some copper-bearing ores much of the value comes from other metals associated with copper or from nonmetallic constituents. Other products commonly contribute to the value of a copper ore.

Commonly associated with copper are minor amounts of gold and silver and locally lead and zinc. Molybdenum is recovered in several plants treating porphyry copper ores, and very minor amounts of platinum, selenium, etc., may be extracted in refining. Nickel, likewise, occurs in certain kinds of copper ore, and cobalt is a valuable associate of copper in some ores of the Belgian Congo and Northern Rhodesia. Mineralogically, a sulfide ore might contain, for example, chalcocite and pyrite dispersed through a gangue of sericite schist; chalcocite, chalcopyrite, and pyrite with a little molybdenite might be associated with gangue minerals derived from the alteration of quartz monzonite rock.

In some ores, copper occurs in coordinate importance with other valuable metals to form a so-called complex ore. By skillful beneficiation, for example, lead, zinc, and copper might be recovered from such material. Sulfide minerals in this kind of ore might be galena, sphalerite, chalcopyrite, and pyrite contained in a gangue of limestone or dolomite. Or, the ore might carry nickel and copper with a sulfide assemblage of pentlandite, chalcopyrite, and pyrrhotite in norite.

Copper itself may occur as a byproduct in some ores, and its value may be only a subordinate item as in some of the large zinc-lead, nickel, and iron deposits.

Copper ores vary widely, and the usual practice is to group them into high-grade and low-grade categories. In the United States most copper comes from the mining and concentrating of ores carrying from 0.4 to 1.20 percent copper, mainly in the sulfide form; the general average content of recoverable copper is about 0.80 percent. High-grade ores commonly contain from 3 to 10 percent copper, although some may be richer, and are generally smelted direct without preliminary concentration.

Among the sulfide copper ores, three outstanding groups should be noted. The first is composed of the porphyry copper and Northern Rhodesian types that carry copper mostly in the form of chalcocite, chalcopyrite, and bornite—iron being contained in pyrite, chalcopyrite, and bornite. Copper ranges in amount from a fraction of one percent to several percent, and iron is generally low to moderate in amount. A second group includes the deposits commonly known as cupriferous pyrite bodies. These contain very abundant pyrite and pyrrhotite and are high in iron and sulfur. Copper is carried in these ores by chalcopyrite generally ranging from 1 to 3 percent. Notable examples are at Jerome, Ariz.; Rio Tinto, Spain; and Cyprus. A third group comprises the ores carrying some of the copper as enargite or tennantite, containing arsenic. Well-known deposits of this kind are at Butte, Mont.; Bor, Yugoslavia; the Cordilleran region of South America; and Tsumeb, South-West Africa.

Various groupings of oxidized copper ores may be made according to their response to metallurgical treatment. For example, we may recognize (1) the malachite-bearing ores in dolomite of the Congo that are successfully concentrated by flotation; (2) the various mixtures of malachite, azurite, chrysocolla, and tenorite that are subject to treatment by leaching with sulfuric acid; and (3) the unusual oxidized mineral assemblage at Chuquicamata, Chile, consisting principally of brochantite, atacamite, antlerite, chalcanthite, krohnkite, and natrochalcite, also treated by leaching.

In addition, there are various mixtures of oxidized and sulfide copper minerals occurring together in ores that are treated by leaching or by leaching followed by flotation.

There are ores in which copper is carried as the native metal. In these the gangue may be conglomerate or basalt, as in the ores from the Lake Superior district in Michigan, or sandstone, as in the much smaller deposits at Corocoro, Bolivia.

The kind of gangue accompanying a copper ore may be of considerable importance in its mining and treatment. The mineralogy, texture, and physical characteristics of the gangue, which is generally the preponderant material, may dictate the type of mining method to be employed. Similar factors control crushing, grinding, classification, and flotation of the ore during its treatment.

Copper ores are found with diverse textures, depending upon the size, relative abundance, and arrangement of their constituents. Ores in which the sulfide grains are scattered through the host rock are properly termed disseminated ores. However, when the sulfide minerals are aggregated together in rich abundance, the ore is designated as massive sulfide. Or, if the valuable minerals occur in a multitude of veinlets, it is called a stringer ore, or a stockwork.

In summary, the type of copper ore (whether oxidized or sulfide), its richness in copper, the amount of accompanying metals of value, the content of substances detrimental to treatment, the kind of gangue, and the texture and hardness of the ore all influence the selection of methods for its treatment.

WORLD RESERVES

The total reserve of copper in the world is presently estimated to be 212 million tons or enough to last about 50 years at the current

TABLE 7.—*World copper reserves*

Country	Ore reserves copper content, thousand short tons	Country	Ore reserves copper content, thousand short tons
North America:		Asia:	
Canada	8,400	China	3,000
Cuba	200	Cyprus	200
Haiti	75	India	100
Mexico	750	Israel	250
United States	32,500	Japan	1,200
		Philippines	1,000
Total	41,925	Turkey	580
South America:			
Bolivia	55	Total	6,330
Chile	46,000	Africa:	
Peru	12,500	Angola	40
		Republic of the Congo	20,000
Total	58,555	Northern Rhodesia	25,000
Europe:		Southern Rhodesia	475
Austria	60	Kenya	20
Bulgaria	300	Mauritania	460
Finland	750	South-West Africa	525
East Germany	500	Uganda	210
Ireland	280	Republic of South Africa	900
Norway	500		
Poland	11,400	Total	47,630
Spain	4,500	Oceania: Australia	1,200
Sweden	700		
U.S.S.R.	35,000	Grand total	212,000
Yugoslavia	2,750		
Total	56,740		

annual production rate of slightly more than 4 million tons. The tabulation of reserves by country and continent in table 7 is from estimates reported in a variety of sources for significant copper producing areas of the world. All quantities shown were considered to be measured or indicated ores that were minable under technologic and cost-price conditions prevailing in 1960.

Standard definitions for the three categories of reserves agreed to by the Federal Bureau of Mines and Federal Geological Survey were used in appraising the estimates. The definitions are:

Measured Ore.—Tonnage is computed from dimensions revealed in outcrops, trenches, workings, and drill holes, and the grade is computed from results of detailed sampling. Sites for inspection, sampling, and measurement are so closely spaced, and the geologic character is so well defined, that the size, shape, and mineral content are well established. The computed tonnage and grade are accurate within limits which are stated, and no such limit differs from the computed tonnage or grade by more than 20 percent.

Indicated ore.—Tonnage and grade are computed partly from specific measurements, samples, or production data and partly from projection for a reasonable distance on geologic evidence. The sites available for inspection, measurement, and sampling are too widely or otherwise inappropriately spaced to outline the ore completely or to establish its grade throughout.

Inferred ore.—Quantitative estimates are based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on an assumed continuity or repetition for which there is specific geologic evidence of their presence. Estimates of inferred ore should include a statement of the special limits within which the inferred ore may lie.

Physical measurement of ore deposits is only one of the factors in determining the size and grade of reserves. In addition, ore reserves increase as technological advances lower costs and permit the mining and processing of lower grades of ore. And, because the grade of ore mined is also dependent on the market price of copper, a rise in price will automatically make available supplies of ore previously uneconomical to mine. A lowering of the price or any condition or event increasing the cost of production, such as inflation, will have the reverse effect of raising the economic grade of ore that can be mined and reduce the reserve of copper. The grade of ore that can be mined and processed economically differs from country to country, from district to district, and from mine to mine, depending upon the factors that influence cost. Location, water supply, transportation, and metallurgy are some of the conditions that affect costs and may determine whether or not a deposit can qualify as a reserve.

There is little doubt that potential copper resources are very large and, as demand increases and old deposits become depleted, new deposits must be found and developed. An outstanding feature of reserve forecasts over the past three decades has been the upward trend in the quantity available, despite the large tonnage of ore mined. Table 8 shows this progression of copper-reserve estimates for the United States since 1931.

In summary, the copper reserve picture for the world assures a plentiful supply of copper for many years to come.

PRINCIPAL COPPER MINES IN THE WORLD

North America

UNITED STATES

The principal sources of copper in this country are in the Western States. In 1960 copper production was reported from 16 states and reached 1,083,000 tons after falling below

TABLE 8.—*Trend of U.S. copper-reserve estimates*

Year	Tons recoverable copper	Price, cents	Life, years	Annual rate of production used to estimate life, tons	Reference
1931	At least 18, 500, 000	9	31	600, 000	Barbour, Percy. World Copper-Ore Reserves. Eng. and Min. J., vl. 131, p. 178.
1931	18, 800, 000	9	31	600, 000	Rawles, W. P. The Nationality of Commercial Control of World Minerals. AIME, Contr. 41, 1933.
1934	18, 900, 000	10	32	600, 000	Barbour, Percy. World Copper-Ore Reserves. Eng. and Min. J., vl. 135, pp. 448–449.
1935	16, 000, 000 23, 500, 000	10 12	22 32	750, 000	Leith, K., and D. M. Liddell. The Mineral Reserves of the United States and Its Capacity for Production, Nat. Res. Comm., Washington 1936, p. 55.
1936	23, 700, 000	12½	33	725, 000	Do.
1944	20, 000, 000	13	25	800, 000	Cannon, R. J., M. Mosier, and Helena Meyer. Mineral Position of the United States. Dept. of Interior, 1947, pp. 240–241.
1945	29, 200, 000	13	36	800, 000	Federal Trade Commission Report on the Copper Industry, 1947, p. 4.
1960	32, 500, 000	32	30	1, 100, 000	U.S. Geological Survey and U.S. Bureau of Mines.

the million mark in 1958 and 1959; the mines in six states furnished 97 percent of the 1960 output. These were: Arizona, Utah, Montana, Nevada, New Mexico, and Michigan.

Arizona

Bagdad Mine.—In western Yavapai County, this is 27 miles by road from Hillside, a station on the Santa Fe Railway. The ore body at Bagdad is a chalcocite-enriched zone in gray quartz monzonite porphyry that crops out in the form of an irregular stock, roughly 2 miles long (east and west) and 1 mile wide (north and south). It joins a complex of older rocks on the north and is enclosed by a granitic complex on the other sides. Some roof pendants of the older granite are present in the stock of quartz monzonite. The northwest-trending Hawkeye fault cuts through the quartz monzonite and the ore body and dips 70° to 80° in an easterly direction. The chalcocite ore body is present on the dropped hanging-wall block but is absent on the footwall side. Numerous minor fractures cut the quartz monzonite in the vicinity of the ore body. The principal sulfide minerals are pyrite, chalcopyrite, and molybdenite. The minerals generally are scattered as grains through the monzonite but in places occur in veinlets of quartz. Some galena, sphalerite, and bornite are found in the monzonite. In the upper or oxidized portion the quartz monzonite shows alteration by sulfuric acid solutions generated by oxidation of the sulfides.

A change from block caving to open-pit mining was made in 1948 and the annual production of copper advanced from 7,000 tons that year to 12,000 tons in 1960. In 1954 the Bagdad ore reserve was estimated at 30 million tons of sulfide ore, averaging 0.754 percent copper, and 30 million tons of leachable oxide-carbonate material, containing 0.435 percent copper. A dump leaching plant was built in 1960 to recover copper from a substantial mine dump containing soluble copper minerals.

Christmas Mine.—In Gila County, 8 miles north of Winkelman and 22 miles south of Globe, this mine was opened in 1905 and was worked intermittently for fifty years producing approximately 1,500,000 tons of ore averaging 2.4 percent copper.

The Inspiration Consolidated Copper Co. began intensive exploration and development in 1954 of underground drifting and both surface and underground drilling, developing an estimated proven and probable ore reserve of 20 million tons containing 1.83 percent copper. The chance of developing additional ore is reported to be good.

The mineral deposits are of the contact metamorphic or pyrometasomatic type. The ore body is tabular and ranges from 20 to 100 feet in thickness. Chalcopyrite is the most abundant ore mineral, but variable amounts of bornite, chalcocite, and oxidized copper minerals are generally present. The gangue is chiefly garnet, quartz, magnetite, and unreplaced limestone. The factors that controlled the localization of the ore minerals are: (1) Proximity to the limestone-quartz diorite contact, (2) favorable character of certain limestone beds, (3) garnetization of the limestone, and (4) postgarnetization fracturing.

Development completed by the end of July 1962 included sinking a hoisting shaft 18 feet in diameter 1,793 feet, a ventilation shaft 12 feet in diameter 1,033 feet, and driving the 1,600 level haulage drift between the hoisting shaft and the ore body. The 4,000-ton-per-day concentrating plant began operating in in August 1962. Concentrates are trucked 37 miles to the Inspiration smelter in the Globe-Miami district.

Esperanza Open-Pit Mine.—The Duval Sulphur & Potash Co. mine, 28 miles south of Tucson, started production in March 1959 after completing an extensive surface drilling and underground exploration program, initiated in 1955, and removing about 6 million tons of waste. Production capacity is expected to reach 12,000 tons of ore per day from a reserve of 49 million tons, averaging 0.75 percent copper and 0.022 percent molybdenum.

The ore body is an enriched blanket averaging 130 feet in thickness and is covered by an average of 95 feet of overburden. The ore is localized in three types of rocks: (1) A series composed largely of graywacke, arkose, and conglomerate breccia; (2) an intrusive andesite; and (3) a quartz monzonite porphyry. There is an unusually regular chalcocite enriched blanket with a capping of about the same thickness, but the protore is rich enough in places to constitute ore, especially where it has a good molybdenum content. The primary mineralization is composed of quartz, clay minerals, biotite, chalcopyrite, molybdenite, and minor pyrite.

Inspiration Mine.—The Inspiration Consolidated Copper Co. mine, formerly an underground block-caving operation, consists of two open-pit properties, the Live Oak and the Thornton, in the Miami-Inspiration ore zone, about 6 miles west of Globe. This ore zone is in Precambrian Pinal schist, which is chiefly a sericite schist consisting of quartz, sericite, and biotite. The principal intrusive masses closely associated with the ore deposits are the Schultze granite and the Lost Gulch monzonite.

The ore occurs in blanket deposits as disseminated chalcocite or oxidized copper minerals or mixtures of these in both schist and porphyry close to the porphyry contact. The porphyry and schist were thoroughly shattered. Then mineral solutions permeated the ore zone through minute, closely spaced fractures and deposited the sulfides together with silica in a very irregular network of veinlets. The predominant sulfide deposited was pyrite, with very subordinate chalcopyrite and molybdenite. The feldspars of the porphyry were attacked and partly sericitized by the solutions. A little sulfide penetrated the walls between fractures, but most of it was confined to fractures. Subsequent oxidation produced the silicates, carbonates, and oxides—providing a major source of the copper mined.

The conversion from underground block caving to surface open-pit mining, which was started in April 1948 and was completed in August 1954, together with successful development of the Dual Process for treating mixed oxide-sulfide ore by leaching followed by flotation, resolved certain operational problems, lowered costs, allowed profitable treatment of lower grade ores, and increased ore reserves. The high-average ratio of waste removal to ore mined dropped from more than 3 tons of waste per ton of ore to 1.83 tons in 1957 and to 1.18 tons in 1958. Construction of facilities for recovery of byproduct molybdenum was completed, and plant operation commenced in April 1958. The company mining engineers estimated the proven ore reserve in the Inspiration mine to be 444,000 tons of recoverable copper as of December 31, 1958.

Lavender Pit and Copper Queen Mines.—These Phelps Dodge Corp. mines are in the Warren mining district at Bisbee near the southeast corner of Arizona. Since 1880 this area has been one of the major sources of copper in the United States, having furnished over 2½ million tons from within an area of 4 square miles.

At Bisbee Pre-Cretaceous rocks were intruded by the Sacramento Hill granite porphyry stock, and after considerable erosion the Dividend Fault with a displacement of 2,000 to 5,000 feet truncated the porphyry chimney. Mineralizing solutions came after the intrusion in various fracture zones in the limestone and followed porphyry dikes and sills. Oxidation and secondary enrichment in the mineralized granite porphyry produced a siliceous iron bearing gossan underlain by secondarily enriched low-grade ore bodies. Prior to 1917 the porphyry stock was drilled and two ore zones were proved, known as the East and West ore bodies. The West ore body was elliptic in shape with a major axis of 1,200 feet and a minor axis of 800 feet; it contained chalcocite, some bornite, chalcopyrite, and considerable pyrite in a siliceous gangue. This ore body was mined from 1917 to 1929 as the Sacramento open-pit mine, producing 159,000 tons of copper.

Stripping of the East ore body (Lavender pit) was started in 1951, and by 1959, 202,000 tons of copper had been produced.

In 1954 the ore reserves of the Lavender pit were estimated to be 41 million tons of 1.14 percent copper ore and 31 million tons of low-grade sulfide suitable for leaching with an average grade of 0.42 percent. These reserves were estimated to last 12 years at a production rate of 16,000 tons of ore per day or 38,000 tons of copper per year. Planned expansion of the pit announced in 1959 indicated the development of sufficient ore to last 15 years at the current rate.

Ore bodies south of the Dividend Fault are deep and are mined by underground methods. They are of two distinct types: A pyrite periphery prophyry contact type and an irregular-bed replacement type. Ores of the former have a more massive character, while those of the latter tend to be tabular, since the shape of the ore body is usually influenced by bedding of the limestone replacement. To remove the ore the open-stope, cut and fill, and square-set stoping methods are used.

Mining began in the Copper Queen underground unit in 1880. By the end of 1959 about 3 million tons of copper, 90 million ounces of silver, 2 million ounces of gold, 143 thousand tons of lead and 168 thousand tons of zinc was produced. During the last several years copper has been produced at the rate of about 30,000 tons per year. Reserve data on the Copper Queen mine are not known.

Magma Mine.—This Magma Copper Co. mine is at Superior about 65 miles east of Phoenix in the Pioneer (Superior) mining district, Pinal County. The mine has been successfully operated almost continually since 1910. Production in recent years has been in the range of about 450,000 tons of 5 to 6 percent copper ore, annually yielding from 20,000 to 27,000 tons of copper. Two types of ore bodies are found in the Magma mine. Most of the ore has come from steep dipping vein deposits which are developed for a maximum distance of 9,000 feet along the strike of the vein and to a depth of 4,900 feet below zero level, or to an elevation of 1,370 feet below sea level. The principal ore mineral in the vein ore bodies is chalcopyrite with enargite, bornite, and hypogene chalcocite found in varying abundance. Replacement ore bodies were discovered in beds cut by the vein systems in the eastern end of the mine about 1949. Here the mineralization extends away from the veins along favorable beds for more than 500 feet and in some places as much as 800 feet. The average thickness is around 15 to 20 feet but at times reaches 30 feet. In the replacement ore bodies important copper minerals are chalcopyrite, bornite, and chalcocite. At the present time more than half of the ore comes from the replacement ore bodies. About 400,000 tons of ore or about 20,000 tons of copper is produced per year. The ore also contains a significant amount of silver and gold.

On January 1, 1962, the ore reserves were estimated to be 882,000 tons, averaging 7.06 percent copper. Of this, 729,000 tons of 7.22 percent ore were in the bedded ore body.

Miami Mine.—Now owned by Tennessee Corp. this mine began operating in 1911, and to the end of 1959 it had produced 1.186 million tons of copper. During the last few years of operation, underground mining at this property was carried on, in part, to break up the remaining low-grade area preparatory to producing copper through in-place leaching. In 1960 approximately 10,000 tons of copper was produced by this method. Intensive studies indicated economic advantages in the conversion to a total leaching operation which was accomplished in June 1959. The Castle Dome open-pit copper mine, belonging to the corporation, began operating in 1943; operations were terminated in 1953 after approximately 249,000 tons of copper had been produced. After the mining was terminated the dumps were prepared for leaching, and the company continued to produce about 2,500 tons of copper per year by this method. During 1961 and 1962 plans were prepared and a plant was constructed to leach the mine dumps of the Copper Cities mine by the same method. Production from the dumps of this mine will replace the production from the Castle Dome mine as it is depleted.

Copper Cities Open-Pit Mine.—Also owned by the Tennessee Corp. this is 3 miles north of the Miami mine. The deposit is a typical low-grade dissemination of chalcopyrite and chalcocite in quartz monzonite and quartz-monzonite porphyry. A churn-drilling exploration program, started early in 1946 and completed in 1949, developed an ore reserve estimated at 33 million tons carrying 0.7 percent copper. An additional 9 million tons was discovered by drilling in 1956. The ore reserve as of January 1, 1959, was estimated to be 29.2 million tons. Stripping began in June 1951 and initial mining of ore began in August 1954. Sulfide ore is mined and is concentrated at 12,000 tons per day for an annual production of approximately 18,000 tons of copper.

Mineral Hill Mine.—This is 16 miles south of Tucson and 8 miles west of Sahuarita, in the Pima Mining District. The Banner Mining Co. optioned the property in 1950, obtained a Defense Minerals Exploration loan, and began an exploration program. A substantial ore body was discovered, and the company began a development and construction program that brought the mine into production in 1954. Two ore bodies about 3,000 feet apart, the Mineral Hill and the Daisy, were developed. The Daisy ore body was developed first by diamond-drill holes from the surface then by a 450-foot vertical shaft. Some of the ore was within 25 feet of the surface and was localized along a northeast to east striking fault, which probably is a segment of the Mineral Hill Fault. Ore occurs in sedimentary rocks in a zone near the contact between Permian limestone and quartzite; the best ore is in the limestone.

Copper deposits at Mineral Hill mine are of the contact metamorphic type. The east-west pre-ore fault traverses the property for about 5,500 feet with some minor offsets in one of about 400 feet. Ore mineralization is localized along this fault zone at and along intersections with cross faults and at or near intrusive contacts in limestone and quartzite. The main deposit is formed in the sedimentary rocks near the fault contact with a granite stock at or near the intersection of two faults. The copper ores occur as replacement in the limestone along shear zones and as disseminations in contact circuits. The main copper mineral is chalcopyrite with small amounts of chalcocite and bornite. Exploration was continued in an area north of the Mineral Hill deposit and a major ore body was discovered. A 5-compartment shaft was sunk 1,700 feet deep on the new deposit, and full production began at the end of 1961 from ore too deep for open-pit mining. Exploration of the Palo Verde ore deposit has developed 58 million tons of ore of a grade comparable to that produced by open-pit mining. Reserves at the Mineral Hill and Daisy mines are unavailable. About 1,000 tons of copper ore is produced per day.

Mission Mine.—The Mission project of the American Smelting and Refining Co.—formerly called the East Pima—is about 15 miles southwest of Tucson where the company started exploring the deposit in 1954. During the following 5-year period 346 holes totaling 190,000 feet were diamond drilled and 2,200 feet of underground workings were driven to test the potentiality of the ore body.

The deposit lies within an extensive zone of porphyry-copper type alteration-mineralization in sedimentary rocks that have been folded, faulted, and intruded by monzonite porphyry. Disseminated pyrite and chalcopyrite pervade all rocks within the zone, but ore-grade copper mineralization occurs principally along certain of the sedimentary horizons, forming gentle to moderately steep-dipping tabular bodies—ranging from a few feet to more than 200 feet in thickness. The ground is intensely broken and is structurally complicated. Leaching and secondary enrichment are confined to a thin layer at the top of the Papago formation completely buried under alluvium and caliche. Pyrite and chalcopyrite are the predominant sulfides. Molybdenite is sparsely and erratically distributed. Hydrothermally altered calcareous rocks, tactite, and hornfels contain the most copper.

The company constructed a 15,000-ton-per-day concentrator, and production of 45,000 tons of copper annually was begun in July 1961. The ore reserve has been estimated at 65 million tons of 0.9 percent copper.

Morenci Mine.—This Phelps Dodge Corp. property near the town of Clifton in southeastern Arizona is the largest producer of copper in the State and ranks second in the United States. Ore is mined at 52,000 tons per day by the open-pit method; it is concentrated and smelted nearby. Blister copper is cast into 700-pound anodes and shipped to the Phelps Dodge refinery in El Paso, Tex. Molybdenite is recovered as a byproduct.

Three types of ore bodies occur in the Morenci district. They are: (1) Irregular or roughly tabular contact-metamorphic bodies in limestone or shale near porphyry; (2) lodes or veins in fault zones; (3) irregular deposits of low-grade disseminated ore in porphyry. Early production of approximately 991,000 tons of copper came from ore bodies of the first two types.

The open-pit ore body, a disseminated deposit of the third type, is in a medium hard monzonite porphyry. The average thickness of the capping was 216 feet, and the maximum thickness was about 500 feet. The ore extends through a vertical range of about 1,300 feet, and the surface outline of the ore body forms a rough oval—covering approximately 900 acres. Some oxidized-copper minerals are present in part of the capping. This is considered leach material and is dumped where provision can be made for extracting the copper content at some future date. The principal sulfide minerals are chalcocite and pyrite. Chalcopyrite and bornite have been identified and covellite is present in minor amounts. The chalcocite occurs as a coating on pyrite and also is present as a dissemination in the gangue.

Mining began in 1942 on the open-pit ore body, estimated to contain 284 million tons—averaging 1.036 percent copper. By the end of 1960 more than 257 million tons of ore had been mined, and about 2.4 million tons of copper had been produced from this ore body. The tonnage and grade of present reserves are not available. However, exploration for new ore bodies has continued, and reserves are estimated to be adequate for many years operation at the current rate of production—approximately 100,000 tons of copper per year.

New Cornelia Mine.—This Phelps Dodge Corp. mine is at Ajo in the southwestern section of the State. Large scale mining operations were started in 1917, when a 5,000-ton-per-day leaching plant was completed. In 1924 a 5,000-ton-per-day flotation plant was built, and additional plant facilities have since increased processing capacity to more than 30,000 tons of ore daily.

The ore body is described as almost wholly in monzonite porphyry, although the volcanic rocks to the southwest and southeast are also considerably mineralized. It is crudely elliptical in shape, about 3,600 feet long and 2,500 feet wide. Its average thickness is 425 feet, and the maximum is about 1,000 feet. The primary mineralization is chiefly chalcopyrite with some bornite and a little pyrite. The gangue consists of quartz and orthoclase, and the sulfides are distributed both in veinlets and in grains scattered through the altered monzonite; the richest ore accompanies the more intensely altered rock.

The ore body was oxidized to a surprisingly level plane near the water table at an altitude of approximately 1,800 feet. Except for local variations of as much as 50 feet, the transition from sulfide to oxidized zone was about as sharp as could be mined by steam shovel. The depth of oxidized ore ranged from 20 to 190 feet, averaging 55 feet. Minerals of the oxidized ore were malachite with a little azurite, cuprite, tenorite, and chrysocolla. A little chalcocite was found just beneath the bottom of the oxidized zone.

Information regarding ore reserves is not available, however, the mine apparently has many years of production ahead at the recent annual rate of between 60,000 to 70,000 tons of copper.

Pima Mine.—The Pima Mining Co. mine, 50 percent owned by Cyprus Mines Corp., is in the northeastern part of the Pima mining district about 20 miles south-southwest of Tucson. The deposit was discovered by geophysical means beneath 200 feet of overburden.

In November 1951 the Pima Mining Co. was incorporated to explore and develop the new ore body by shaft sinking and underground work. Late in 1955, after extensive surface and underground drilling had delineated a large quantity of fairly low-grade copper ore instead of a smaller quantity of high-grade ore, the company decided to develop the deposit as an open pit mine.

The Pima deposit includes two distinct types of ores: (1) Highly altered limestone, having strong and relatively high-grade mineralization; and (2) low-grade disseminated mineralization in volcanics and sediments. The ore-bearing rocks dip about 45 degrees to the south and trend east. They average about 200 feet in thickness and in the main part of the mine have been developed over a lateral extent of 1,600 feet. The principal ore mineral is chalcopyrite; pyrite and magnetite are accessory minerals. Chrysocolla (copper silicate) and the black copper oxide, tenorite, are oxidation products occurring for a short distance below the bedrock surface.

An open-pit mine was developed, and a 3,000-ton-per-day concentrating plant was built. It began operating in 1957 on an ore body estimated to contain 6,400,000 tons of approximately 2 percent copper. In 1959 the rated daily capacity of the concentrator was increased to 4,000 tons. An agreement was made with neighboring Banner Mining Co. under which Pima would enlarge its pit to include a certain portion of Banner property and would mine and mill 1.8 million tons of the Banner ore from that area. A substantial tonnage of low-grade material is known to exist.

The company plans to expand the open pit, eliminate the inclined skip, and provide for all truck haulage. The plans include increasing mill capacity to 8,000 tons per day.

Ray Mine.—This property of the Kennecott Copper Corp. is about 80 miles east and slightly south of Phoenix and about the same distance north of Tucson in what is known as the Mineral Creek Mining District. Ore was mined by the block-caving system from 1911 to 1955 when conversion from underground mining to an open-pit operation was completed. The change in mining methods took 7 years and involved removing 43 million tons of overburden.

The rocks that contain the ore body are Precambrian Pinal schist with intrusions of quartz porphyry and diabase. The mineralized diabase formerly too low grade to mine by underground methods has become ore as a result of the change in operations.

The schist and porphyry ores are mineralized principally with supergene chalcocite, but the predominant mineral in the diabase is chalcopyrite. Copper silicates, cuprite, malachite, tenorite, and native copper compose about 20 percent of the schist ore.

Annual recovery of copper from in-place leaching of the caved areas in the old underground mine increased from 3,600 tons in 1954 to 17,700 tons in 1957. New pumps were installed in 1959 for leaching additional caved areas to further production of copper from this source.

Information about the ore reserve of the Ray deposit is not available. Ore is produced from the open-pit mine at the rate of 22,500 tons per day. The ore is concentrated, and the concentrates are smelted in company facilities at Hayden. Blister copper is produced at the rate of 60,000 tons per year.

Lone Star Area.—Northeast of Safford, the area has been drilled by the Bear Creek Mining Co., a subsidiary of Kennecott Copper Corp.

An 800-foot shaft (started in September 1960), and underground development work will allow bulk sampling of the ore body.

San Manuel Mine.—Operated by the San Manuel Copper Corp., this is in the Old Hat mining district, Pinal County, approximately 45 miles northeast of Tucson. The concentrator, smelter, administration building, and other plant facilities are located 7 miles southeast of the mine area at the town of San Manuel.

The San Manuel ore body is a disseminated copper deposit in quartz monzonite, monzonite porphyry, and diabase. The ore lies within a mineralized zone having a width of 8,000 to 9,000 feet and a known length of 9,300 feet.

The upper and western portions of the ore body are separated into two branches by an area of lean, weakly altered hanging-wall rock. These two branches converge at depth so that, in cross section, they may be likened to a U or V leaning to the northwest. The northwesterly limb of ore is referred to as the North ore body and the southeasterly limb, as the South ore body. To the east, the central area of lean material gradually diminishes and disappears as the two limbs join to form a single mass of ore.

The main primary minerals are chalcopyrite, pyrite, and quartz; there are minor amounts of molybdenite. These minerals are distributed quantitatively into three zones known as the ore zone; the hanging-wall zone, which lies between the North and South ore bodies; and the footwall zone, which surrounds the ore and the hanging-wall zones.

Except for the west end the upper portions of the ore body and much of the central lean-hanging-wall zone have been oxidized or partially oxidized. The chief minerals resulting from oxidation and enrichment are chrysocolla, chalcocite, and various iron oxides. Cuprite, native copper, and black copper oxides are often seen where the oxidized-zone grades into the chalcocite zone. Copper carbonates are very rare.

There is complete or nearly complete oxidation of the copper minerals and a relatively sharp line of demarcation between the oxide ore and the underlying sulfide. Little copper was leached from the oxidized zone, and the zone of chalcocite enrichment contains only a relatively small tonnage. Most of the sulfide ore can be mined as clean sulfide with a minimum of mixed sulfide-oxide ore.

A drilling program was completed early in 1948 which proved 479.5 million tons of ore, averaging 0.77 percent copper—consisting of 367.6 million tons of sulfide ore, containing 0.79 percent copper, and 111.9 million tons of oxidized ore, containing 0.72 percent copper.

Silver Bell.—This operation of the American Smelting and Refining Co. consists of two open-pit copper mines and a concentrator located about 40 miles northwest of Tucson.

The two pits, known as the Oxide and the El Tiro, are approximately 2½ miles apart in a northwesterly trending zone of hydrothermal alteration. Alaskite, dacite, andesite, and monzonite porphyry have been enriched by supergene chalcocite to form the two ore bodies. Within the ore bodies, where alteration is strong, the upper limit of the sulfide zone usually is highly irregular but sharp. There is no transition zone of mixed oxide and sulfide minerals, except locally in fringe ore areas where alteration is relatively weak and rocks are reactive. In general the base of oxidation conforms to modern topography, though local relief exceeds 200 feet. The water table for the most part is now well below the chalcocite zone.

The American Smelting and Refining Co. started developing the two pits in December 1951. Since then and up to January 1, 1957, 21 million tons of waste and 6.4 million tons of ore, assaying about 0.9 percent copper, was removed from the Oxide pit; 15 million tons of waste was stripped, and 1 million tons of ore was mined from the El Tiro pit. At the time production of ore started on March 1, 1954, the two ore bodies had a reserve of 32 million tons of 0.9 percent copper.

Michigan

Calumet & Hecla Mines.—The Calumet division of Calumet & Hecla, Inc., is mining copper ore from six sources, the Seneca, Allouez, Oceola No. 13, Centennial, and two Ahmeek shafts near Calumet in the northern peninsula. Total production from all sources amounts to about 6,500 tons of ore a day, averaging around 1 percent copper, it is treated at the Ahmeek concentrator. The Tamarack reclamation plant at Torch Lake is still retreating old tailings, accounting for 1,500 tons of copper in 1960; total mine output of the Calumet division was almost 16,000 tons of copper in 1960.

Copper deposits in the district are commonly divided into two broad groups—lode and fissure. The first group comprises conglomerate lodes (mineralized beds of felsite conglomerate interstratified with the lavas) and amygdaloid lodes (mineralized vesicular, brecciated, or scoriaceous tops of lava flows). The second group are veins along the fractures that parallel or cross the beds. The economically important lode deposits, with a single exception, are confined to the portion of the Keweenawan series that is composed predominantly of lava flows, but they have a wide stratigraphic range within that portion. The fissure deposits are confined to the same stratigraphic portion of the series, although the valuable fissure deposits and the lode deposits occur in different areas along the strike of the formation. The Nonesuch lode is a copper-bearing sediment that occurs well up in the sedimentary portion of the series where mineralization is mainly in sandstone and to a less extent in shale. Reserves at the Calumet and Hecla mines are not known.

White Pine Mine.—This mine of White Pine Copper Co., a wholly owned subsidiary of Copper Range Co., in Ontonagan County has become one of the 10 major copper producers in the United States since beginning production in 1955. Facilities include the mine, mill, smelter, refinery, power plant, and a complete town. Initial designed capacity for an annual production of 36,000 tons of copper has been increased to 50,000 tons; production in 1960 was 40,000 tons.

The copper-bearing beds at White Pine are primarily in the lower 20 to 25 feet of the Nonesuch shale. This cupriferous zone is divided into four stratigraphic units which are in ascending order, the lower sandstone, the parting shale, the upper sandstone, and the upper shale. Most of the copper occurs as chalcocite in the upper and parting shales, except in a small area near the White Pine fault where it is abundant in the upper and lower sandstones. It is present in five different layers in values averaging from 1 to 3 percent. Copper content of the shale beds decreases with increasing sand content.

The White Pine ore body still contains at least 300 million tons of ore. Ore found by exploration since production started has substantially exceeded the tonnage mined, and the limits of the ore body have not yet been determined.

The Southwest ore body, discovered in 1959, is between one and two miles southwest of White Pine on the opposite side of the White Pine fault. The ore occurs at a depth of 2,000 feet from the surface and contains about 1.5 percent copper. In November 1961 the new ore body was reached with a development shaft, and the grade of the exposed ore confirmed information obtained from exploratory drilling. The company expects to have this property in full production by early 1964.

Montana

The Butte district mines operated by The Anaconda Company are at Butte in southwestern Montana.

All production before 1952 was from underground-vein mines, but today there are three different methods of mining: Underground vein, underground block caving, and open pit. The underground copper-vein mines in the Butte district are the Mountain Con, Leonard, Belmont, and Steward; the Kelley mine is the block-caving operation; and the Berkeley Pit is the surface or open-pit mine. From 1880 to July 1, 1959, 300 million tons of ore were mined, recovering nearly 15 billion pounds of copper. In addition, the operations produced more than 28 million tons of zinc ore, yielding 4.5 million pounds of zinc; 8 million tons of manganese ore, containing 3.5 billion pounds of manganese; 618 million ounces of silver; and 2.3 million ounces of gold.

The highly complex ore deposits are localized on the south margin of the Boulder batholith in an area of approximately 6 square miles. Fractured quartz monzonite was altered and mineralized by ore-bearing solutions penetrating fractures. Subsequent faulting and repeated mineralization have created an extremely complex maze of veins and veinlets belonging to at least three systems. The oldest, largest, and most productive veins are in the east-west trending Anaconda system; next in size, age, and productivity are the mineralized faults of the Northwest veins. The Steward or Northeast-fault veins intersect and displace veins of the two earlier systems and in turn are displaced by various postmineral dikes and faults. Although each system displaces its predecessor veins, all are nearly comtemporaneous and are characterized by identical ores distributed in a concentric zoning pattern. In the central and intermediate zones, mineralization consists of copper sulfides oxidized and enriched to varying depths. In the outer limits of the intermediate zone and in the peripheral zone, copper mineralization gives way to zinc, manganese, and silver. The zonal arrangement is vertical as well as lateral but is masked and complicated by oxidation and supergene enrichment.

Minable low-grade copper ore bodies, of the Kelley mine, locally called ore zones, are in the eastern part of the central zone of mineralization. The high-grade ore occurs in pyrite-enargite veins and ore shoots related to branching and interlacing structures of different ages, which intersect the quartz-monzonite. The most highly productive Anaconda system of fractures has a prevailing east strike and south dip; the Blue vein set of horizontal slip fractures strikes northwest and dips southwest. Lastly, the Steward fault veins range in width from a few inches to a maximum of 50 to 60 feet. Some veins are traced as far as 7,000 feet in length and extend to a depth of several thousand feet. Some veins extend to the surface; some are blind.

The Kelley low-grade ore bodies may be divided into two types. The wide-vein zones consist of closely spaced fissure veins with numerous ore veinlets and stringers traversing the intensely altered quartz-monzonite, making certain parts of it minable by block caving. The other type is related to the horsetail system of southeast-striking fractures, branching from the high-grade east-west veins, that have replacement copper ore minerals localized to a degree suitable for block caving. 180 million tons of low grade (1.0 percent) copper ore is known to be available for block caving.

The mineralized quartz monzonite that constitutes the Berkeley ore zone is part of the central zone of mineralization created by the hydrothermal processes previously mentioned and enriched by downward percolation of surface waters. It included not only the zone of secondary enrichment but remnants of high-grade ore veins that originally were mined underground. Chalcocite is the principal ore-bearing mineral, with lesser amounts of enargite, bornite, and chalcopyrite present. Post-mineral faulting that complicated underground mining is present within pit limits but is not expected to interfere with open-pit operations.

The enriched zone ranges from 100 to occasionally 600 feet in vertical thickness (the average is about 200 feet) and is about 2,600 feet wide by at least 4,700 feet long. Below the enriched zone replacement minerals grade rapidly into primary sulfides. Barren leached capping, totaling 100 to 300 feet overlies the enriched zone. The leached capping constitutes the bulk of the waste material, but occasional barren or weakly mineralized areas are encountered in the ore zone.

In 1959, the open-pit ore reserve was 123 million tons, averaging 0.75 percent copper and 0.17 ounces silver. To mine this ore required removal of 138 million tons of waste and 40 million tons of leach material. The leach material averages 0.2 percent copper.

The reserve of the vein mines was estimated at 9.6 million tons of ore having a grade of 4.35 percent copper in 1957.

Nevada

Liberty and Veteran Open-Pit Mines.—These mines of the Nevada Mines Division, Kennecott Copper Corp., are in the Robinson Mining District in White Pine County, a few miles west of Ely. The productive portion of the Robinson Mining district, sometimes called the Ruth-Kimberly area, covers an area of about 20 square miles and had produced more than 2 million tons of copper.

The geology of the district shows sedimentary rocks of limestone, quartzite, and shale invaded by monzonite and monzonite porphyry. The principal ore bodies, which are of the disseminated type, occur in the monzonite and have been formed by chalcocitic enrichment of pyrite-chalcopyrite protore. There has also been considerable mineralization of the limestones, but relatively little sulfide ore has been found in these rocks. The ore deposits at Ely are believed to be genetically connected with the intrusion of the monzonite. Supergene enrichment may have been in operation for a long period, possibly beginning before the eruption of the Pliocene lavas.

Underground mining at the Ruth mine ceased in February 1958 with the exhaustion of ore in the Minnesota-Hi ore body. A lower ore body, known as the Deep Ruth with an estimated 25 million tons of ore, averaging about 0.8 percent copper, has been partially developed for mining at some future date.

In 1960 production came wholly from the Liberty pit where 7.35 million tons of ore averaging 0.79 percent copper provided 47,439 tons of copper. The total estimated ore reserve of the Nevada Mines Division is not known.

Yerington Mine.—The Yerington mine of The Anaconda Company is at Weed Heights, Lyon County, 80 miles southeast of Reno. The initial exploration, upon which the Yerington open-pit project was planned, was conducted by the company from 1942 to 1945 and consisted of both surface drilling and underground workings. Stripping of overburden began in June 1952, and the first copper was shipped in November 1953; the planned production of 5 million pounds of copper per month was attained in May 1954.

The Yerington ore body is a disseminated porphyry-copper deposit. Copper mineralization is associated with an intrusion of quartz-monzonite porphyry into a granodiorite mass, the mineralization occurring in the quartz-monzonite porphyry and the bordering granodiorite. Minor intrusions consist of andesite and rhyolite dikes. Chrysocolla is the chief copper mineral, along with minor amounts of malachite and other copper silicates and carbonates. The outlined ore within the deposit averages 0.82 percent copper. The original estimated ore reserve, determined by preliminary exploration, was 35 million tons of 0.97-percent oxide copper underlain by 15 million tons of similar grade sulfide ore.

The Yerington operation comprises stripping and mining the oxidized-copper deposit, leaching the ore with sulfuric acid, recovering the copper by precipitation with shredded iron as cement copper, and shipping to the company smelter at Anaconda, Mont. The sulfuric acid used was manufactured at Weed Heights from sulfur ore mined by The Anaconda Company at the Leviathan mine in Alpine County, Calif., 58 miles west of Weed Heights, until June 1962 when the Leviathan mine was closed.

The production rate of oxide ore was reduced after October 1961 when the new concentrator for sulfide ore treatment began operations.

This plant was operating at its rated capacity of 5,000 tons of ore per day at the end of 1961.

New Mexico

Chino Mine.—This mine of the Chino Mines Division, Kennecott Copper Corp., is a completely integrated unit. Copper ore is mined, concentrated, smelted, and refined; molybdenum is recovered as a byproduct. The Chino mine is at Santa Rita, in the Central Mining District of Grant County; the concentrator, smelter, and fire refinery are at Hurley, approximately 9 miles from the mine.

The geologic detail of the deposit is complex. Extensive sills of quartz diorite intruded sediments, and these in turn were intruded by a stock of granodiorite porphyry. Fracturing and faulting in many directions were intense. Dikes radiate from the granodiorite core. Mineralizing solutions permeated this fractured zone around the relatively unbroken and impervious granodiorite core and deposited the primary ore minerals, copper-bearing pyrite, and chalcopyrite. These minerals were deposited partly in the intrusive and partly in the intruded rock. Silicification and sericitization occurred with deposition of the ore minerals. Kaolinization accompanied decomposition of the sulfide minerals.

Leaching of the upper zone, followed by subsequent secondary enrichment over a wide area, formed an ore body of economic grade that could be mined by open pit.

The total production, from the inception of open-pit mining in 1910 to the end of 1958 was 207 million tons of copper ore. The 1960 production rate was 22,500 tons of ore and 45,000 tons of waste per day. The average copper content of the ore is approximately 0.84 percent. The monthly output of the smelter is about 12 million pounds of copper. Ore reserves are not known.

Miser's Chest Group of Mines.—This group owned by the Banner Mining Co., is in Hidalgo County, 6 miles south of Lordsburg. The mines and mill were closed in October 1957 owing to the low price of copper, but development work continued. Operations were resumed in 1959 and in 1960 copper production was 1,847 tons.

The exposed rocks of the Lordsburg mining district consist chiefly of basalt and rhyolite flows, plugs, and associated fragmental material belonging to two groups of different age and character. An irregular stock of porphyritic granodiorite intrudes the rocks of the earlier group, and both the stock and earlier rocks are cut by several varieties of dikes that are separated from the later volcanic rocks by an unconformity. The ore deposits are siliceous veins in fault fissures and shear zones concentrated in and around the northern and eastern margins of the granodiorite stock. There are two main groups of these veins, one striking northeast and the other almost due east. Oxidation and secondary enrichment have affected the ores to extremely variable depths. In places, almost unaltered sulfides are found at the surface, yet in other sections oxidation and leaching extends to the 1,400 foot level.

The Bonney vein has been developed by the Banner Mining Co. to a vertical depth of 1,560 feet and for 2,000 feet along the strike. The minimum stoping width is 4 feet, and the maximum vein width is about 20 feet. The reserves of ore are unknown.

Tyrone Deposits.—This Phelps Dodge Corp. property, a potential resource of copper, is in the Big Burro mountains of Grant County, approximately 10 miles southwest of Silver City. The deposits have all the characteristics of a chalcocite porphyry ore with the chalcocite either disseminated regularly throughout large masses of fractured country rock or concentrated along exceptionally strong veins or shear zones. The overburden is of variable thickness, either barren of copper or containing carbonates and other oxidized copper minerals. The principal ore bodies lie within a northeastward trending zone of fracture between Leopold and Tyrone. They are very irregular in size and shape, ranging from roughly blanketlike masses—grading upward into oxidized ground and downward in primary pyrite—to strong veins or shear zones—which are likewise barren near the surface and too lean to be of value below, where chalcocite gives way to primary pyrite.

In 1949 Phelps Dodge Corp. initiated a drilling program at Burro Mountain to develop a large low-grade ore body, minable by open-pit methods. This development drilling was continued into 1958 when it was suspended. Encouraging results were reported each year.

North Carolina

Ore Knob Copper mine.—In Ashe County, this mine, operated by Appalachian Sulphides, Inc., a wholly owned subsidiary of Nipissing Mines Co., Ltd., produced ore at the rate of 24,000 tons per month, equivalent to 450 tons of copper in 1960.

Discovered in 1855, the Ore Knob began operating as a mine in the spring of 1873; in the next ten years it produced 12,500 tons of copper. Federal Bureau of Mines drilling in 1942 and 1943 disclosed a substantial reserve in the mine. Nipissing Mines Co., Ltd., leased the mine in 1953 and started an exploration program that indicated more than a million tons of ore. Shaft sinking started in 1955, and production of ore commenced in 1957.

The steeply dipping fissure vein in gneiss which contains the ore is as much as 50 feet wide and more than 1,500 feet long. There are vein splits that branch into the hanging wall from the main ore zone at a low angle (branching upward), and these are mainly pyrite with some chalcopyrite.

The vein is parallel to the strike but steeper than the dip of foliation. It is along a shear or fault that cuts across the dip of gneiss and locally formed breccia fragments. Coarse biotite in the hanging wall and foot wall is related to vein formation.

Ore minerals are pyrite, chalcopyrite, and minor quantities of sphalerite, while the gangue contains biotite, albite, calcite, and many silicate minerals.

The ore reserve estimated in 1957 at 1,300,000 tons, averaging 3.0 percent copper was exhausted in 1962 and the mine was closed.

Pennsylvania

Cornwall iron mine near Lebanon, operated by the Bethlehem Steel Co., is primarily an iron mine but it has been a source of copper since 1920 after successful flotation experiments with the ore in 1919. Copper production increased significantly in 1928 as a result of further flotation-plant improvements. Flotation of pyrites was started in 1940 because the pyrite carried recoverable cobalt. From that time until recently, Cornwall ore accounted for nearly all U.S. cobalt production.

The ore is a contact replacement type. High-grade, iron-bearing solutions coming from or through the traprock sill caused replacements of the limestone at its contact with the upper side of the traprock intrusion. The ore consists of magnetite with pyrite and chalcopyrite. It contains recoverable copper, gold, silver, cobalt, and sulfur. The gold and silver apparently are in solid solution in the chalcopyrite, and cobalt occurs similarly in the pyrite.

Tennessee

Tennessee Copper Division of the Tennessee Corp., operating the Boyd, Calloway, Eureka, and Mary mines in the Ducktown Basin mining district in Polk County is the largest producer of copper in the eastern United States. The ore, concentrated in two flotation mills, yields copper, pyrite, and zinc concentrates; the pyrite concentrate is roasted to produce sulfur dioxide for use in manufacturing sulfuric acid and iron oxide; the iron oxide is sintered for use in iron and steel plants. Annual production of copper from 1955 to 1960 has ranged from 9,000 to 13,000 tons.

The deposits are great lenses of massive sulfide ore. They extend, with interruptions, for thousands of feet on the strike and are up to 300 feet thick. Except where faulted they parallel the foliation of the schists which are closely folded.

The country rock consists of schist and graywacke intruded by gabbro. The great group of granitic batholiths of the southern Appalachian Mountains lies a few miles east, and the deposits may have been formed in connection with the intrusion of the granite, probably near the end of the Paleozoic era.

The minerals include pyrrhotite, pyrite, chalcopyrite, magnetite, garnet, amphibole, and chlorite. The ore near the surface is altered to iron oxide or gossan, which extends to a depth of about 100 feet; below the gossan at the water level a zone of chalcocite from 3 to 8 feet thick was mined, containing 5 to 25 percent of copper. The primary copper ore carries about 1 to 3 percent of copper. Reserves of ore are unknown.

Utah

The Utah Copper mine of the Kennecott Copper Corp., sometimes referred to as the Bingham Pit, is the second largest copper producer in the world; an average of approximately 90,000 tons of ore is mined and milled each day. The mine is near the town of Bingham in Salt Lake County and along with two nearby concentrators (the Magma and Arthur mills) and a smelter and electrolytic refinery at Garfield, the Utah Copper Division, Kennecott Copper Corp., has a fully integrated operation from ore to refined copper.

The Bingham District has been a steady and large producer of copper since 1896 and has one of the largest reserves of developed ore in the United States.

The igneous rocks in this district are intrusives of monzonite in the forms of stocks, dikes, and sills and andesite flows and tuffs. The monzonite intruded sedimentary quartzites, limestone, and shales to form two extensive irregular stocks—the Bingham and the Last Chance. Dikes connect these major masses and, together with smaller stocks, traverse sediments to the south and east of the main stocks. Mineralization is more intense in and around the Bingham stock and most of the ores within the stock are copper ores. In the sedimentary rocks close to the stocks copper ores also prevail, but they grade outward into zinc-lead-silver ores that give an irregular but definite zoning of the metals.

The ores of the Bingham stock are typical of the disseminated copper deposits. The monzonite has been intensely shattered and altered. The primary ore minerals are pyrite and chalcopyrite, which occur as grains and veinlets disseminated through the deposit. Molybdenite is present locally.

Based on recent activities of the Kennecott Copper Corp. at its Utah Copper Division such as, building the electrolytic refinery, purchasing the Garfield smelter of the American Smelting & Refining Co., driving the 5,490 level railroad tunnel underneath the pit, and announced plans for modernizing the smelter; it is evident that Kennecott has assigned a life expectancy to the Utah operation of at least 20 years, a reasonable plant amortization period. An ore production of 32 million tons was reached in 1956 and the grade of ore averaged 0.86 percent copper from 1957 through 1960. Using these criteria the reserve in 1961 is estimated to be 640 million tons of ore averaging 0.85 percent.

CANADA

Newfoundland

Tilt Cove Mine.—Owned and operated by Maritimes Mining Corp., Ltd., this mine is on tidewater at Tilt Cove on the Eastern side of the Burlington Peninsula. An intensive prospecting program started in 1954 resulted in blocking out sufficient ore to justify preparation for mining. In 1956 a 2,000 tpd mill was completed, and shaft sinking was started. Milling was started in August 1957, and the concentrates have been smelted by Gaspé Copper Mines, Ltd., at Murdochville, Quebec.

Chalcopyrite and pyrite occur in a chloritized zone along a contact between pillow andesites and dykelike intrusions of quartz-diorite porphyry. Two types of ore bodies occur on the property—a massive type, consisting of lenticular pods of fine-grained pyrite and chalcopyrite, and a disseminated stockwork type in which pyrite and chalcopyrite form irregular clusters, networks of stringers, and irregular veins. The massive sulfide type of deposit is lenticular, has sharp, clearly defined boundaries, and occurs usually at the contact between the quartz-diorite porphyry and the chloritized andesite. The disseminated type of ore body usually occurs some distance from the intrusive-volcanic contact, is lower in grade than the massive type, and the mineralization extends into the wall rocks—so that ore limits are by assay boundaries.

Mining is now only by underground operations; production averaged 2,232 tons per day during 1961.

Ore reserves estimated on December 31, 1961, totaled 3,050,000 tons of unstated grade. Production of 814,748 tons of ore in 1961 averaged 1.68 percent copper and returned 5,146 ounces gold.

Buchans Mine.—This is in the central part of the island 3 miles north of Red Indian Lake and is operated as the Buchans Unit of American Smelting and Refining Co. Geophysical prospecting and diamond drilling led to discovery of two deposits in 1927, and two more ore bodies in the northwest were revealed by diamond drilling from 1947 through 1950.

The ore bodies occur on the north flank and around the westward plunging nose of a dome-shaped structure, at the east end of a northeasterly trending anticline, and are replacements of volcanic breccias and associated tuffs. The shape of the ore bodies ranges from lensoid to tabular. The ore can be divided into three main groups from hand specimens: Breccia, containing numerous rock fragments; baritic, containing abundant barite; and normal, from massive sulfides with few fragments. Ore minerals present are galena, sphalerite, chalcopyrite, pyrite, gold, silver, and minor amounts of bornite and other minerals. The gangue minerals are quartz, barite, and calcite.

Ore reserves reported on December 31, 1961, were 4,627,000 tons of 1.25 percent copper.

Quebec

Horne Mine.—The mine and the smelter of Noranda Mines, Ltd., are at Noranda in Rouyn Township, northwestern Quebec. The mine and plant have produced continuously since 1927, and the smelter has been enlarged so that it is now able to treat custom ores and concentrates from most of the copper mines in western Quebec, Ontario, and a mine in Manitoba.

The ore bodies at the Horne mine occur in metamorphosed rhyolitic flows, tuffs, and agglomerates as massive sulfide replacements of brecciated rhyolite and as disseminated pyrite and chalcopyrite mineralization in massive-appearing rhyolite rocks. Faulting and shearing are considered to be the main structural factors controlling the emplacement of the ore bodies. Principal metallic minerals present are pyrite, pyrrhotite, chalcopyrite, sphalerite, gold, silver, and associated tellurides.

Approximately 95 percent of the total output of the Horne mine comes from cut-and-fill stopes, the remainder from blast hole stopes. The production rate at the Horne mine in 1959 was 3,810 tons per day. As of January 1, 1960, the sulfide ore reserve at the Horne mine was 9,303,000 tons of 2.29 percent copper and 0.19 ounce gold per ton.

Gaspé Copper Mine.—Deposits are owned and exploited by Gaspé Copper Mines, Ltd., a subsidiary of Noranda Mines, Ltd. The mine site is in the northwest corner of Holland Township, Gaspé North County, in the Gaspé Peninsula, 25 miles from the south shore of the Gulf of St. Lawrence.

Two major ore zones have been outlined on the company-owned property—the Needle Mountain ore bodies and the Copper Mountain ore body. The former consists of bedded replacement deposits of chalcopyrite and pyrrhotite, while the Copper Mountain ore body consists of late-stage pyrite—chalcopyrite mineralization filling fractures in a siliceous host rock. The Needle Mountain ore bodies, where most of the mining and development has been done, are higher in grade and more uniform in constitution than the Copper Mountain deposit.

The production schedule calls for 8,000 tons of ore per working day from the mine; 90 percent is supplied from the underground operation, and the remainder is from the open pit. The ore reserve reported on January 1, 1960, was 63,710,000 tons, having a copper content of 1.29 percent.

Quemont Mine.—This property of Quemont Mining Corporation, Ltd., is contiguous to, and directly north of, the Horne mine of Noranda Mines, Ltd. The property lies within the city limits of the City of Noranda. Mine and mill began production in June 1949 at its rated capacity (2,000 tpd); it has continued to produce at this or a slightly higher rate.

The ore bodies at the Quemont mine consist of sulfide replacements of a brecciated rhyolite, and three types are mined: Massive sulfide replacement ore; chloritized breccia ore, containing disseminated sulfides; and shattered breccia ore, containing sulfide stringers. The ore occurs in a dome-shaped structure in which the permeable rhyolite breccia is the core, and a thick series of impermeable porphyritic rhyolite forms the capping. Three main ore bodies have been exploited, the West, the East, and the Southwest. Exploration at depth is contemplated to explore the ore zone.

As of December 31, 1959, the ore reserves totaled 6,220,000 tons, containing 1.32 percent copper, 2.71 percent zinc, 0.176 ounce of gold per ton, and 1.06 ounces of silver per ton.

Waite Amulet Mine.—Owned and operated by the Waite Amulet Mines, Ltd., this is in Duprat and Dufresnoy Townships, approximately 9 miles north of Noranda.

The ore bodies occur as two types of massive sulfide lenses, lying along flow contacts in early Precambrian extrusives. The structure of the region is complicated, and the structure localizing the ore bodies is not easily recognized. The massive sulfide lenses consist of (1) pyrite and sphalerite, containing 10 to 11 percent zinc and low copper; and (2) massive pyrrhotite lenses, carrying 4 to 7 percent copper and low zinc. Minor metals in the ore are lead, silver, and gold. The ore reserve reported on December 31, 1959, was 550,000 tons of approximately 4.4 percent copper and 3.6 percent zinc. The reserves have become depleted, and mining will cease by the end of 1962; the company has been absorbed by Noranda.

Sullico Mines, Ltd.—This property is in the township of Bourlamaque, 5 miles southeast of Val d'Or. Two large sulfide replacement ore bodies occur in a series of siliceous volcanics which strike north 60 degrees and dip steeply to the south. The ore has been localized in a quartz-chlorite alteration zone that has been folded, fractured, and in places, replaced by the sulfides. The zone of alteration has been traced over a length of 1,500 feet, is 600 feet wide, and persists beyond the bottom level of the mine. Ore bodies within the zone of alteration have lengths of from 300 to 500 feet, widths up to 95 feet, and range in vertical height from 600 to 800 feet. The principal minerals are chalcopyrite, sphalerite, and pyrite with small values in gold and silver.

Mine production in 1959 was 2,600 tons per day from stopes above the 2,500-foot level. Seven levels are being developed below the 2,500-foot level. The ore reserve reported December 31, 1959, was 3 million tons—averaging 1.0 percent copper, 0.73 percent zinc, and 0.008 ounce of gold and 0.35 ounce of silver per ton.

Normetal Mining Corporation, Ltd.—A copper-zinc property that consists of 12 mining claims in Desmeloizes Township, 13 miles north of Dupuy station. Development and exploration of the mine has been accomplished by means of four shafts; three are in use today.

The ore bodies are massive sulfide replacement lenses in sheared rhyolite agglomerate which has been intruded by various igneous rocks. Principal sulfide minerals in order of abundance are: Pyrite, sphalerite, chalcopyrite, and pyrrhotite and minor amounts of galena, arsenopyrite, chalcocite, and bornite. Silver and gold are also found in the ore. The sulfides are not evenly distributed in the ore bodies, since it appears that the copper values are concentrated along the hanging-wall side while the massive pyrite and sphalerite occur along the footwall. The ore body varies in length and width but on the 2,600 level shows a length of 1,025 feet and average width of 18.4 feet. Ore reserves as of December 31, 1959, were reported as follows:

	Tons	*Copper, percent*	*Zinc, percent*
Copper-zinc ore	1, 405, 900	4. 00	3. 22
Zinc ore	192, 800	. 37	19. 00
Total	1, 598, 700	3. 59	5. 05

Golden Manitou Mine.—Operated by Manitou-Barvue Mines, Ltd., this is in Bourlamaque Township, Abitibi County, in northwestern Quebec, and consists of 48 claims with an area of 1,850 acres.

The ore bodies occur in sheared Keewatin volcanics which lie along the southern contact of the Bourlamaque batholith. The ore shoots vary greatly in length and are from 6 to 60 feet wide. No definite bottom has been established for the ore zone, which has been developed down to the 2,950 level. The zinc ore bodies contain sphalerite, pyrite, arsenopyrite, chalcopyrite, and galena, while the copper ore body is a mixture of chalcopyrite and pyrite, containing low but recoverable values in gold.

Ore reserves at the end of 1959 were: Copper ore (above the 1,870-foot level): 797,238 tons—averaging 1.14 percent copper, 0.25 ounce silver, and 0.017 ounce gold. Zinc ore (above the 3,000-foot level): 438,172 tons—averaging 7.14 percent zinc, 0.98 percent lead, 5.63 ounces silver, and 0.03 ounce gold.

Campbell Chibougamau Mines, Ltd.—The mines are at Doré Lake, Obalski Township, Abitibi-East County, in the Chibougamau District of northwestern Quebec. In addition to the main property on Merrill Island, the company owns the Cedar Bay property in McKenzie Township, 6 miles from the mill, and has leased approximately 120 acres adjoining the main mine from Merrill Island Mining Corp., Ltd.

The Merrill Island ore body, which extends southeastward into the property of Merrill Island Mining Corp., Ltd., is localized along a shear zone in altered and silicified anorthosite. The shear zone ranges in width from 100 to 600 feet, is steep dipping, and has been traced for a strike length of 3,000 feet. The ore bodies occur in the shear as massive-sulfide replacements with pyrrhotite, chalcopyrite, pyrite, and sphalerite—the principal minerals, occurring in that order of abundance. The ore widths average 40 feet but range from 12 to 85 feet. Contacts are gradational, and the ore limits are determined by assay boundaries. A new ore occurrence has been encountered at depth by diamond drilling, and an internal shaft is being sunk below the 1,900 level for exploration of this zone.

Proven and probable reserves as of June 30, 1959, totaled 10,191,134 tons, averaging 2.5 percent copper and 0.068 ounce of gold per ton.

Opemiska Copper Mines, Ltd.—At Chapais, the company owns 58 claims in Levy Township, Abitibi-East County, in the Chibougamau District. The mine is serviced by three shafts: Springer No. 1 shaft, 2,320 feet deep; Springer No. 2, shaft, 2,414 feet deep; and Perry exploration shaft, 2,000 feet deep. Springer No. 2 is the ore hoisting shaft. Mill capacity was expanded to 2,000 tons per day in November 1959.

The ore bodies consist of veins localized in a composite basic sill, intruded into acid and intermediate volcanic rocks of Keewatin age, the whole assembly having been upturned and folded after emplacement of the sill. Massive stringers and lenses mineralized with chalcopyrite, pyrite, and magnetite and minor amounts of pyrrhotite, gold, silver, and molybdenite constitute the ore. Sulfide minerals also occur as fracture fillings and are disseminated in the wall rocks. The east-west veins have been the most productive. Mineable widths range from 3 to 73 feet; lengths are variable (to 3,000 feet); and the vertical extent is controlled by the contact between the gabbro sill and the underlying rhyolites; one zone was traced for a vertical distance of 1,200 feet.

Reserves as of December 31, 1959, totaled 5,278,700 tons of positive and indicated ore, averaging 2.97 percent copper.

Ontario

The International Nickel Company of Canada, Ltd.—The original discovery of the Sudbury District copper-nickel ores was made when the Canadian Pacific Railway, building its transcontinental right-of-way, cut through a mineralized outcrop near the present site of the Murray Mine in 1883. Most of the important ore bodies were discovered within the next few years.

The ore bodies in the Sudbury District are associated with the norite member of the Sudbury irruptive. The contact of the norite with the underlying rocks is the primary structure which determines the location of ore deposition. Essential but secondary structures are: Depressions in the relatively smooth norite footwall; shearing that roughly coincides with the base of the norite; contact breccias at the base of the norite; and norite dykes or offsets penetrating the footwall rocks. The common ore minerals are pyrrhotite, pentlandite, and chalcopyrite. Minor amounts of cobalt, selenium, tellurium, and the platinum metals also occur in the ore.

During 1959, the tonnage mined was mainly produced from underground operations at the five producing mines, Frood-Stobie, Creighton, Garson, Levack, and Murray; the balance was produced from the Frood Open Pit. Thirteen operating shafts serve these mines for hoisting ore and handling men and supplies.

The ore reserve, reported December 31, 1960, is as follows:

Tons of ore:	*Nickel-copper content, tons*
290,273,000	8,715,300

Falconbridge Nickel Mines Ltd.—In 1928, Ventures, Ltd., acquired a group of claims of the Sudbury Basin and incorporated Falconbridge Nickel Mines, Ltd., to develop the property. Additional property in the Sudbury area was acquired in later years, and an active exploratory program was maintained. New ore bodies were discovered and developed.

Underground operations are carried on at the Falconbridge, East, and McKim mines in the Falconbridge area on the south rim of the basin and at the Hardy, Boundary, Onaping, Fecunis Lake, and Longvack mines in the Onaping area on the north rim. All these ore occurrences lie at or directly below the contact of the norite with the footwall rocks. Pyrrhotite, pentlandite, and chalcopyrite are the main ore minerals. Ore reserves at December 31, 1959, were as follows:

	Tons	Nickel, percent	Copper, percent
Developed ore: Falconbridge, East, McKim, Hardy, Onaping, Fecunis Lake, and Longvack mines	22, 200, 050	1. 56	0. 87
Indicated ore: Sudbury District only	23, 982, 400	1. 34	. 77
Total	46, 182, 450	1. 45	. 82

Geco Mines, Ltd.—The property of Geco Mines, Ltd., 1 mile north of Manitouwadge Lake in the Thunder Lake District, Port Arthur Mining Division of Ontario, consists of 57 mining claims. Preliminary diamond drilling indicated the presence of a sizeable copper-zinc ore body and Geco Mines, Ltd., was incorporated in October 1953 to explore and develop the property. The first ore was produced from an adit driven into the A zone in 1955.

The Geco ore body occurs in a band of quartz sericite schist at the contact between the schist and granite or garnetiferous hornblende-biotite gneiss. Mineralization consists of pyrite, chalcopyrite, sphalerite, and pyrrhotite, with minor amounts of gold and silver. A lenticular core of massive sphalerite-pyrrhotite mineralization occurs close to and parallel with the south wall of the orebody. This core has a maximum thickness of 60 feet but tends to lens out along the strike and at depth. The high-grade zinc core is surrounded by a wide envelope of disseminated sulfides including chalcopyrite, sphalerite, pyrite and pyrrhotite.

Ore reserves at the end of 1959 were as follows:

Ore body:	Tons	Copper, percent	Zinc, percent	Silver, ounces per ton
A	3, 016, 300	1. 94	1. 93	1. 00
B	7, 098, 400	1. 57	4. 51	1. 79
C	5, 927, 800	2. 38	5. 33	3. 28
Total	16, 042, 500	1. 94	4. 38	2. 19

These reserves allow for 10 percent dilution and include ore to 25 feet below the 1,450 level.

Wilroy Mines, Ltd.—This company owns 30 mineral claims to the west of, and adjoining the property of, Geco Mines, Ltd. Diamond drilling from the surface indicated sufficient ore to warrant bringing the mine into production, and shaft sinking started in 1956. The mine plant and mill were completed in July 1957, having a capacity of 800 tons per day. By the end of 1959 the shaft had reached a depth of 1,562 feet, and mill capacity had been increased to 1,100 tons per day.

The Wilroy deposits occupy the same band of metasediments in which the Geco ore bodies were found. Massive sulfides replace an iron formation to form a lenticular ore body which strikes east-west, dips north at 70°, and plunges east at 44°. The ore consists of massive pyrite, pyrrhotite, sphalerite, magnetite, chalcopyrite, and galena. Zoning of the sulfides is apparent, and copper is more abundant in the center of the ore mass while sphalerite predominates on the borders. Ore reserves on December 31, 1959, were:

	Copper, percent	Zinc, percent	Silver, ounces per ton
Tons:			
2,708,066	1. 63	4. 85	1. 58

Reserve figures allow for 10 percent dilution.

Manitoba-Saskatchewan

Flin Flon mine.—This mine of Hudson Bay Mining and Smelting Co., Ltd., second largest copper producer in Canada, is on the border of Manitoba and Saskatchewan 87 miles north of The Pas, Manitoba.

The Flin Flon deposit is in a sheared greenstone-quartz porphyry complex. The lenticular ore bodies are in a footwall and a hanging-wall zone separated by a band of barren schist as much as 100 feet thick. The average dimensions of the massive pyritic ore lenses are as much as 900 feet long, 70 feet wide, and range from 1,500 to 2,500 feet in depth. Three types of ore occur in the mine—massive sulfide; disseminated pyrite and chalcopyrite; and disseminated ore containing bands of massive sulfides. The massive-sulfide type ore is characterized by sharp boundaries either against the wall rock or against the disseminated ore. The disseminated ore does not have a sharp cut-off, and ore limits are established by assay boundaries. Minerals present are pyrite, chalcopyrite, galena, gold, and silver. The ore contains a small amount of arsenic, selenium, and cadmium. Ore reserves December 31, 1959:

Location:	Tons	Copper, percent	Zinc, percent	Gold, ounces per ton	Silver, ounces per ton
At or near Flin Flon	11, 842, 100	3. 12	3. 4	0. 066	0. 93
Near Snow Lake	5, 615, 500	1. 68	8. 5	. 051	1. 13

Lynn Lake Mine.—This property of Sherritt Gordon Mines, Ltd., was discovered in September 1941. Surface diamond drilling and underground exploration programs led to development of two ore zones. The mine plants, the mill, and the branch line of the Canadian National Railways were completed in 1953, and production started in 1954. The Sherritt Gordon nickel refinery is at Fort Saskatchewan, Alberta. The plant was completed in May 1954 with a designed yearly capacity of 16.8 million pounds of nickel. Subsequent expansions have raised this yearly capacity, and in December 1959 production was at the rate of 30 million pounds of nickel a year.

The ore bodies at Lynn Lake occur in faulted basic rocks which have been intruded as irregular stocks or plugs into Precambrian metasediments and volcanics. These plugs—consisting of varying amounts of diorite, gabbro, amphibolite, and norite—are numerous in the area but only two are known to contain ore bodies. Faulting is common with the major faults trending north and a secondary group of faults striking northeasterly. Movement along the faults has caused shearing and brecciation, and the ore minerals occur as bodies of massive sulfides, as disseminated sulfides, and as stockworks of sulfide stringers in the fractured zones. The two principal ore bodies are the A and the EL. The A ore body contains 4,975,000 tons, averaging 1.22 percent nickel and 0.64 percent copper, and is a disseminated-sulfide type. The EL ore body has massive-sulfide mineralization and stockworks of sulfide stringers filling fractured zones in the basic rock. Combined tonnage and grade of the two types of ore in the EL ore body totals 2,445,000 tons, averaging 2.50 percent nickel and 0.93 percent copper.

The copper precipitate recovered at the nickel refinery is shipped to Noranda, Quebec, or Tacoma, Wash., for smelting. Production in 1959 was 12,406 tons of nickel, 5,171 tons of copper and 314,343 pounds of cobalt. Ore reserves at the end of 1959 were reported as 14,158,000 tons, averaging 0.96 percent nickel and 0.54 percent copper.

British Columbia

The Britannia mine, of the Howe Sound Co. is on the east side of Howe Sound, approximately 30 miles north of Vancouver, and is one of the oldest and largest base-metal mines in Canada. From 1939 through 1957 mine production averaged about 4,200 tons of ore per day; then the property closed early in 1958 because of low base-metal prices. It was reopened in January 1959 and operated for the balance of the year at an average rate of 1,200 tons a day.

The ore bodies occur in a northwesterly trending shear zone in a roof pendant imbedded in the Coast Range batholith. The shear zone has been traced for a distance of eight miles, has a maximum width of 2,000 feet, strikes roughly north 70° west and has an average dip of 70° to the south. Three distinct types of ore bodies occur at Britannia: Large siliceous replacement, containing disseminated pyrite chalcopyrite, and some sphalerite; stringer-lodes, containing chalcopyrite and pyrite; and the barite-sphalerite type of zinc.

Ore reserve figures are not published, but it is estimated that the reserve is sufficient to maintain a 1,200 ton per day operation for at least five years.

CUBA

The major copper producer in Cuba is the Matahambre mine in the Province of Pinar del Rio, 100 miles west of Havana. Ore zones lie between, under, and sometimes in members of four fault systems. The zones are tubular or pipelike, each containing many shoots occurring as vein segments, lenses, and wedges. Major ore zones are elongated vertically, and converging at depth they plunge generally toward the northwest. The ore minerals are chalcopyrite and pyrite. Mill heads run 6 percent; a 32 percent copper concentrate is produced with a 98 percent recovery.

In 1957 daily production was curtailed from 1,100 tons per day to 700 tons per day and annual output of copper has declined from 20,000 tons in 1955 to 10,000 tons in 1959. Reserves are not known but the company is optimistic about encountering a sizeable ore body at depth.

HAITI

Consolidated Halliwell, Ltd., of Canada holds title to a 100-square-mile-mining concession, through its Haitian subsidiary, Sedren, S.A., in the northwestern part of the Republic of Haiti. The district is known as Terre-Neuve, and is 180 miles north of the capital, Port-au-Prince, and 13 miles from tidewater at Gonaives. Almost 81,000 feet of diamond drilling was completed at the Meme, Casseus, and Brasillac showings, including 11,290 feet of underground drilling in the main Meme workings. Two distinct types of ore have been explored, surface secondary oxides and underground primary sulfides.

The surface-oxide mineralization occurs as rich pockets of erratic distribution which are easily accessible and appear limited in tonnage. The copper minerals are entirely oxides and carbonates, principally malachite and azurite. The primary ore is entirely beneath the surface and contains chalcopyrite and bornite in nearly equal proportions, with minor chalcocite in local instances. The principal gangue minerals are epidote, garnet, calcite magnetite, chlorite, and quartz.

At 30 cents per pound for copper, ore reserves after dilution have been estimated at 4,031,400 tons, averaging 1.88 percent copper.

MEXICO

A little more than half of Mexican copper production comes from copper ore deposits, and the balance is recovered from complex lead-zinc-copper ores. Reserves of copper ore are not well known for Mexico; however, under favorable economic conditions most of the large operating mines apparently have ample reserves to supply continuing operations at present production rates.

Cananea Consolidated Copper Co., S.A.—This subsidiary of Greene Cananea Copper Co., owned by The Anaconda Company, operates underground and open-pit mines, a concentrator, and a smelter near Cananea, Sonora, 50 miles southwest of Bisbee, Ariz.

The ore bodies are relatively homogeneous deposits, occurring in breccia pipes associated with porphyry and granite intrusives. The mineralized pipes occur in an area 6 miles wide and 15 miles long. The principal ore mineral is chalcocite; the ore gangue is an intensely siliceous, kaolinized, sericitized, fine-textured volcanic rock. The ore bodies are limited by assay boundaries.

Ore reserves are believed to be large at the present operating grade of 0.7 to 0.8 percent copper, but they are not blocked out in advance of requirements. Production in 1959 was 32,182 tons of copper, 433,771 ounces of silver, and 9,030 ounces of gold.

Boleo Mine.—This Lower California mine was operated by Compagnie du Boleo from 1886 until 1954. Compagnie Minera Santa Rosalía, S.A., a semiofficial agency of the Mexican Government, is conducting studies to develop low-cost methods to concentrate and smelt complex low-grade copper ores from numerous but small occurrences in the district. The ore series includes three beds of conglomerate averaging 100 feet in thickness. The ore minerals are principally chalcocite with minor bornite and chalcopyrite. Reserve information is not available, however, there apparently is enough ore in the area to encourage continuing research on economical recovery methods.

South America

BOLIVIA

Corocoro Mine.—Operated by the Bolivian Government, it is of unusual interest because of the presence of native copper that constituted much of the production for many years. In recent years chalcocite has supplemented the native metal as the principal mineral in the ores. The deposits are found in beds of two unconformable clastic formations known as the Ramos and Vetas. The Ramos beds dip eastward while the Vetas dip westward, and they are separated locally by the steep dipping Corocoro fault. Native copper is localized in certain sandstone beds of the Ramos and in the oxidized zone of the Vetas. Throughout the Vetas chalcocite is interstitial with sand grains and rock fragments in certain red sandstone and arkose beds. The localization of chalcocite in a particular bed seems related to processes of sedimentation.

It is estimated that approximately 7 million tons of ore, containing 350,000 tons of copper, have been taken from the district. A reserve of 750,000 tons of 2.6 percent copper ore was estimated in 1957.

Chacarilla Copper Mine.—This mine 90 miles southwest of LaPaz, is being developed by six Japanese companies. The reserve has been estimated at 900,000 tons of 4 percent copper ore, and if development is successful a monthly production of 700 to 1,000 tons of ore is scheduled. The concentrates will be shipped to Japan.

CHILE

The copper mining industry of Chile consists of three sectors: American great mining companies, medium mining companies, and small copper-mining companies. The great mining enterprises are those producing 25,000 tons or more of copper per year. At present there are three companies in this category: Chile Exploration Co., Chuquicamata mine; Andes Copper Co., El Salvador mine; and Braden Copper Co., El Teniente mine. Medium mining companies produce less than 25,000 tons of copper annually but have capital of more than 15 million pesos. Small mining companies are firms or individuals with capital not greater than 15 million pesos. The great mining companies account for about 90 percent of Chilean copper output, and the balance is divided between the medium and small producers.

Chuquicamata, 160 miles northeast of the port of Antofagasta by rail, is considered to be the largest economic copper deposit in the world. It is owned by the Chile Exploration Co., which is controlled by the Chile Copper Co., a subsidiary of The Anaconda Company. The mine lies at an altitude of 9,300 feet in the northeastern part of the Atacama Desert, one of the most arid regions in the world. Because of the extreme aridity, large quantities of sulfate and other water-soluble minerals have accumulated that normally would have been carried away by rainfall.

The deposit is a pear-shaped porphyry mass about 2 miles long, 3,600 feet wide, and with unknown depth. It is in the midst of a large body made up of granodiorite and monzonite porphyry. Mineralization is related to extensive fracturing and shearing, accompanied by much silicification and sericitization, and occurs in veins and innumerable networks of veinlets. The ore body contains three types. Oxide ore occurs in the upper section and has averaged 1.63 percent copper. Below the horizon of oxide ore there is an area of mixed ore lying above the huge reserve of sulfide ore, averaging slightly less than 2.00 percent copper. The principal oxide mineral is antlerite, $Cu_3(SO_4)(OH)_4$, and the most important minor oxide minerals are atacamite, brochantite, chalcanthite, and krohnkite. The sulfide minerals in the upper part of the sulfide zone are mainly chalcocite and covellite; enargite is found at increasing depth.

Approximately 190,000 tons of ore and waste is mined daily. The annual output of the sulfide plant and the oxide plant is 300,000 tons of copper. At this rated capacity, proven ore reserves at Chuquicamata are sufficient for more than 50 years. From the start of operations in 1915 through December 1959 Chuquicamata produced 6,835,000 tons of copper; 1959 production totaled 306,500 tons, a record output.

El Salvador Mine.—This mine of Andes Copper Mining Co., a subsidiary of The Anaconda Company, is a major porphyry copper deposit in the great copper belt of the Chilean Andes. The mine is in Atacama Province, 65 miles inland from the Pacific port of Chanaral and 20 miles north of Potrerillos. Production that was started in April 1959 replaces that of the old mine and concentrator at Potrerillos which discontinued operations June 10, 1959. The mine, concentrator, and smelter were designed for copper production of 100,000 tons per year; production in 1960 was 87,000 tons.

A broad band of intrusive rhyolite dikes and sheets and monzonite porphyry extends for several miles to the southwest of Indio Muerto Peak, making a major structural axis along which the El Salvador center of intrusion and mineralization occurs. Mineralizing activity along this axis is in a belt 3 miles long and 1 mile wide. Within the zone several centers of better-grade copper mineralization and more intense alteration are localized by intrusive rocks. El Salvador is in the southernmost and largest of these centers. Occasional small, scattered argentiferous lead-zinc veinlets fringing the copper mineralization indicate weak, widespread metal zoning. The ore body is a zone of secondary enrichment that ranges in thickness from a few feet at the edges to more than 950 feet in its central portion. Chalcocite is the principal ore mineral.

Block caving is the mining method used, and the mine has capacity to produce 24,000 tons of ore per day. The average grade of ore is 1.5 percent copper, and the reserve is estimated at 375 million tons.

La Africana Mine.—Operated by the Santiago Mining Co., a subsidiary of The Anaconda Company, this is 15 miles west of Santiago at an altitude of about 3,000 feet. Production started in 1957. Expansion of mill facilities has increased annual production capcity to 6,000 tons of copper in the form of concentrates.

The ore body is a fault fissure 10 to 60 feet wide in coastal grandiorite batholith of Cretaceous Age. The oxidized-leached zone reaches a depth of 160 feet; below is a zone of secondary enrichment 30 to 100 feet in depth, assaying 6 to 12 percent copper with chalcocite being the chief mineral. In the primary ore zone the principal copper mineral is chalcopyrite. Ore mined averages 3.2 percent copper from which a 29-percent copper concentrate is produced. Ore reserves are estimated at 2.5 million tons, averaging 3.5 percent copper.

Braden or El Teniente Mine.—Braden Copper Co., a subsidiary of Kennecott Copper Corp., owns this mine, in the Chilean Andes, 7,000 feet above sea level at the town of Sewell, 80 miles southeast of Santiago.

The Braden deposit is unique among first ranking copper producers of the world for being located in and around an old explosive volcanic vent. Only underground mining has been practiced, and only sulfide ore has been treated. Molybdenum is recovered. Annual production of copper is between 180,000 and 190,000 tons. Mine production in 1960 was 11.5 million tons of ore, averaging 1.95 percent copper. In 1947 reserves were estimated at 200 million tons of 2.18 percent copper.

Medium and Small Mines.—Of the medium and small mining companies, 10 account for about 60 percent of the production of this group. The nine long established firms in this group are: Cia. Minera Tocopilla, Cia. Minera du M'Zaita, Cia. Minera Disputada, Cia. Minera Cerro Negro, Cia. Minera Tamaya, Cia. Minera Aysen, Sali Hochschild, Renacimiento Aurifero, and Capote Aurifero. The 10th, the Santiago Mining Co. La Africana mine, started production in 1957.

Two other important copper deposits have been developed and are nearing the production stage. The Cerro de Pasco Corp. has been engaged in an exploration program on the Rio Blanco copper property, 35 miles northeast of

Santiago, since 1955. Reserves of 121 million tons of ore, averaging 1.6 percent copper, have been delineated, and the company is studying the economic feasibility of the project. An 11,000-ton-per-day block caving operation is planned. The next step will be driving a 3-mile adit under the ore body from which further exploration and development of the ore body can be conducted at depth.

The Empressa Minera de Mantos Blancos, a subsidiary of the Mauricio Hochschild organization, has explored and developed the Mantos Blancos deposit, 28 miles east of Antofagasta at an elevation of about 3,000 feet. Drilling since 1952 has proven the first 10,500,000 tons of about 2 percent copper ore. The several ore bodies lie within an area 2.5 miles long by 1,640 feet wide and extend in depth below 164 feet; many of the drill holes are bottomed in ore. The mineralization consists of copper oxides—mainly the copper oxychloride, atacamite.

The leaching plant was officially inaugurated March 27, 1961. The annual capacities of the open-pit mine and leaching plant were designed for producing 18,000 tons of fire-refined copper.

PERU

Until 1960 the Cerro de Pasco Corp. was the principal producer of copper in Peru. The corporation operates copper-producing mines at Cerro de Pasco, Morococha, Yauricocha, and the recently reopened San Cristóbal mine; concentration plants located at Cerro de Pasco, Casapalca, Morococha, and Mahr Tunnel; and a smelter at Oroya. Northern Peru Mining Co., a subsidiary of the American Smelting and Refining Co., produces copper from its Quiruvilca mine. Other copper producers include several Peruvian-owned organizations, operating mines and concentration plants, and the French-owned Campagnie des Mines de Huaron. In addition, small copper mines, mainly Peruvian-owned, sell their ores to the principal producers or other ore buyers for processing or export.

In 1960 Peru advanced to one of the major copper-producing countries of the world when more than 145,000 tons was recovered from the Toquepala mine of Southern Peru Copper Corp. The Quellaveco, Cuajone, Antamina, and Cobriza deposits have been explored and contain large reserves of low-grade ore.

Cerro de Pasco.—Deposits are localized in and around the eastern and southern portion of a body of pyroclastic rock, agglomerate, and quartz-monzonite porphyry that appears to be a deeply eroded volcanic vent. A large cresent-shaped replacement mass of pyrite and silica is contained in the contact zone between the volcanic rocks of the vent and the limestone east of the major fault. At intervals within the massive pyrite body are found economic concentrations of copper-silver ore, silver ore, and lead-zinc silver ore. The copper ore bodies vary greatly in size, and few persist more than 300 feet vertically. Enargite-famatinite, luzonite, and tetrahedrite-tennantite are the usual ore minerals but bornite, chalcocite, and chalcopyrite dominate in localized occurrences. Vein mineralization accounts for about half the ore tonnage. Some veins follow fractures within the pyrite mass, and others extend for hundreds of feet west into the volcanic rocks of the vent. Most of the copper and zinc in the mantle of oxidized material, known locally as pacos, were leached—except in small areas adjacent to the limestone where these metals occur as carbonates. Rich secondary sulfide ores, chalcocite, and covellite extended below the pacos 500 feet to the primary pyrite material; mining today is limited to primary ores.

Morococha.—Deposits, mined by Cerro de Pasco Corp., a subsidiary of Cerro Corp., are about 100 miles east of Lima at an altitude of 14,500 feet. They are of several types: (1) Fissure veins in altered limestone, volcanic rocks, and quartz-monzonite; (2) limestone replacement mantos, pipes, and sills; and (3) contact metamorphic zones adjacent to the intrusion. Mineral and metal zoning is well exhibited at Morococha, both on a horizontal or district pattern and on a vertical scale in the separate ore bodies. Enargite in the central zone gives way to chalcopyrite and bornite in the surrounding limestone. Reserves are unknown but are understood to have decreased in recent years.

Yauricocha Mine.—This mine of Cerro de Pasco Corp. is in the Department of Lima, Province of Yauyos. High-grade sulfide ores in steeply dipping irregular mantos in limestone and an extraordinary pipe of rich oxidized ore, all carrying silver and gold as well as copper, comprise the valuable deposits. The ore bodies are replacements in limestone adjacent to and probably genetically related to a stock of monzonite porphyry. The principal ore mineral is enargite. Only direct smelting ore is mined; the grade of ore shipped in 1959 was 5.8 percent copper, 1.2 percent lead, 2.3 percent zinc, and 4.5 ounces of silver per ton. Reserves have been estimated at about 700,000 tons of ore.

San Cristobal.—The deposit, in the Department of Junin, mined by Cerro de Pasco Corp., consists of fissure vein systems of zinc-lead-copper-silver ore. Ore extensions found in the early 1950's replenished depleted reserves. In 1960 the mine was reported to have 1.5 million tons of measured ore—averaging 1.2 percent copper, 9 percent lead, and 12 percent zinc. Sphalerite is the dominant ore mineral within the mine area and chalcopyrite is next, but silver, lead, and gold contributed about half the total value.

Quiruvilca.—This mine of Northern Peru Mining Co., a subsidiary of American Smelting and Refining Co., is in the Province of Santiago de Chuco, in the Department of Liberstad, about 80 miles from the port of Salaverry at an altitude of 13,000 feet. The copper veins occur in a small portion of a large mineralized area within which there is considerable diversification in the content of the veins. There are three mineralized areas in the larger district—a southern group of silver veins with quartz filling, a central group of enargite and tetrahedrite veins, and a northwesterly group of silver veins with barite gangue. Operations have been centered largely on the copper group. Those copper veins are notable for their persistence in strike and mineralization, and the ore averages more than 5 percent copper. Copper production ranges between 5,000 and 6,000 tons a year. Reserves are unknown.

Toquepala.—This Southern Peru Copper Corp. mine is in southern Peru, 55 airline miles north of the small city of Tacna and the same distance inland from the port of Ilo. The Toquepala ore body lies in a mineralized zone, elliptical in shape and about two miles long, which has been the locus of intense igneous activity. Several small intrusive bodies having irregular forms occur within and adjacent to a centrally located large breccia pipe. The mushroom-shaped ore body consists of a flat-lying enriched zone of predominant chalcocite with a stemlike extension of hypogene chalcopyrite ore in depth within and around the pipe. Hydrothermal alteration is pervasive in the zone. The principal sulfides, pyrite, chalcopyrite, and chalcocite, occur mainly as vug fillings in the breccia, and as small grains scattered through all the altered rocks.

Operations at Toquepala of the Southern Peru Copper Corp. began January 1, 1960, and the scheduled rate of production was reached in March. Mine production of ore and waste averaged 166,897 tons per day. Ore milled averaged 26,052 tons per day and contained 1.73 percent copper, which is substantially higher than the average grade of the ore body. According to published data the deposit contains 400 million tons of open-pit ore, averaging a little more than 1 percent copper. Production in 1960 was 145,115 tons of blister copper.

Cuajone.—This porphyry copper deposit is the northernmost of a group of three deposits in southern Peru controlled by the Southern Peru Copper Corp.—Toquepala, Quellaveco, and Cuajone—all within a 20-mile belt. The principal ore body, the Chuntacala, is on the southern part of the northeastward-dipping Cuajone quartz-monzonite stock. It is roughly circular in plan and about 3,000 feet in diameter near the surface. With depth the ore body divides into two distinct roots; the northern portion tapers downward as an inverted cone; and the southern portion follows down the south contact zone of the quartz-monzonite intrusive. Sulfides within the ore body occur as small veinlets that may be as much as 2.5 inches wide but are usually 0.5 inch wide, or less, in closely spaced array. Pyrite is the most abundant of the sulfide minerals; chalcopyrite is the principal ore mineral. Minor quantities of bornite, galena, sphalerite, and enargite were noted in the drill samples. Molybdenite is common but spotty. Supergene enrichment processes have formed chalcocite and covellite. Oxide minerals and local concentrations of native copper occur where the zone of oxidation encroaches upon enriched ore. Reserves have been estimated at 500 million tons of slightly more than 1.1 percent copper ore.

Quellaveco.—The deposit is the smallest of the three having an estimated reserve of 200 million tons of ore of approximately the same grade as the other two.

Antamina.—This deposit, approximately 100 miles northwest of the town of Cerro de Pasco, has an indicated ore body of approximately 100 million tons of 1.5 percent copper ore. Exploration and development activities by Cerro de Pasco Corp. at this deposit were temporarily suspended in 1957.

Cobriza.—The deposit, 115 miles southwest of La Oroya, was explored by the Cerro de Pasco Corp., and the tonnage of 3.5 percent copper ore developed in 1961 would support mining for an annual production of approximately 9,000 tons of copper in concentrates for about 10 years.

Europe

AUSTRIA

The Mitterberg mine, near Salzburg, is the most important of 22 copper mines listed for Austria. Two others, the Schwaz and the Untersulzbach, are intermittent producers but only Mitterberg operates continuously. It has been known as an important source of copper since ancient times. The ore averages 1.6 percent copper and occurs in veins with siderite, andesite, and calcite as matrix; chalcopyrite is the principal ore mineral. The reserve is estimated at 3 million tons of ore, averaging 2 percent copper.

BULGARIA

Bulgaria has more than doubled its production of electrolytic copper in the last five years. Recently discovered deposits at Panagyuriste, in the Stara Planina mountains, and near Malko Turnovo provide sources for further expansion of mine capacity. The lead-zinc ores of the Rhodopt region have important copper values. Information regarding production, reserves, and descriptions of the operating copper mines is not available. It is known that smelting and electrolytic refining capacities are being increased and a large expansion of Bulgarian copper production is planned for 1962. Refinery output was 14,000 tons of electrolytic copper in 1960.

FINLAND

Outokumpu.—This mine is in eastern Finland, in the Province of North Karelia, about 30 miles northwest of the town of Joensuu. The massive sulfide ore deposit, about 3,800 meters long, 300 to 350 meters wide, and 7 to 9 meters thick, is part of a beltlike complex of quartzite and serpentine rocks. The ore minerals are chalcopyrite, pyrite, and pyrrhotite; the average metal content of the ore is 3.7 percent copper. Reserves are estimated at about 15 million tons.

Paronen.—The mine is in the Parish of Ylöjärvi about 12 miles northwest of the town of Tampere. In the area the rocks are mainly volcanics which are strongly broken in places, forming two almost parallel breccia zones. The ore deposit forms part of the larger zone, and the breccia differs considerably from the surrounding volcanics. The angular fragments of discolored tuffite and porphyrite have been cemented by a mass of ore-bearing, fine-grained, needlelike tourmaline. Chalcopyrite and arsenopyrite occur in varying amounts, and commercial ore bodies are likely to be limited, often irregular in form, and without any definite geological contacts. The ore is low grade, containing about one percent copper, minor amounts of silver and gold, and in places about 0.1 percent tungsten trioxide (WO_3). The ore reserve is estimated at 1 million tons.

Vihanti mine.—This is approximately 30 miles south of the town of Oulu on the Gulf of Bothnia. The ore bodies are located in a schist zone where the main rocks are mica schist, quartzite, and marble—the latter largely altered to a skarn. Mineralization occurs in at least two separate and parallel zones in an area which is about 4,000 feet long and 650 feet wide. Sphalerite is the most abundant ore mineral, galena and chalcopyrite occurring as a weak dissemination throughout the ore. Accessory minerals are cubanite, tetrahedrite, and tennantite. Copper production in 1959 was 3,227 tons contained in concentrates.

Kotalahti.—This mine, in the center of Finland south of Jyväskylä, started operations in October 1959 and produced 40,652 tons of ore that year; 4,742 tons of nickel concentrate and 390 tons of copper concentrate were recovered.

Pyhasalmi.—This deposit in the Province of Oulu has been developed for an annual production rate of 600,000 tons of ore; the expected recovery of copper, beginning in 1962, is 16,500 tons. The deposit contains copper, zinc, pyrite, and precious metals.

EAST GERMANY

Most of the German copper has come from the Mansfeld area. The ore body is a thin but extensive cupriferous bed of black shale, 30 to 40 centimeters thick, which contains as much as 2 percent copper. Comprehensive exploration in the Sangerhausen basin developed a 35-centimeter-thick copper-slate deposit, having higher copper content than that of the Mansfeld basin Copper production will shift from the Mansfeld to the Sangerhausen area as the newly developed Niederroeblingen copper mine reaches the planned production rate. As a consequence copper production of East Germany is expected to be 70 percent higher in 1965 than in 1958 or about 41,000 tons.

IRELAND

Avoca Mine.—This property of St. Patrick's Copper Mines, Ltd., is 43 miles south of Dublin and 7 miles from the small harbor of Arklow. The outcrops in the area were first worked many centuries ago, but the earliest underground mining was in the 1750's. Mining was carried on continuously until around 1880. Workings in a strike length of about 3 miles, having more than 100 abandoned shafts as much as 700 feet deep, indicate the intensity of historical mining activity.

The ore bodies are sulfide-rich sheets, lenses, and associated tonguelike zones lying within altered schistose rocks. The ore minerals in order of abundance are: Pyrite, chalcopyrite, sphalerite, and galena. Reserves of about 20 million tons of ore, assaying 0.95 to 1.36 percent copper, have been developed.

Mountain Mine.—Near Allihies in County Cork, this is being developed by Can-Erin Mines, Ltd., of Canada. Limited drilling has proved a total of 2,350,000 tons of ore, averaging about 2 percent copper.

NORWAY

The cupriferous iron pyrites mine of Orkla Grube-Aktiebolag is at Medalen. Deposits are massive pyrite lenses in gabbro and contain about 2 percent copper. Smelting and refining plants at Thamshamn in Orkedalsfjorden are operated by Orkla Metal-Aktieselskap, a subsidiary; the head office is in Løkken Verk. In

1959, 342,303 metric tons of ore was mined of which 245,616 tons was smelted, yielding 3,800 tons of copper and 78,349 tons of sulfur. The ore reserve in mid-1959 was estimated to be sufficient for about 15 years production.

The other principal producer of copper in Norway is Sulitjelma Gruber, A/S, which operated cupriferous pyrite mines at Sulitjelma about 60 miles east of Bodø. The ore, in lenses, consists of copper-bearing pyrite and pyrrhotite, disseminated through mica schist. Some of the pyrite is massive. Copper production in 1958 was approximately 3,800 metric tons. Ore reserve data are not known.

POLAND

The principal copper-mining districts are the Złotoria and Bolesławiec-Grodziec basins—estimated to contain 200 million tons of ore, averaging approximately 0.7 percent copper. Production in 1957 came from three mines, the Konrad, Lubichow, and the Leona and amounted to 1,256,000 tons of ore, containing 0.61 percent copper. Full capacity of these three mines is scheduled for an annual output of 2.5 million tons of ore. The 1960 annual rate of copper production was about 10,000 tons.

Exploration revealed new reserves in the Lublin-Głogów area in Lower Silesia, and development of three mines in this area will start in the next five years. The first ore is expected from the Lublin mine in 1964 with production on an industrial scale scheduled for 1966. Development of the Polkowice I will start in 1963 and at the Polkowice II in 1965. These three mines will be in full production in the 1970's. The smelter and refinery planned to treat the Głogów ore will be put into operation by 1968–70.

Deposits near Głogów are of the sedimentary type in an area of about 200 square kilometers, containing an estimated reserve of about 10 million tons of copper. The average copper content of the ore has been estimated between 1.4 and 2.0 percent.

SPAIN

The copper-bearing massive pyrite deposits in southern Spain have been worked for more than 3,000 years and have been an important source of copper and pyrite since Roman times. The most important producer is the Compania Espanola de Minas de Rio Tinto, formerly a British company, but now controlled by the Spanish government. The Rio Tinto mining area is about 37 miles north of the port of Huelva in Huelva Province and accounts for more than 90 percent of the output of copper from Spanish mines. Cupreous pyrite is mined by surface (open cast) and underground methods. Copper is recovered from the ore by leaching and cementation; by direct smelting to produce a copper matte and sulfur dioxide for making sulfuric acid; and by flotation followed by smelting. Reserves in 1958 were estimated at 4.5 million tons of copper (content of ore).

SWEDEN

Most copper mining in Sweden is carried on by the Boliden Mining Co., which operates several mines in a 200-mile strip from the Gulf of Bothnia in the east to the Lapland mountains in the west. The mines are grouped into four distinct areas near Boliden, Kristineberg, Adak, and Laisvall. There are three mines in the Boliden area—Boliden, Renström, and Långsele. Kristineberg is 60 miles west; Ravliden, a small producer, is 3 miles further west. The Adak district, 80 miles northwest of Boliden has two producing mines, the Adak and Rudtjebacken. These are State owned but operated by the Boliden company. The Laisvall mine is 140 miles west of Boliden, near the Lapland mountains where lead-bearing ore is mined.

The three areas of Boliden, Kristineberg, and Adak comprise the Skellefte District with mineralization occurring in Precambrian rocks. The principal ore bodies are massive sulfide ores—the most common being compact pyrite with subordinate pyrrhotite, chalcopyrite, sphalerite, and galena in varying amounts. Some of the ore bodies are in drag folds, while others are in shear zones or at the junction between bedding and shear zones. The dips of the ore bodies are generally steep and the wall rocks are mostly sericitic or chloritic schist. All the mines are small producers, working at shallow depths. In 1958 reserves were estimated at approximately 70 million tons or sufficient to insure 40 years production at present capacity.

U.S.S.R.

Principal copper deposits occur in five general areas, Kazakhstan, the Urals, Uzbekistan, Noril'sk, and Armenia. Quantitative data showing total copper production of the U.S.S.R. or any of its regions are not available. However, annual percentage increases to 1955 and results of the Fifth Five Year Plan have been published. This information formed the basis for developing production data in tonnage. Annual copper production increased 25 percent between 1955 and 1959 (from 385,000 to 480,000 tons), and the U.S.S.R. Seven Year Plan (1959–65) proposes to almost double 1959 production by 1965. The copper content of reserves in the Soviet Union was estimated to have been about 35 million tons at the beginning of 1959. A reserve goal approaching 45 million tons by 1965 is anticipated in the Seven Year Plan. The quality of the reserves are not known and they may include low-grade protore uneconomical to mine at present values.

Kazakhstan, accounting for more than half of the U.S.S.R. output of copper ore, has producing mines in three areas, Dzhezkazgan-Karsakpay, Balkhash-Kounradskiy, and the Altai in East Kazakhstan. The Dzhezkazgan deposits are copper-impregnated sandstones, of the Rhodesian type, forming gently dipping lodes extending outward from feeder faults. The ore averages 1.62 percent copper and contains chalcopyrite, bornite, and chalcocite as the principal ore minerals. The most recent reserve estimate of 3.5 million tons of copper content is now considered too modest. The porphyry copper-type deposits in the Balkhash-Kounradskiy area are extensive and low grade. They consist of disseminated yellow sulfides and supergene chalcocite in small porphyry masses and invaded rocks; small quantities of molybdenum, gold, and silver are also present. The shallow enriched zones, averaging about 1 percent copper can be economically mined. The copper content of reserves in the region estimated at 2 million tons are believed to include areas of protore carrying only 0.5 to 0.7 percent copper. In the Altai region of eastern Kazakhstan, a major lead-zinc center, complex ores contain recoverable copper. Other main deposits in Kazakhstan are at Bozshakul' and Uspenkiy.

The principal copper mines in the Urals are at Krasnoural'sk, Kirovgrad, Degtyarsk, Karabash, Sibay, and Blyava. Copper-bearing pyritic lodes yield most of the copper ores mined in this region. The copper content of the ore is less than 3 percent, but it also contains extractable quantities of zinc and has values in gold and selenium. In 1950 the total reserve in the Urals was estimated at 4 million tons of copper contained in 246 million tons of ore. There are low-grade copper deposits in the western foothills of the Urals and in the Donets Basin that have not been developed. The Gay (section of Orsk) deposits discovered in 1958 contain five ore bodies having values in copper and zinc sulfides. Two of the ore bodies (1 and 3) now being developed average 4 percent copper; in some sectors the ores are 11 to 12 percent, and samples assaying 30 percent copper have been reported.

The Noril'sk district is east of the lowlands of the Yenisey River and borders the northwestern section of the Siberian massif. Magmatic copper-nickel deposits occur as intrusive stocks, sills, and dikes. Pyrrhotite, chalcopyrite, and pentlandite form low-grade disseminations and veinlets in peridotite to form 1- to 3-percent copper ore, carrying 0.5 percent nickel and some of the platinum group metals.

In Armenia copper ore is mined on a small scale at four localities, Akhtala-Shamlug, Dastakert, Kadzharan, and Kafan. Copper reserves in the Caucasus although lowgrade are extensive (600,000 to 1,200,000 tons copper content).

In Northern Karelia and the Kola Peninsula are significant deposits of copper-nickel ore containing cobalt and platinum group metals. Reserves in central Asian U.S.S.R. are important. The largest at Almalyk, 56 miles southwest of Tashkent is reported to have a copper content of 3 million tons.

YUGOSLAVIA

Bor Mine.—Situated about 75 miles from Belgrade, this is the principal source of copper in Yugoslavia. Annual production of the Bor mine is about 30,000 tons of copper, scheduling operations at 4,000 tons per day of 1.8 percent copper ore and 500 tons per day of 5 to 6 percent copper ore. The important deposits at Bor are three massive bedlike ore bodies in altered andesite porphyry. The largest contains pyrite and enargite with minor amounts of luzonite and famatinite. The ore, enriched by secondary chalcocite and covellite, carries from 5 to 6 percent copper and some gold. The second ore body also yields 5 to 6 percent copper ore, and the third contains pyrite and chalcopyrite with a copper content of 1 to 2 percent.

Majdanpek Mine.—In the eastern part of Yugoslavia, this is actually in the northeastern part of the Republic of Serbia. It is about 75 miles from Belgrade, 9 miles from the Danube, and 25 miles north of the Bor mine. Exploration by the Yugoslavian Government in 1949 led to the development of extensive copper ore deposits at Majdanpek, which is one of the oldest mining districts in Yugoslavia, having about 2,000 years of mining history. This copper-bearing area is in the most northern part of the andesite mass of East Serbia. Magnetite, pyrite, and chalcopyrite occur as either fine disseminations or as irregular veins. Chalcopyrite is the principal copper ore mineral. Ore reserves of the Bor-Majdanpek combine have been estimated at 275 million tons averaging about one percent copper; Majdanpek accounted for 221 million tons, containing an average of 0.824 percent copper.

The Majdanpek mine is expected to produce 12,000 tons of ore per day for a recovery of 25,000 tons of copper annually. When the whole Bor-Majdanpek copper mining complex is put into operation in 1962, it is expected to produce annually 55,000 tons of copper, 3 tons of gold, 34 tons of silver, 400,000 tons of pyrite concentrate, 230,000 tons of sulfuric acid, 575,000 tons of superphosphate, and 6,000 tons of synthetic cryolite.

Asia

CHINA

There are many copper occurrences in China. A Chinese source reports that discoveries of more than 3,000 copper deposits have been made mainly in Liaoning, Hopeh, Shansi, Kansu, Szechwan, Yunnan, Kweichow, and Anhwei Provinces. Intensive prospecting, exploration and development are credited for the more than tenfold increase in mine production and additions to resources of copper during the past decade. The most significant producing areas are in the southwestern provinces of Yunnan, Szechwan, and Kweichow.

Approximately 80 percent of the copper deposits in China are of four types: Bedded deposits, stringer-vein disseminated deposits, contact replacements, and copper-bearing pyrite. The Tung-ch'uan and I-men mines in Yunnan Province are in bedded deposits; the Chung-t'iao Shan mine in Shansi and the Te-hsing mine in Kiangsi are in stringer-vein disseminated deposits; the ore bodies of the T'ung-kuan-shan mine in Anhwei and the T'ien-pao-shan mine in Kirin are contact-replacements; the Pai-yen mine in Kansu exploits cupriferous-pyrite bodies; the deposits of the Chao-yüan mine in Shantung are of the vein type; the Kuang-t'ung mine in Yunnan, the Hui-li mine in Szechwan, and the Wei-ning mine in Kweichow work copper-bearing shale rock; and the deposit at the T'ao-k'o mine in Shantung is the copper-nickel type.

In 1959 the copper ore reserve of China was estimated between 3 to 5 million tons of copper (content of ore).

CYPRUS

Cyprus was perhaps the earliest important producer of copper smelted from sulfide ores. The metal was undoubtedly produced and delivered to the Egyptian kings before the Island was conquered by Thotmes III about 1500 B.C. The Roman occupation of Cyprus in 58 B.C. followed 14 centuries of control by Egyptians, Phoenicians, Assyrians, Persians, and the Ptolemies. Roman production was probably active until A.D. 200. There was no interest in metal mining from the Roman period until 1878 when Great Britain gained control of Cyprus. Casual prospecting was carried on between 1882 and 1914. More intensive exploration was resumed in 1919, and cupreous pyrite has been actively mined since 1922, except during World War II.

Skouriotissa Mine, Cyprus Mines Corp.—The property situated at the foot of Foucassa Hill was probably the largest of the ancient producers. The massive sulfide ore body is flat-lying, lenticular, roughly elliptical in plan, about 2,000 feet long, and as much as 600 feet wide—tapering from a thickness of a few feet at the edge to 150 feet near the center. It is intensely impregnated with sulfates of copper, iron, and zinc—including chalcanthite, brochantite, and melanterite. The ore reserve estimate as of December 31, 1960, was 2,750,000 tons, containing 2 percent copper and 40.0 percent sulfur.

Mavrovouni Mine, Cyprus Mines Corp.—The ore body is a large flat-lying body of cupreous pyrite. It is almost completely surrounded by andesitic lava that has been hydrothermally altered for hundreds of feet on all sides of the ore. The ore body shows extensive secondary alteration of chalcopyrite to chalcocite, covellite, and bornite. There are localized variations in copper content from 1 to 10 or 12 percent or more in bodies of sizeable tonnage. Crude ore production in 1960 totaled 873,000 tons, compared with 913,000 tons in 1959. The ore reserve at the end of 1960 was estimated to be 2 million tons, averaging 3.6 percent copper and 47.5 percent sulfur.

The Cyprus Sulphur and Copper Co., Ltd., a British company, produced cement copper from leach solutions at the inactive Limni mine from May 1958 until August 1959, when mining operations were resumed. In 1959 the company continued stripping operations at its Kinousa opencast mine, mining about 80,000 tons of ore—averaging 0.88 percent copper. Ore reserves at the end of March 1959 were 162,500 tons, averaging 0.26 percent copper at the Kinousa mine and 2,235,000 tons of 1.30 percent copper at the Limni mine.

INDIA

The Mosaboni and adjacent Badia mines of the Indian Copper Corp., Ltd., have been the only significant producing copper mines in India. Exploration and development are being conducted by the corporation at the Surda mine and Pathagarah prospect northwest of the present working area. The Mosaboni and other mines are in the Singbhūm district of the State of Bihār, 15 miles south of Ghatsila, 135 miles from Calcutta. Ore reserves as of December 31, 1958, were estimated at 4 million short tons, averaging 2.51 percent copper. The principal ore mineral is chalcopyrite, which occurs in veins in altered granite.

Occurrences of copper reported in various states are in Botang, near Rangpo in Sikkim; Khetri and Daribo in Rajasthan; Baragonda in the district of Hazaribagh; and Bairukhi in

Santhal Parganas, both in Bihār; Belliguda in the Chitaldrug district of Mysore, Almora; and the Tehri-Garhwal districts of Uttar Pradesh. Other than the Singbhum belt only the deposits in Sikkim and Rajasthan are said to be promising. Investigations of the deposits at Khetri and Daribo in Rajasthan by the Indian Bureau of Mines and Geological Survey have been encouraging.

ISRAEL

The Timma mine of the Israel Mining Industries, 15 miles north of the Red Sea port of Eilat, is in the area of the fabled King Solomon's mines. Operations began in April 1958 and in 1959, 495,000 tons of ore, containing 1.45 percent copper, was processed to yield 4,930 tons of copper. Proved reserves are estimated at 17 to 18 million tons of ore, averaging 1.4 percent copper. New deposits discovered in April 1960 are expected to double the potential ore reserve.

The Timmá deposit is a sedimentary one with copper mineralization diffused in sandstone and shaly sandstone rock. The copper occurs mainly in the form of chrysocolla (copper silicate). Ore is mined by the open-pit method and is leached with sulfuric acid. Copper is precipitated from the acid copper sulfate solution with scrap iron and recovered as cement copper, averaging about 80 percent copper.

JAPAN

Deposits of copper are widely distributed in Japan. A reserve estimate of 85 million tons of ore, averaging 1.4 percent, was made from a Japanese Government survey of 184 mines in 1956. Most of the ore bodies contain less than a few hundred thousand tons but they commonly occur in clusters. The bedded cupriferous pyrite-type deposit is the most productive in Japan. These are massive, pyritic replacements of green schist. The sulfide minerals present are pyrite, pyrrhotite, chalcopyrite, and sphalerite. Another type of replacement is known as black ore; these deposits contain galena, sphalerite, chalcopyrite, and pyrite replacing tuffs and shales. Many Japanese mines obtain copper from fissure veins containing chalcopyrite associated with pyrite or pyrrhotite. Some of the larger Japanese mines are:

Besshi Copper Mine.—This mine of the Sumitomo Metal Mining Co., Ltd., is in Ehime-ken in Shikoku. The ore is cupriferous pyrite, averaging 2.16 percent copper in a reserve of about 7 million tons.

Kosaka Mine.—Operated by the Dowa Mining Co., Ltd., this is at Kazuno-gun, Akita-ken. In 1913 this property was considered the largest copper mine in Japan. Mining was suspended in 1946 because all workable ore had been depleted; however, copper is being recovered by leaching and cementation. The reserve is estimated at 20 million tons of ore with a grade of 0.4 percent copper. Annual production is about 1,000 tons of copper.

Hanoka Mine, Dowa Mining Co., Ltd.—This is 2.5 miles north of Odate station, Akita-ken, and is known as the largest typical massive kuroko or black ore deposit in Japan. The deposit consists of more than 10 irregularly massive ore bodies distributed in an area 3 miles long and 1½ miles wide. Ore minerals are copper, lead, zinc, and iron sulfides with some gold and silver. The ore reserve as of September 1958 was 1.85 million tons, containing 1.2 percent copper.

The Mitsubishi Metal Mining Co., Ltd., operates 14 mines and produces about 20,000 tons of 21 percent copper concentrates annually. Eleven of these mines have narrow vein deposits, and three work massive, cupriferous pyrite deposits.

Hitachi Mine.—The Nippon Mining Co., Ltd., property is in Ibaraki-ken. The deposit consists of about 60 cupriferous pyrite ore bodies occurring in an area 2,500 meters long and 1,000 meters wide. The company operates 17 other mines in various sections of Japan, and the ore reserves of all operating properties in April 1957 were about 40 million tons.

Ashio Copper Mine.—This famous mine, operated by the Furukawa Mining Co., Ltd., is about 70 miles north of Tokyo in the Tochigi-ken. The deposit is one of the largest of the quartz-vein type in Japan and has been worked since 1620. Besides the true fissure veins, irregular deposits of chalcopyrite called kajika are found at the intersection of numerous radial veinlets or near the axis of folding in sedimentary rocks. Production amounted to 28,500 tons in 1959.

PHILIPPINES

Copper mining replaced the production of gold as the leading mineral industry of the Philippines in 1959 owing to the expansion of operations by the four major producers.

Toledo Mine.—This open-pit mine of the Atlas Consolidated Mining & Development Corp. in Cebu is the largest in the Far East. It accounted for 43 percent of the total copper output in the Philippines in 1959. Almost 4 million tons of ore, averaging 0.62 percent copper, was delivered to the mill for processing. The known ore body is 1,000 feet wide and 400 feet deep and is a disseminated porphyry type deposit. Chalcopyrite is the principal ore mineral. The total reserve at the end of 1959 was 10 million tons of ore with a grade of 0.695 percent copper.

Lepanto Mine.—The Lepanto Consolidated Mining Co. is in the Mountain Province of the Philippines. It is the largest vein copper mine in the country and ranks second in production. The ore body consists of a stockwork of veins and veinlets in a block 1,500 meters long, 30 meters wide, and 50 to 150 meters high. Luzonite, enargite, and precious metals are the ore minerals. The grade varies greatly but only material about 2 percent copper is considered ore. Ore reserves at the end of 1959 totaled 4.7 million tons averaging 3.39 percent copper and 0.129 ounce of gold per ton.

Sipalay Mine.—This property of the Marinduque Iron Mines Agents, Inc., is an open-pit operation of a large low-grade disseminated deposit on the west coast of Negros Occidental. Measured and indicated reserves in 1959 totaled 20.6 million tons of ore, averaging 0.79 percent copper.

Bagaycay.—The property on Samar Island, also owned by the Marinduque Iron Mines Agents, Inc., was discovered in 1955, and mining started in June 1956. One type of ore occurs in carbonaceous shale and in low-rank coal. Ore reserves at Bagaycay in 1959 were about 32,000 tons of direct shipping ore, containing 17.14 percent copper and 3.2 million tons of milling grade ore, averaging 3.55 percent copper.

Santo Tomas II Mine.—Near Baguio, Mountain Province, and owned by the Philex Mining Corporation, the mine started production July 5, 1958, and 1 million tons of ore was milled by the end of May, 1960; open-pit mining produced 800,000 tons and underground block-caving 200,000 tons. Ore reserves on January 1, 1960, were estimated at 22 million tons having a copper content of 0.81 percent. Most of the ore was found in a highly shattered zone of andesite alongside a large tongue of blocky diorite.

TURKEY

Copper production in Turkey is derived almost wholly from two mines which are owned and controlled by the Government. From 1936 through 1950 the Ergani deposit was the principal source of copper output; production at the Murgul mine began in 1951.

Ergani Mine, Mill, and Smelter.—These are in the Elazig II near Maden on the west bank of the Tigris River. Reserves consist of about a million tons of high-grade direct smelting ore in massive pyrite, averaging 10 percent copper and 3 to 4 million tons of disseminated ore underneath the massive pyrite that carries 4 to 5 percent copper. The ore body is bordered by serpentine to the south and is in contact with schist or diabase to the north. It is oval in horizontal section, the long axis is about 360 meters, and the short axis is 170 meters. The ore minerals are pyrite, chalcopyrite, covellite, and some chalcocite.

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Murgul Mine.—This is in the Coruh II near the village of Damar, southeast of the Black Sea Port of Hopa. The deposit consists of several irregular, subhorizontal lenses and stockworks of veins in a thick complex of andesite dacite. The largest lense is Cankara, others are the Sosveni and Satep. The Cankara ore body is 300 meters long, 50 to 80 meters wide, and increases in size with depth. The Sosveni measures 100 by 50 meters in the open pit and the Satep 100 by 60 meters. Ore reserves have been estimated at 16 million tons of about 2 percent copper. Ore minerals are pyrite and chalcopyrite occurring as a stockwork in dacite. The ore is mined by the open-pit mining method at a rate of 1,500 tons per day.

Africa

ANGOLA

The Empresa de Cobre de Angola, a subsidiary of Companhia Uniao do Fabril of Lisbon, Portugal, operates the only producing copper mine. The property is in northwestern Angola at Mavoio in the Uíge District in the Congo area. Production in 1960 amounted to 3,500 tons in ore, matte, and ingots. The ore mined averages between 10 to 14 percent copper. A water-jacket smelting furnace near the mine has a daily capacity of 5 tons of ingots.

REPULIC OF THE CONGO

Copper produced in the Republic of the Congo comes from concessions of the Union Minière du Haut-Katanga in Katanga Province.

The important mines are concentrated in an area about 200 miles long paralleling the Northern Rhodesia border. Producing units are referred to as belonging to the western group around Kolwezi, the central group near Jadotville, and the southeast group near Elizabethville.

Kamoto.—This is an open-pit mine in the western group, producing copper-cobalt ore. The ore body consists of flat-dipping beds of copper oxide ores. Outcrops are cellular quartzite containing vugs and seams of malachite. This mine is the principal supplier of siliceous oxidized ores for the Kolwezi concentrator.

Musonoi.—This open-pit mine of the western group operated only 4 months in 1961 when it furnished the major portion of mixed oxide-sulfide ores for the Kolwezi concentrator. Thereafter operations consisted of stripping overburden, mainly in the southern zone.

Ruwe Mine.—This is an open-pit operation in the western group. The ore body consists of deeply buried flat-lying shale beds containing nodules and seams of malachite. Zones of secondary enrichment occur as veinlets and small masses in the underlying breccia. The pit was extended to the south to mine the breccia in the lower levels. Stripping overburden from the two south extensions was continued.

Kolwezi Mine.—Located in the west, the mine is an open-pit operation. Mining in 1961 was sporadic due to construction of a skip hoist. Stripping overburden from the south end of the mine continued.

Kipushi (Prince Leopold) Mine.—This is an underground mine and is the principal producer in the southeastern group. The deposit is a pipelike sulfide lode along a faulted contact between limestone and members of the Mines series. The lode is 500 to 600 meters long, 20 to 60 meters wide, and dips steeply. It is rich in copper, zinc, and iron sulfides—containing values in silver, cadmium, and germanium. The ore body averages 11 percent copper and 19 percent zinc. The principal ore minerals are chalcopyrite, bornite, and sphalerite. A new top-slicing technique using metal props has been extended to the whole mine.

Kambove-West Open-Pit Mine.—Found in the central group this is being developed and is expected to be a substantial producer. Construction of the new concentrator near Jadotville to process Kambove ore was completed in April 1961.

Ore reserves of copper at the mines in the Congo are not available. The deposits are extensive, however, and the total reserve is believed to be large. An estimate of 20 million tons of recoverable copper is considered to be conservative.

FEDERATION OF RHODESIA AND NYASALAND

The Federation advanced to second place in world mine production of copper in 1959 and maintained that rank in 1960 with record mine output in both Northern and Southern Rhodesia. (The Federation ceased to exist on December 31, 1963, dividing into the Protectorate of Northern Rhodesia and the Colony of Southern Rhodesia.)

Northern Rhodesia

Six companies operate six underground and two open-pit mines within the Northern Rhodesian Copperbelt. These companies fall into two groups, one controlled mostly by British and American interests (Rhodesian Selection Trust, Ltd.) and the other predominantly by South African interests (Anglo-American Corporation of South Africa, Ltd.).

Anglo-American Corp. Group:
- Bancroft Mines, Ltd.
- Nchanga Consolidated Copper Mines, Ltd.
- Rhokana Corporation, Ltd.

Rhodesian Selection Trust Group:
- Chibuluma Mines, Ltd.
- Mufulira Copper Mines, Ltd.
- Roan Antelope Copper Mines, Ltd.

The Copperbelt has been described in great detail by a number of geologists. Briefly, the copper deposits are found in a number of synclinal structures along a belt 140 miles long and about 40 miles wide. They occur as disseminations in sedimentary shale and sandstone. These copper-bearing beds range from a few multiples of 10 to 100 feet in thickness; they extend on strike for a few thousand feet to a few miles and persist for at least several thousand feet in depth. The ore minerals are chalcocite, bornite, and chalcopyrite with minor amounts of other metallic minerals. Most of the ore bodies consist of sulfide ore but there is some mixed oxide-sulfide ore in places, and considerable oxide ore is mined in certain sections.

Bancroft Mines, Ltd.—The property is at the northwest end of the Northern Rhodesian Copperbelt. It is bounded on the north by the Belgian Congo border and on the south by Nchanga Consolidated Copper Mines, Ltd. Ore reserves June 30, 1959, were approximately 105 million tons, averaging 3.82 percent copper in three ore bodies:

	Short tons	*Copper, percent*
Kirila Bomwe South ore body	52, 122, 200	4. 5
Kirila Bomwe North ore body	20, 690, 900	4. 18
Konkola ore body	32, 073, 400	2. 48
Total	104, 886, 500	3. 82

Production was resumed on April 1, 1959, after a stoppage of 1 year, and by the end of the year output was at the annual rate of 55,000 tons of copper.

Nchanga Consolidated Copper Mines, Ltd.—This is the largest producer of copper in the British Commonwealth. Ore comes principally from the Nchanga West underground mine, but two open-pit mines—the Nchanga and the Chingola—are in operation. Ore reserves on March 31, 1960, totaled 180 million tons, containing 4.65 percent copper.

	Short tons	*Copper, percent*
Nchanga West and Nchanga ore bodies	163, 556, 000	4. 64
Chingola ore body	14, 183, 000	4. 89
Nchanga River lode	2, 280, 000	4. 21
Total	180, 019, 000	4. 65

Rhokana Corp., Ltd.—The corporation operates the Nkana mine near Kitwe. Ore is mined from three ore bodies where reserves were estimated to total 120 million tons with 3.07 percent copper as of June 30, 1960:

	Short tons	Copper, percent
Nkana North ore body	24, 328, 000	3. 06
Nkana South ore body	14, 913, 000	2. 62
Mindola ore body	81, 106, 000	3. 15
Total	120, 347, 000	3. 07

Chibuluma Mines, Ltd.—The property is in the Nkana South Limb area about 7 miles west of Kitwe and about 34 miles southwest of the Mufulira mine. Ore reserves at June 30, 1960, were:

	Short tons	Copper, percent	Cobalt, percent
Chibuluma main ore body	7, 420, 000	5. 03	0. 21
Chibuluma West	2, 370, 000	4. 47	. 07
Total	9, 790, 000	4. 89	0. 18

Mine production for the year ending June 30, 1960, was 575,436 tons of ore, averaging 4.65 percent copper and 0.23 percent cobalt; 76,362 tons of copper concentrate were treated by Mufulira Copper Mines, Ltd., yielding 26,465 tons of copper; 36,524 tons of cobalt copper concentrate was treated at the Ndola plant, producing 9,778 tons of cobalt matte, containing 9.46 percent cobalt and 11.61 percent copper. The cobalt matte is shipped to Société Générale Metallurgique de Hoboken in Belgium for refining.

Mufulira Copper Mines, Ltd.—The company operates the second largest Copperbelt mine and the largest in the Rhodesian Selection Trust group. The property is 26 miles northeast of Kitwe. There are three parallel mineralized beds at Mufulira, separated by 25 to 45 feet of waste. The two lower beds coalesce toward the northwest to give a thickness of more than 100 feet in places. Ore reserves on June 30, 1960, were 179 million tons, averaging 3.35 percent copper. A major expansion of the producing capacity of Mufulira was being developed at Mufulira West and was designed to increase capacity by 50 percent.

Roan Antelope Copper Mines, Ltd.—The deposit is in the southwest corner of the Copperbelt near the town of Luanshya. The deposit is large and is important for the great length of ore developed around the nose and along the limbs of the fold in an ore bed 25 to 30 feet thick. Ore reserves at June 30, 1960, totaled 94.6 million tons of 3.04 percent copper. Mine output for the year ending June 30, 1960, was 6.66 million tons of ore, averaging 1.85 percent, and production of copper was 103,422 short tons.

Southern Rhodesia

The areas north and west of Sinoia contain many deposits of copper minerals, and it is from this belt that future production is expected. Copper development in Southern Rhodesia has been controlled by The Messina (Transvaal) Development Co., Ltd., (incorporated in the Union of South Africa) directly or through its subsidiaries M.T.D. (Mangula), Ltd., and M.T.D. (Sanyati), Ltd.

Mangula.—The largest copper mine in Southern Rhodesia is in the Lomagundi District, 30 miles north of Sinoia and 115 miles northwest of Salisbury. The ore is disseminations of sulfide minerals, mainly bornite and chalcocite, in folded structures of arkoses and shales. Mineralization extends for 3,000 feet with a width at the center on the surface of 300 feet. Ore reserves in 1960 were 26 million tons, averaging 1.36 percent copper.

Other important deposits in this area are the replacement ore bodies of the Copper King and Copper Queen mines in the Sebungwe District, 60 miles west of Sinoia; the Alaska mine 12 miles west-southwest of Sinoia, where copper minerals occur in a replacement deposit in dolomite, and quartzites and ore reserves are estimated at 5 million tons of 1.87 percent copper; and the copper-gold carbonate lodes 32 miles west of Sinoia. Another producing property is the Umkondo mine in the Sabi valley, Bikita district, where copper minerals occur in beds of shale and quartzite. Umkondo reserves on September 30, 1959, were 360,160 tons of ore, containing 3.35 percent copper, sulfide, and oxide.

KENYA

The Macalder-Nyanza copper mine, operated by Macalder-Nyanza Mines, Ltd., south of Nyanza near Lake Victoria, produced 1,855 tons of copper in 1960. It has been estimated that the known ore body will support this rate of production for approximately 12 years.

MAURITANIA

The principal copper deposit in Mauritania, known as the Guelb Moghrein mine, is about 2.5 miles from Akjoujt. About 9 million tons of oxidized ore, averaging 2.3 percent copper, is in the upper part of the ore body, and almost 17 million tons of cupriferous pyrite with 1.5 percent copper is in the lower part. The deposit is being developed by Société des Mines de Cuivre de Mauritanie (MICUMA). Lack of water and mineral composition present problems in concentration of the ore.

SOUTH-WEST AFRICA

The Tsumeb mine of the Tsumeb Corp., Ltd., is the major source of copper. Copper minerals—including tennantite, enargite, chalcocite, and bornite—are associated in substantial amounts with lead and zinc ores in massive replacement lenses in dolomite. Ore reserves above the 3,150-foot level on June 30, 1959, totaled 8,165,000 tons—averaging 5.29 percent copper, 14.36 percent lead, 4.45 percent zinc, and 0.013 percent germanium. Drilling below the 3,150-foot level has indicated a minimum of 2 million additional tons of ore—averaging 4.6 percent copper, 7.1 percent lead, and 1.9 percent zinc. Exploratory drilling on the Tsumeb Asis claim near Kombat has disclosed two ore bodies of about 1 million tons each, averaging 11 percent combined copper and lead; production started in April 1962.

The Tsumeb Corp., Ltd., was erecting a copper smelter at Tsumeb which was completed and began production of blister copper in November 1962.

UGANDA

The Kilembe mine, operated by Kilembe Mines, Ltd., is in the foothills of Mount Ruwenzori in the Toro district of Western Uganda. Two ore bodies are being worked. Both deposits are irregularly shaped and occur over a strike length of about 7,000 feet and an average thickness of 40 feet. The upper part of the East deposit is near the surface and is mined by the open-pit method; the lower section of the East deposit and the North deposit are mined by underground methods. The ore contains a wide variety of minerals which occur as disseminations, stringers, seams, and small blebs within the granulitic host rock. Ore minerals are cuprite, malachite, chrysocolla, and chalcocite in the upper zone and chalcopyrite, pyrite, pyrrhotite, and linnaeite in the lower. Ore reserves estimated at the end of 1958 were 8.2 million tons, containing 2.31 percent copper and 0.18 percent cobalt, and 1.57 million tons, containing 1.23 percent copper and 0.22 percent cobalt. Blister-copper production was 17,200 tons in 1962.

REPUBLIC OF SOUTH AFRICA

Most of the copper production of the Republic of South Africa comes from two widely separated deposits, the O'okeip properties near Springbok in Namaqualand (Cape of Good Hope Province) and the Messina mine in the Northern Transvaal near the Southern Rhodesian border.

The principal mines operated by the O'okeip Copper Co. are the Nababiep, East O'okeip, Narrap, Wheal Julia, Nababiep West, and the Carolusberg. The ore bodies occur in metamorphic rocks that consist chiefly of paragneiss, granulite, quartzite, and schist. Mixtures of the oxide minerals, brochantite, chrysocolla, and malachite show in some of the outcrops. Below the oxidized zone, usually less than 70 feet, are bornite, chalcopyrite, and chalcocite. These minerals occur in finely disseminated form, in coarser aggregates with interconnecting veinlets, and in massive form. Sulfide ore reserves on June 30, 1959, totaled 27.8 million tons, averaging 2.19 percent copper.

Artonvilla, Campbell, Harper, and Messina.—In Transvaal, these four producing mines, operated by Messina (Transvaal) Development Co., Ltd., are near the town of Messina, 6 miles south of the Limpopo river which forms the boundary between the Union of South Africa and Southern Rhodesia. The ore bodies are veins and breccia pipes lying in a zone striking northeast for about 10 miles along the Messina fault. The principal ore minerals are chalcopyrite, bornite, and chalcocite. Ore reserves on September 30, 1961, totaled 6,003,810 tons, containing 1.57 percent copper. The Campbell mine presently accounts for about half of the ore produced.

Palabora Mining Co., Ltd.—Controlled by the Rio Tinto Co., Ltd., of London and the Newmont Mining Corp. of New York, this company is developing a long known copper deposit at Loolekop, Palabora, northeast Transvaal about 75 miles east of Pietersburg. Drilling confirms the existence of a low-grade ore body suitable for open-pit mining. Ore reserves have been estimated at 5.7 million tons of 1.26 percent copper and 24.9 million tons of 0.51 percent copper per hundred feet of depth. Production of 2,265 tons of copper in concentrates was reported in 1961 for the first time.

Australia

During the 1950's Australia became one of the major world sources of copper. Mine production of 1950 had increased eightfold to 122,000 tons by 1960, mainly because of continuing expansion at the Mt. Isa mine. Four mines produce approximately 90 percent of Australian copper. The balance is obtained from small copper mines and byproduct recoveries at the large silver-lead-zinc mines.

Mt. Isa Mine.—This property of the Mt. Isa Mines, Ltd.—in which the American Smelting and Refining Co. of the United States has a controlling interest—is the largest producer, accounting for 60 percent of the 1961 output from Australia. The deposits are situated at Mount Isa, 600 miles west of Townsville, in

Queensland. The host rock for the ore bodies is known broadly as a silica-dolomite rock, which consists of brecciated dolomitic and pyritic shales with massive and, at times,, structureless siliceous and dolomitic rocks. The chief ore mineral is chalcopyrite, occurring as fracture and vein filling in the silica-dolomite bodies. Oxidized and secondarily enriched copper ores occur in the oxidized zone near the surface. The estimated reserves of copper ore on June 30, 1961, were 24.5 million tons, averaging 3.7 percent copper.

Mount Morgan Mine.—Operated by Mount Morgan, Ltd., it is also in the State of Queensland, 23 miles southwest of Rockhampton, on the Dee River. The ore body, including the Sugarloaf section, is an irregular quartz-pyrite mass, having a maximum length of 2,100 feet and a maximum width of 900 feet. The principal ore mineral is chalcopyrite. Production in 1961 was 9,300 short tons of copper and 54,000 ounces of gold in concentrates. Reserves as of June 30, 1961, amounted to 13.8 million tons of ore, containing 0.116 ounce gold per ton and 1.10 percent copper.

Mount Lyell.—This group of mines is about 18 miles from Macquarie Harbour on the west coast of Tasmania. The mines are in a narrow belt extending from the northern side of Mount Lyell to the northern side of Mount Owen on the south, a distance of 2½ miles. The ore deposits are associated with the schist-conglomerate contact. Massive sulfide ore bodies occur on or near the contact and low-grade disseminated ore bodies away from the contact. The ore consists mainly of chalcopyrite with some bornite. Ore reserves on June 30, 1962, were 23.5 million tons, averaging 0.80 percent copper. Mine production of copper in fiscal 1962 was 12,332 tons.

Peko Mine.—This property of Peko Mines N.L. at Tennant Creek is the only copper mine in Northern Territory. The ore body or lode contained some copper in the oxidized zone; high-grade copper ore, containing native copper, cuprite, and malachite was found near the water table. Primary ore—containing 4 to 11 percent (average 8.5 percent) copper and 0.05 to 1.25 ounce gold per ton—occurred at 350 feet and continued in depth. The copper occurs chiefly as chalcopyrite, while the gold is fine grained and is closely associated with the chalcopyrite. Ore reserves in mid-1959 were estimated at 1 million tons with an average of 6.3 percent copper. Production of copper in 1959 was 7,500 tons in concentrates.

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CHAPTER 4.—SECONDARY COPPER RESOURCES

A large reserve of secondary copper has been accumulated and is continually being augmented because of its indestructibility and the consumption pattern of the metal and its alloys. Every use of new copper in any form becomes a potential part of this resource except those few applications where reclamation is impossible, for example, copper in chemical compounds used as fungicides and copper and brass powders employed in making paint pigments. Each year this reservoir provides approximately one fourth of the copper consumed in the United States in unalloyed and alloyed products. The collection and processing of copper and copper-base alloy scrap into secondary metal constitutes an important segment of the copper industry in all major consuming countries.

NATURE

Copper recovered from copper scrap, copper-alloy scrap, and other copper-bearing scrap materials as copper metal, or as copper content of alloys, chemicals, or compounds is known as secondary copper. As defined, the term includes the copper content of copper-base and other copper-bearing alloys recovered in alloy form, as well as refined copper produced in processing various kinds of scrap. Some brass scrap is smelted for separate recovery of its copper content; however, a large percentage of reclaimed brass scrap is remelted into brass ingots that are sold as brass in the secondary market. Inasmuch as the copper content of such brass substitutes for primary copper in industrial and commercial products of consumption, it contributes to the available supply of copper and may validly be covered by the term "secondary copper." The same reasoning is applicable to other copper alloys and chemicals.

KINDS OF SCRAP

Secondary copper is recovered from two principal classes of scrap, these are old and new. However, only old scrap is available from the accumulating reserve of secondary copper through reclamation of copper, brass, bronze, and other alloy products that have been used and then discarded because they are obsolete, worn out, or damaged. Such articles are wire, fired cartridge cases, pipe, automobile radiators, bearings, valves, screening, lithographic plates, etc.

The new scrap generated in fabricating and manufacturing semifinished and finished products from primary copper and copper-base-alloy forms does not form a reservoir supply to supplement production of primary copper. Examples of new scrap are defective castings, clippings, punchings, turnings, borings, skimmings, drosses, and slag. Such scrap represents a circulating quantity of copper previously accounted for as supply of primary copper and returned to the fabricating process without reaching the product stage. However, data on the movement of new scrap have significance as indicators of business activity in fabricating and scrap reclamation industries.

SOURCES

Collection of scrap is carried on in almost every community. In many there are collectors or dealers that sort, bale, and otherwise prepare the salvaged scrap for shipment and sale to primary smelters, secondary smelters, ingot makers, brass mills, chemical plants, or other fabricators. However, the principal sources of copper and copper-alloy scrap are the heavily populated industrial centers; most of the plants engaged in recovering secondary copper are located in these areas. Distribution of the primary and secondary smelters and brass mills (1958) producing most of the secondary copper in the United States is as follows:

State:	*No. of plants*
Primary and secondary smelters:	
Illinois	15
Ohio	12
New York	12
New Jersey	10
California	9
Massachusetts	5
Michigan	5
Brass mills:	
Connecticut	15
Illinois	6
Michigan	6
Pennsylvania	6
New Jersey	5
New York	5
California	3

Types and quantities of old scrap consumed by producers of secondary copper, 1956–60, are shown in table 9.

TABLE 9.—*Consumption of old scrap, short tons*

Type of scrap	1956	1957	1958	1959	1960	Total	1956-60 (average)	Percent
Aluminum bronze	1,240	925	833	1,142	843	4,983	997	0.16
Auto radiators (unsweated)	57,815	51,819	46,682	51,561	44,111	251,988	50,398	8.15
Bronze	24,758	21,665	18,659	23,926	23,408	112,416	22,483	3.64
Cartridge cases and brass	16,607	14,139	11,634	15,964	14,340	72,684	14,537	2.35
Composition or red brass	71,449	59,074	55,343	65,737	58,793	310,396	62,079	10.04
Low brass	2,242	2,841	2,038	1,575	1,311	10,007	2,001	.32
Low-grade scrap and residues	142,887	149,540	149,771	127,537	144,346	714,081	142,816	23.11
Nickel silver	3,395	2,799	2,637	2,638	2,913	14,382	2,877	.47
No. 1 wire and heavy copper	86,689	87,368	83,636	110,322	90,302	458,317	91,663	14.83
No. 2 wire and mixed heavy and light copper	114,158	99,540	111,872	121,609	117,071	564,250	112,850	18.26
Railroad-car boxes	63,174	55,931	44,895	56,674	48,727	269,401	53,880	8.72
Yellow brass	68,913	62,810	58,803	63,236	53,636	307,398	61,480	9.95
Total	653,327	608,451	586,803	641,921	599,801	3,090,303	618,061	100.00

MAGNITUDE OF INDUSTRY

Near the beginning of the 20th century, the secondary metal industry comprised a group of independent junk collectors and dealers who gathered, sorted, and sold scrap metals and waste materials to relatively uncertain markets. As more scrap metal sources were developed and collection became better organized, some of the collectors and dealers sought to increase their margin of profit by remelting their scrap and producing commercial ingots. These ingots were generally poor in grade, by present standards. Having no precedent with which to base expansion and improvements, this embryonic industry added technical personnel and began educating itself in the art and technology of reclaiming values from scrap and waste materials. The quality of products and the degree of specialization in all segments of the industry soon improved considerably. Collecting, marketing, melting, refining, and alloying became individual operations, each contributing to the general advance of the industry as a whole.

As a result, the secondary copper industry has grown to be the largest of the nonferrous secondary metal industries. Approximately 25 percent of the total copper consumed in the United States is produced from old scrap. The industry consists of several thousand collectors and dealers, several hundred foundries, about eighty ingot makers and secondary smelters, around fifty brass mills, and a dozen primary smelters which process some scrap. These processors also recover an equivalent amount of copper from new scrap and the total from new and old scrap often approaches recoverable mine production.

ACCUMULATING POOL

Consumption of new copper in the United States from the beginning of recorded production in 1845 through 1960 totals approximately 51 million tons. In the period from 1908 through 1960, more than 16 million tons of secondary copper was recovered from old scrap. An important aspect of these data is that an ever increasing resource is being created that is capable of providing about one-third of the national requirements.

There is no statistical series showing the amounts of copper consumed in end-use items that would indicate the quantity in service in nondissipative uses; nor is there any related quantitative data about consumption and reclamation by an industry classification. Although it is generally known that more old scrap is salvaged from capital goods such as buildings, ships, railroads, bridges, and industrial machinery than from consumer goods such as automobiles, radios, and cooking utensils, there are no continuing statistics showing significant uses of copper in units of capital goods that would support the construction of an estimated reserve of copper in use.

However, table 10 presents an interesting development showing expansion of the copper-in-use pool in the United States from 3 million tons at the end of 1907 to almost 33 million tons at the end of 1960. These figures are based on the estimate that three-fourths of the new copper is consumed in the manufacture of reclaimable products.

Although adequate data for adjustment of the annual increments are not available, there are some factors that should be considered in the accumulation of the in-use pool. Examples of such factors are imports and exports of copper-bearing manufactured products and imports and exports of new and old copper scrap that are not included in calculating apparent consumption. However, the error introduced by exclusion of this foreign-trade material is believed to be consistent with the limits of accuracy in other portions of the problem.

WORLD RESERVE

The major uses of copper in the principal foreign consuming countries are about the same

TABLE 10.—*Estimated accumulation of copper-in-use in the United States, 1845–1960*
(thousands of tons)

Year	Consumption, apparent			Pool of copper-in-use	
	New copper	Old scrap	Total	Increase=75 percent of total minus old scrap	Total at end of year
1845–1907	[1] 6, 083				
In use through 1907					[2] 3, 000. 0
1908	240. 0	[1] 50. 0	290. 0	167. 5	3, 167. 5
1909	344. 3	[1] 55. 0	399. 3	244. 5	3, 412. 0
1910	366. 2	64. 5	430. 7	258. 5	3, 670. 5
1911	340. 9	76. 0	416. 9	236. 7	3, 907. 2
1912	388. 0	107. 0	495. 0	264. 2	4, 171. 4
1913	406. 1	91. 5	497. 6	281. 7	4, 453. 1
1914	350. 8	87. 9	438. 7	241. 1	4, 694. 2
1915	568. 3	121. 2	689. 5	395. 9	5, 090. 1
1916	739. 4	175. 0	914. 4	510. 8	5, 600. 9
1917	697. 4	194. 9	892. 3	474. 3	6, 075. 2
1918	830. 8	176. 7	1, 007. 5	578. 9	6, 654. 1
1919	457. 2	152. 6	609. 8	304. 8	6, 958. 9
1920	526. 9	169. 0	695. 9	352. 9	7, 311. 8
1921	305. 5	132. 0	437. 5	196. 1	7, 507. 9
1922	448. 3	202. 8	651. 1	285. 5	7, 793. 4
1923	650. 2	270. 9	921. 1	419. 9	8, 213. 3
1924	677. 4	266. 2	943. 6	441. 5	8, 654. 8
1925	700. 5	291. 0	991. 5	452. 6	9, 107. 4
1926	785. 1	337. 3	1, 122. 4	504. 5	9, 611. 9
1927	711. 5	339. 4	1, 050. 9	448. 8	10, 060. 7
1928	804. 3	365. 5	1, 169. 8	511. 8	10, 572. 5
1929	889. 3	404. 4	1, 293. 7	565. 8	11, 138. 3
1930	632. 5	342. 2	974. 7	388. 8	11, 527. 1
1931	451. 0	261. 3	712. 3	272. 9	11, 800. 0
1932	259. 6	181. 0	440. 6	149. 4	11, 949. 4
1933	339. 4	260. 3	599. 7	189. 5	12, 138. 9
1934	322. 6	310. 9	633. 5	164. 2	12, 303. 1
1935	441. 4	361. 7	803. 1	240. 6	12, 543. 7
1936	656. 2	382. 7	1, 038. 9	396. 5	12, 940. 2
1937	694. 9	408. 9	1, 103. 8	419. 0	13, 359. 2
1938	407. 0	267. 3	674. 3	238. 4	13, 597. 6
1939	714. 9	286. 9	1, 001. 8	464. 4	14, 062. 0
1940	1, 008. 8	333. 9	1, 342. 7	673. 1	14, 735. 1
1941	1, 641. 6	412. 7	2, 054. 3	1, 128. 0	15, 863. 1
1942	1, 608. 0	427. 1	2, 035. 1	1, 099. 2	16, 962. 3
1943	1, 502. 0	427. 5	1, 929. 5	1, 019. 6	17, 981. 9
1944	1, 504. 0	456. 7	1, 960. 7	1, 013. 8	18, 995. 7
1945	1, 415. 0	497. 1	1, 912. 1	937. 0	19, 932. 7
1946	1, 391. 0	406. 5	1, 797. 5	941. 6	20, 874. 3
1947	1, 286. 0	503. 4	1, 789. 4	838. 7	21, 713. 0
1948	1, 214. 0	505. 5	1, 719. 5	784. 1	22, 497. 1
1949	1, 072. 0	383. 5	1, 455. 5	708. 1	23, 205. 2
1950	1, 447. 0	485. 2	1, 932. 2	964. 0	24, 169. 2
1951	1, 304. 0	458. 1	1, 762. 1	863. 5	25, 032. 7
1952	1, 360. 0	414. 6	1, 774. 6	916. 4	25, 949. 1
1953	1, 435. 0	429. 4	1, 864. 4	968. 9	26, 918. 0
1954	1, 235. 0	407. 1	1, 642. 1	824. 5	27, 742. 5
1955	1, 336. 0	514. 6	1, 850. 6	873. 3	28, 615. 8
1956	1, 367. 0	468. 5	1, 835. 5	908. 1	29, 523. 9
1957	1, 239. 0	444. 5	1, 683. 5	818. 1	30, 342. 0
1958	1, 157. 0	411. 4	1, 568. 4	764. 9	31, 106. 9
1959	1, 183. 0	471. 0	1, 654. 0	769. 5	31, 876. 4
1960	1, 148. 0	429. 4	1, 577. 4	753. 6	32, 630. 0
Total	51, 084. 3	16, 481. 7	61, 483. 0	29, 630. 0	

[1] United States production.
[2] Estimated.

Source: Merrill, C. W. The Significance of the Mineral Industries in the Economy. Ch. in Economics of The Mineral Industries, AIME, New York, 1959, p. 26.

as those in the United States with a similar relationship existing between consumption of scrap and total copper. Further, scrap is collected, marketed, and processed in foreign countries in much the same manner as it is in the United States. This is particularly true in Europe where 40 to 45 percent of the World copper is consumed, principally in Great Britain, West Germany, U.S.S.R., France, and Italy. Because of this implied parallelism, the accumulated copper that is recoverable but still in use in the World is estimated by applying the ratio of World to United States consumption for the period 1908–60 to the resource pool as developed for the United States.

$$\frac{\text{World secondary resource}}{\text{U.S. secondary resource}} : \frac{\text{World consumption}}{\text{U.S. consumption}}.$$

$$\text{World secondary resource} = \frac{32{,}630{,}000 \times 113{,}562{,}000}{45{,}001{,}300},$$

$$\text{World secondary resource} = 82{,}000{,}000 \text{ tons.}$$

World consumption of 113,562,000 for the period 1908–60 was compiled from various sources. Smelter production is used for the periods 1908–21 and 1939–45, as there are no World consumption data for those years; consumption data appearing in the American Bureau of Metal Statistics 1933 yearbook are used for 1922–25; Bureau of Mines data are used for the other years. Although the consumption statistics used in developing an estimate of the World secondary copper reserve are not strictly comparable, the differences are not great, and the result indicates the probable magnitude of such a resource.

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CHAPTER 5.—TECHNOLOGY

Technology is defined as the science of systematic knowledge of the industrial arts. The expansion of nearly all phases of industry is due largely to development of the science through research and application of scientific knowledge through engineering. Management must continually seek improved technology to increase efficiency of operations and to lower costs.

PROSPECTING AND EXPLORATION, CURRENT ORE SEARCH TECHNIQUES

Prospecting is the search for ore occurrence, and exploration is the work involved in gaining knowledge of the size, shape, position, and value of an ore body. These two activities, although quite different in purpose, use the same tools. Many writers consider prospecting as a phase of exploration and refer to the search for ore as exploration for new ore bodies; others use the terms interchangeably; such as, geochemical exploration and geochemical prospecting or geophysical exploration and geophysical prospecting. The separation of prospecting from exploration is difficult, and consequently prospecting and exploration of copper deposits are treated as a unit in this report.

Historically, mineral deposits have been discovered by prospectors, local groups organized to prospect and explore a single property, and small companies. The most advanced techniques now used—comprising the expensive requirements of mapping, drilling, underground workings, sampling and assaying, metallurgical testing, and other related activities—are beyond the financial capacity of individuals or small companies. The major companies, for the most part, find operation of small mines uneconomic and generally do not become interested in a mining property or a mineralized area unless it promises to become a large-scale producer.

Two fundamental approaches to exploration are common, basic exploration and property acquisition, as well as combinations of the two in varying proportions.

Basic exploration as practiced by large exploration companies consists of several stages. First, an area is selected by a study of the regional geology, using photogeology as a tool. Next, the area often is mapped by airborne magnetic and electromagnetic methods on a fairly close spacing. Some reconnaissance geochemical work may also be carried out. Results obtained are used to determine the extent of stage three, detailed ground surveys. This includes checking of geophysical anomalies using corresponding ground techniques, detailed geochemical work and geological mapping and possibly shallow drilling, pitting, stripping, and trenching. The extent of the final drilling program is in turn conditioned by the quality of these results.

The favored exploration approach by some companies is the acquisition of prospects by option. It also fits into the basic exploration programs of others.

Generally the planning and organization of a large-scale exploration program consists of four main stages:

1. Obtaining an overall picture of the geology by aerial photography, photogeological interpretation, and field reconnaissance; preparation of a large-scale geological map; and development of the geological history of the area.
2. Airborne geophysical exploration, geochemical survey of silts and soils along streambeds and other prominent exposures, and field investigations for mapping widely spaced traverses to locate all superficial mineralization that can be found easily.
3. Geological mapping and geophysical, geochemical, and mineralogical prospecting of promising areas on a close grid.
4. Proving the deposit—essentially, delineating and sampling the ore. More detailed mapping and geophysical and geochemical studies may be necessary, but the fieldwork consists mostly of obtaining samples from the ore body exposed by pitting, trenching, drilling, and shaft sinking.

Geophysical prospecting is used to measure and interpret anomalous physical or physicochemical phenomena within the crust of the earth. For example, magnetic material in the earth increases the strength of the normal magnetic field, and the resulting magnetic anomaly can be measured with sensitive magnetometers. Hence this method has been important in locating magnetic iron ores (magnetite) and has been helpful in tracing geological formations and certain types of nonferrous mineral deposits having a greater or smaller content of magnetic minerals than the enclosing or adjacent rocks. Various other geophysical methods, such as resistivity and radio frequency, depend on electrical phenomena. The petroleum industry has been eminently successful in developing and applying gravitational and seismic methods to location of underlying oil-bearing structures. Gravitational methods are based on gravity differences between different types of rocks, and seismic methods depend upon differences in the speed of refracted and transmitted seismic waves through different rock layers.

Data obtained by exploration are required for determining ore reserves, planning mining methods and equipment, projecting the scale of operations, and other technological and economic factors essential to establishment of a mining enterprise.

These objectives postulate that the ore body be penetrated by boreholes and/or underground workings at appropriately spaced intervals and that the exploratory work be carried far enough to permit sound planning of subsequent operations. For example, porphyry-copper deposits usually are explored by a network of boreholes or underground workings on a 100-to-200-foot spacing over the entire area of the deposit, in advance of mining, to predetermine the factors that predicate a heavy expenditure for equipment and to avoid placing surface structures on ground that may later be mined or caved. However, exploration of a vein deposit, especially if it is to be mined by supported stopes, need only be carried far enough to demonstrate the existence of a workable ore body of sufficient extent and value to justify relatively moderate expenditures for development and equipment. Deferred interest charges on advance exploration and the cost of maintaining underground workings limit the amount of exploration that may be done in advance of mining; hence, in many underground mines the developed ore reserve rarely exceeds 10 years and often is less than 3. A continuing program of exploration and development is relied upon to add reserves to replace mined-out ore.

Boring

Boring is employed extensively, either as the principal exploratory method or to supplement exploration by underground and surface workings. Several types of drills are used for this purpose, the principal ones being churn drills, diamond drills, rotary drills, and hammer drills.

Churn Drills.—These are employed when solid cores are not required, stratigraphic thicknesses do not have to be measured accurately, and only vertical holes are desired. In churn drilling, a string of tools with a cutting bit at the lower end is suspended from a rope or cable and is alternately raised and dropped by a machine near the collar of the hole. The release of tension in the cable as the bit strikes the bottom of the hole imparts a slight rotation or churning action to the bit. Water is used in the bottom of the hole during drilling, and the cuttings are brought to the surface with a bailer at regular measured intervals for examination and analysis.

Diamond Drills.—These are used widely in exploration because of their speed, adaptability for directional drilling, and portability, and because they provide accurate information about the rock types drilled. The diamond drill is a rotary drill designed to cut an annular groove about a central core of the rock penetrated. The bit is typically a hollow metal cylinder set with industrial diamonds on its inner, outer, and downward surfaces; it is joined to hollow steel connecting rods that are rotated by mechanical equipment at the collar of the hole. Water circulating through the hollow rods cools the bit and flushes the fine cuttings from the hole. The core formed as the drill advances is recovered in sections for inspection and testing.

Rotary Drills.—These rotate alloy steel or tungsten carbide drill (tricone) bits in the bottom of the hole to achieve a constant chipping, scaling, and grinding action. Downward pressure of the drill bit is supplied by the weight of the string of metal rods that connects the bit to the rotary table at the collar of the hole. Cuttings are either bailed or conveyed to the surface by a circulating fluid such as water, air, or a heavy medium mixture (fig. 3).

Hammer Drills.—Their best application is in exploratory drilling underground, where relatively short holes are to be drilled, and core recovery is not required. The maximum depth of drill holes for hammer drills is about 250 feet, but the most efficient range is less than 150 feet. These are common heavy rock drills, using sectionalized, hollow drill steel and standard bits.

Underground Exploration

Most prospects and small mines rely principally upon underground methods of exploration. A typical example in exploration of narrow veins is sinking a shaft in or alongside the vein and then driving underground-horizontal workings known as drifts or levels in the vein at convenient intervals. Exploration for parallel ore bodies or to find faulted segments of the main ore body is done by diamond drilling or by making horizontal openings (crosscuts) that penetrate the enclosing country rock at an angle to the prevailing strike of the vein or stratified country rock. In suitable topographic situations, a horizontal opening or adit may be driven into a hillside to reach or follow a vein that crops out at a higher level.

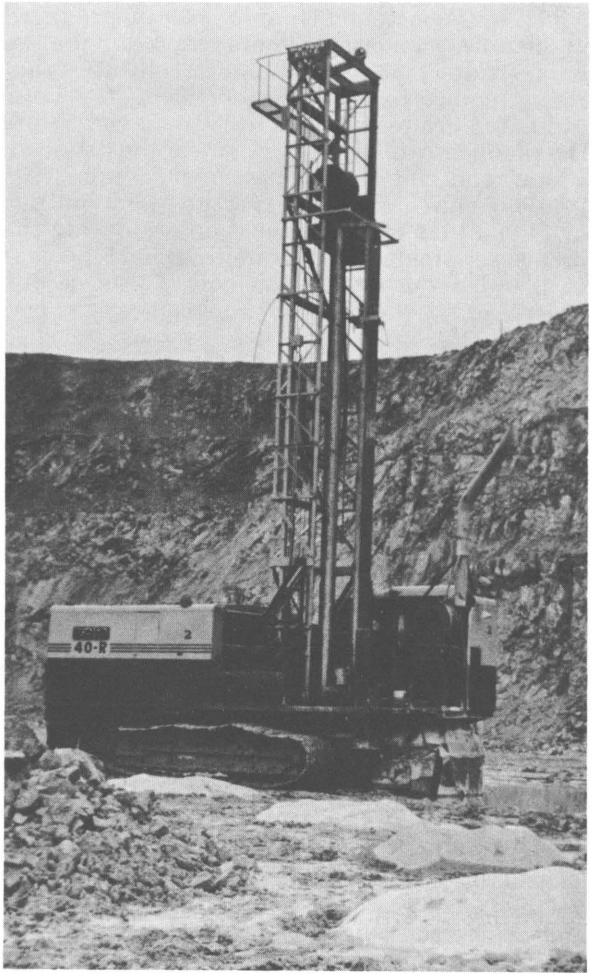

FIGURE 3.—Rotary Drill.

MINE DEVELOPMENT

The term "mine development" is employed to designate the operations involved in preparing a mine for ore extraction. In underground mines these operations include, principally, preparation of openings to and into the ore body—such as tunnels, crosscuts, drifts, raises, and shafts.

In most mines, both exploration and development continue after ore extraction has begun, often nearly to the cessation of mining. Although exploration and development work are similar, the emphasis is placed on ore finding in exploration; whereas in the development, operations are mainly preparation for removing ore from the mine.

The major operations in developing an open-pit mine are stripping, (removal of barren or low-grade overburden) and establishment of mine transportation systems.

Development of an underground mine involves the following: An efficient entry, whether a shaft or adit; auxiliary entries, required for safety and ventilation considerations, if workings extend beyond depths specified by various State laws; and such networks of drifts, crosscuts, and raises (or winzes) at various levels and intervals that may be required by the form of the deposit and the details of the mining method. Transportation systems for removing ore to the treatment plant and pumping infiltrated waters are common to both surface and underground operations.

The cycle of operations in metal-mine development underground consists of drilling, blasting, and removing broken rock. Drilling is generally done with compressed-air hammer drills or, more rarely, with diamond drills. Blasting is done with various types of explosives, detonated by electric caps or by fuses and caps.

Compressed-air or electric-powered shoveling and loading machines are used for removing broken rock and loading in headings and shafts in most important underground operations. Scrapers are used in inclines, and gravity is employed in steeper raises (usually more than 38°) for transfer of broken rock to mine haulageways. Transportation of broken ore and waste rock is commonly by car and track haulage, using storage-battery or compressed-air locomotives for short hauls beyond the range of hand tramming and either storage-battery or trolley locomotives for longer distances. Ore is also transported by shuttle cars, diesel trucks, and conveyor belts.

Some companies consider stope preparation a step in mine development. This operation includes all of the auxiliary workings directly related to preparing a given block of ore for mining and is confined to main entries and haulageways. This is an important distinction in mining massive deposits covering an extensive horizontal area, as in the porphyry-copper mines to be mined by caving methods, where advance preparation of stopes is a definite and extensive phase of operation that can be charged against a specific block of ore; but in narrow veins, thin beds, and relatively small irregular ore bodies there is usually no essential difference between development and preparation.

MINING

There are two principal types of copper ore deposits, those near the surface and those deep below the surface. Veins and other deposits of tabular or irregular form are usually deep and are mined by underground workings; methods employed are aimed at complete extraction of ore and proper support to prevent loss of adjacent or overlying ore bodies and destruction of surface structures. The large disseminated deposits are mined by open-cut power-shovel methods, if they lie close enough to the surface, and the cost of removing the overburden is not excessive. If the overburden ratio is too high, these deposits can be mined by caving systems which are amenable to mass-production operation at minimum cost.

In recent years improvements in underground methods have consisted mainly of modifying existing techniques. Progress has been reflected in the growth of mechanization. Improved drilling equipment, loading equipment, and mechanical ventilating systems have been introduced.

Production from open-pit mines in the United States increased, in comparison to underground mines, from 1939 to 1952; the decrease from then until 1960 is due to opening of large underground mines in Arizona, Michigan, and Montana. Table 11 shows the relative importance of the two major copper-mining methods and points to the progressive increase in the proportions of copper ore and copper extracted by open-pit methods.

Mining Methods

The principal mining methods employed in modern copper mining are:

- Open pit:
  - Conventional.
  - Glory-hole.
- Caving:
  - Block.
  - Top slicing.
  - Sublevel.
- Supported stopes:
  - Naturally.
  - Artificially:
    - Shrinkage.
    - Cut-and-fill.
    - Timbered.

Open pit.—Open-pit methods are applicable to mining ore deposits at or near the surface. If the top of the ore body is below the surface, the overburden and barren capping overlying the ore must be removed in advance of ore recovery. Removal of this material is known as stripping and is part of development.

The choice between open-pit and underground mining of a given ore deposit is based upon factors such as size, shape, and depth of ore body; relative costs of mining by open pit or by an underground method applicable to the deposit; dilution of ore with waste in relation to ultimate recovery of ore; topography and surface improvements; climate; availability of skilled labor (for underground mining); probable continuity of operation; and available capital. An important consideration in choosing the open-pit method is preliminary stripping, which must be done before ore can be produced at planned capacity. The average amount of rock stripped at several mines indicates that waste equal to about a fifth of the total estimated ore reserve has to be removed before the planned rate of production can be attained. Three relatively new mines, opened from 1955 to 1960 and having an average daily output of 14,000 tons of ore, yielded no ore during the first year; yielded ore at the rate of 25 percent of planned output by the end of the second year; and, at the rate of 75 percent by the end of the third year. These mines reached designed capacity during the fourth year, after about 30 percent of the total waste had been removed. It is generally planned to do a major part of preliminary stripping while treatment plants are being built so as not to delay full production.

Among the advantages of open-pit mining are its flexibility, the ability to obtain mass production, the ease with which the rate of production can be increased or decreased once the pit has been developed fully, small shutdown expense, the ability to mine selectively to meet requirements for certain grades of ore, virtually complete extraction of the ore inside the pit limits, the comparatively small labor force required, and elimination of hazards inherent in underground-mining operations.

However, certain disadvantages may outweigh the advantages and affect direct economic considerations. Large open-pit operations involve heavy capital outlay for equipment, and when the amount of overburden to be removed is extensive, a correspondingly high capital expenditure is required for stripping. This capital is nonproductive until ore mining is begun, and during the stripping period interest charges accumulate. The time elapsing before production begins may in itself be a serious disadvantage, especially if exploration is undertaken when ore prices are favorable and the demand for ore is strong. Disposal of the waste from stripping operations sometimes becomes a serious problem, especially when the terrain is flat or dump areas near the mine have a high real estate value. Climatic conditions may limit or necessitate complete closing of operations during certain months, and in areas where torrential rains are prevalent the pits may become flooded, hampering mining operations. Figures 4 and 5 show the Utah mine in Utah and the Chuquicamata mine in Northern Chile.

The mining cycle for an open-pit operation consists of drilling, blasting, loading, and transportation or ore and waste. Drilling is usually divided into primary and secondary. Primary drilling is the sinking of vertical or near-vertical blastholes behind the open face of

TABLE 11.—*Copper ores and copper produced in the United States, distributed by principal mining methods*

Year	Production			Distribution by mining method					
	Ore			Open pit		Block caving		Other	
	Thousand short tons	Copper, thousand short tons	Copper, percent	Ore, percent	Copper, percent	Ore, percent	Copper, percent	Ore, percent	Copper, percent
1939	55,239	714	1.29	59	42	20	15	21	43
1943	98,120	1,069	1.09	69	55	16	14	15	31
1946	62,232	595	.96	66	60	17	15	17	25
1947	87,864	832	.95	73	69	14	12	13	19
1948	84,729	818	.97	76	69	14	11	10	20
1949	76,033	731	.96	78	72	12	9	10	19
1950	94,586	886	.94	81	76	8	7	11	17
1951	95,494	901	.94	84	76	7	7	9	17
1952	99,947	901	.94	85	77	7	6	8	17
1953	101,065	906	.90	83	75	8	7	9	18
1954	93,654	816	.87	83	75	10	15	7	10
1955	112,550	979	.87	83	77	5	10	12	13
1956	131,776	1,082	.82	78	73	9	13	13	14
1957	129,716	1,061	.82	77	72	11	14	9	14
1958	114,824	959	.84	76	71	13	15	11	14
1959	103,716	807	.78	79	74	9	12	12	14
1960	134,994	1,058	.78	80	75	10	10	10	15
1961	142,722	1,142	.80	80	74	9	11	11	15
1962	150,217	1,203	.80	81	75	9	11	10	14
1963	146,450	1,187	.81	81	74	9	12	10	14

an unbroken bank. Secondary drilling is required for breaking boulders too large for shovels to handle or blasting unbroken points of rock that project above the digging grade in the shovel pit.

Benches of open-pit copper mines normally are from 25 to 60 feet high. The height is selected to give maximum digging efficiency but sometimes is limited for ore-waste separation. The height may be reduced where the rock is hard and difficult to break and increased where it is softer.

Blastholes range in diameter from 6 to 12 inches and are drilled from 2 to 15 feet below grade. The holes usually are drilled with a rotary drill, using multicone-type cutting bits. Smaller diameter holes spaced more closely are used in harder ground. Distances between holes range from 12 feet for 6-inch holes in very hard ground to as much as 50 feet for 12-inch holes in easily broken ground. In very hard ground, percussion-type drills with tungsten carbide bits are used. Performance of heavy percussion-type drills ranges from about 60 to 150 feet per shift; that of rotary-type drills is from about 150 to 500 feet per shift. Bit performance varies greatly, depending on the type of rock; for 12-inch bits it ranges from 600 to 3,000 feet per bit. Figures 6 and 7 show plan and section of primary blasthole arrangements.

For secondary drilling, portable compressors and wagon drills have been replaced at most mines by self-contained units with compressor and drill installed as integral parts. The drills are mounted on hydraulically controlled arms that can be adjusted to drill horizontal or vertical holes. When extremely dense boulders are encountered, a "drop ball" is used. Where adaptable, this is an efficient tool for breaking oversize boulders. In mines where only a few boulders occur, mudcap or adobe shots, which require no drilling, are used.

Blasting is of primary importance. Good breakage depends on the proper selection of explosives and the proper arrangement of drill holes. Gelatinized nitroglycerine explosives are used in wet holes and the ammonium nitrate type in dry holes. Usually the charges are placed at the bottom of the hole and exploded by detonating fuse, but often small additional charges, commonly called deck charges, are placed high in the hole. Delays are used where toe holes or multiple rows of holes are fired in the same blast.

Commercial ammonium nitrate, sensitized by addition of diesel fuel or some other suitable petroleum product, has been adopted as a low-cost efficient blasting agent and is used widely. The ready supply of the chemicals and the ease with which they can be formed into an efficient blasting agent in the field enables the blaster to prepare the explosive on the job.

Ore and waste are loaded by full-revolving electric and diesel powered shovels. At most mines shovels with 4-to-6-cubic-yard capacities are used, but larger mines have shown an increasing tendency to use 7-to-13-cubic-yard shovels. Four-to-six-cubic-yard shovels generally load 3,000 to 6,000 tons per operating shift, and the larger shovels load as much as 15,000 tons per operating shift. The larger shovels are particularly useful in waste areas where large boulders can be loaded and dumped

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Figure 4.—Utah Copper Open-Pit Copper Mine, Utah.

(Courtesy, Kennecott Copper Corp.)

Figure 5.—Chuquicamata Mine, Atacama Desert, Northern Chile.
(Courtesy, The Anaconda Company)

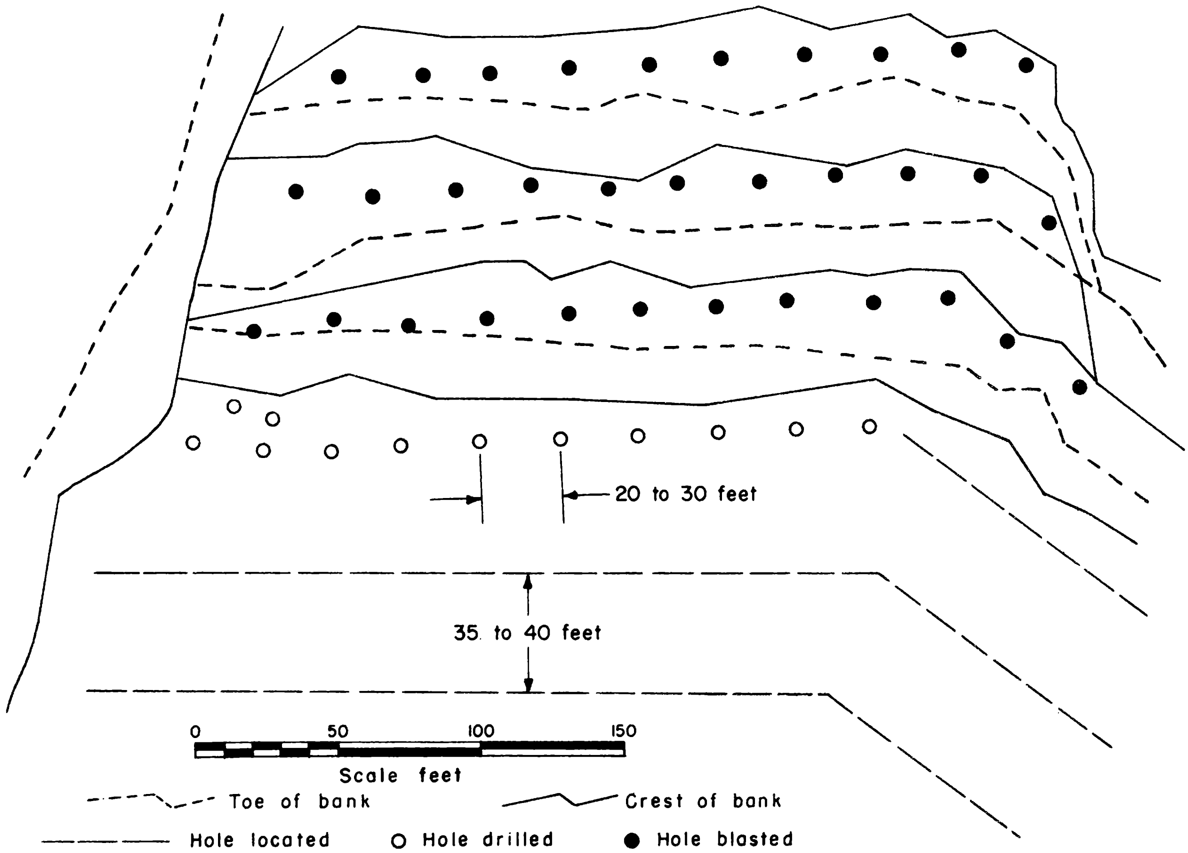


FIGURE 6.—Plan of Located, Drilled, and Blasted Holes.

without secondary blasting. In the ore areas, boulders must be broken to a size that the crushing facilities can handle.

Before World War II, the cost of breaking ground in open-pit mines far exceeded the combined cost of loading and hauling ore. Today the cost of loading and hauling has increased while the relative cost of breaking ground has decreased. It is now about half the total cost of mining. Loading and transporting ore are closely related. The sizes and number of shovels used are determined by daily production, type of material handled, type of haulage, and working conditions such as height of bank, angle of swing, working radius, and clearance. On the other hand, selection of haulage equipment is influenced by the type of loading equipment used.

In general, large mines, or those with long hauls, have rail haulage; medium-sized mines have truck haulage or truck haulage in combination with some other type of haulage. (Rail haulage has been replaced by truck haulage in a number of the larger mines.) Some types of auxiliary haulage are inclined skips (Figure 8), vertical skips, inclined-belt conveyors, standard-gage railroad cars, large capacity tractor-type trucks, and tractor-drawn scrapers.

Bulldozers are used to push materials for distances to 200 feet; scrapers are used from 200 to 1,500 feet; trucks are used for distances ranging from 600 feet to 1 mile; and rail haulage is used for distances of more than 1 mile. Performance with bulldozers ranges from 500 to 1,500 tons per shift, that of scrapers from about 400 to 1,500 tons per shift, that of large trucks from 500 to 2,000 tons per shift, and that of rail haulage from about 1,000 to 3,000 tons per locomotive shift for distances of about 3 miles.

Glory Hole.—In some instances when open-pit operations extend to depths that cause the stripping ratio to become uneconomic, the glory-hole mining method has been used. This method has also been used for mining relatively small ore bodies or the upper parts of bodies remaining at or near the surface. In glory-hole mining, the ore is broken around one or more raises extending upward from an underground haulageway driven below the ore or beneath

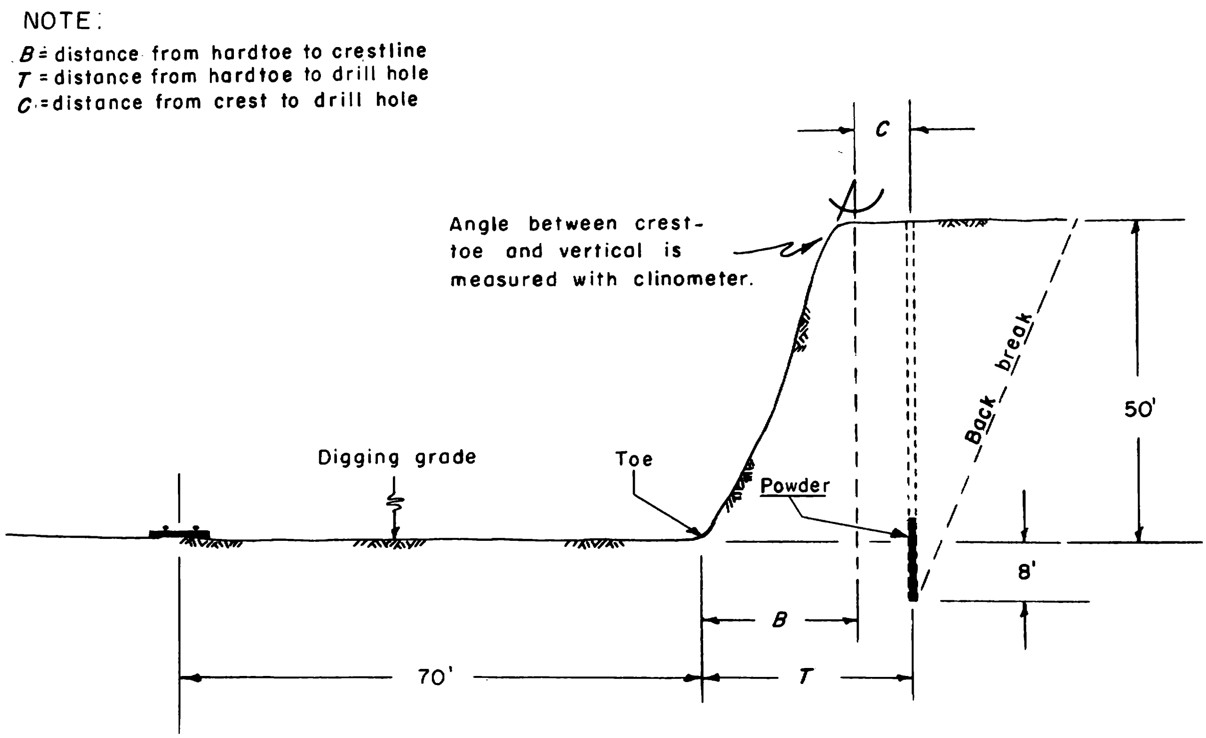


FIGURE 7.—Vertical Section of Primary Drill Hole.

the ultimate bottom of the glory hole or pit. It is thus a combination of surface and underground mining with the ore breaking done on surface but removed through underground workings. Under favorable conditions glory-hole mining is as economical as open-pit mining for the same scale of operations.

Caving Methods

Caving methods are of three distinct types, block, top slicing, and sublevel:

Block Caving.—This method is amenable to mass production and is efficient and low cost—permitting scientific planning, centralized management, labor specialization, and modern mechanization. The successful use of this method requires detailed engineering study of the nature of an ore body by systematic and detailed exploration and sampling. Adequate development, preparatory work, transportation, ore drawing, and allied mining operations are equally important.

Block caving consists of dividing suitable ore bodies into blocks of predetermined size and undercutting each to induce rock stresses to cave and crush the ore to sizes that can be readily handled. Block caving is applicable to homogeneous and rather weak ore bodies of regular outline with enough horizontal area to cave freely; strong walls and capping or overburden that caves freely are required also. The method utilizes instability of the ore for caving, shear and compressive stresses for crushing, and gravity for moving the ore to drawpoints. The method is nonselective, and lean sections of ore and waste will be broken up and drawn with the ore (fig. 9).

Main haulageways are driven on a level sufficiently below the bottom of the ore so that branching transfer raises may be installed to connect with a grizzly or slusher sublevel and so that closely spaced branching draw raises can be driven to the bottom of the planned undercut block (figs. 10-11). Detailed information about the two large block-caving mines in the United States is presented in Bureau of Mines publications.[3] Figure 12 shows the block-caving system at the Braden Copper Company El Teniente mine in Chile.

Top Slicing.—This is an important modification of caving, whereby the ore is extracted by excavating a series of horizontal or inclined timbered slices alongside each other, beginning at the top of the ore body and working progressively downward. Each slice, when mined out, is caved by blasting out the supporting timbers and allowing them to crush, bringing the capping or overburden down upon the

[3] V. B. Dale. Mining, Milling, and Smelting Methods, San Manuel Copper Corp., Pinal County, Ariz. BuMines Inf. Circ. 8104, 1962, 145 pp.
C.C. Popoff. Block Caving at Kelly Mine, The Anaconda Co., Butte, Mont. BuMines Inf. Circ. 7758, 1956, 102 pp.

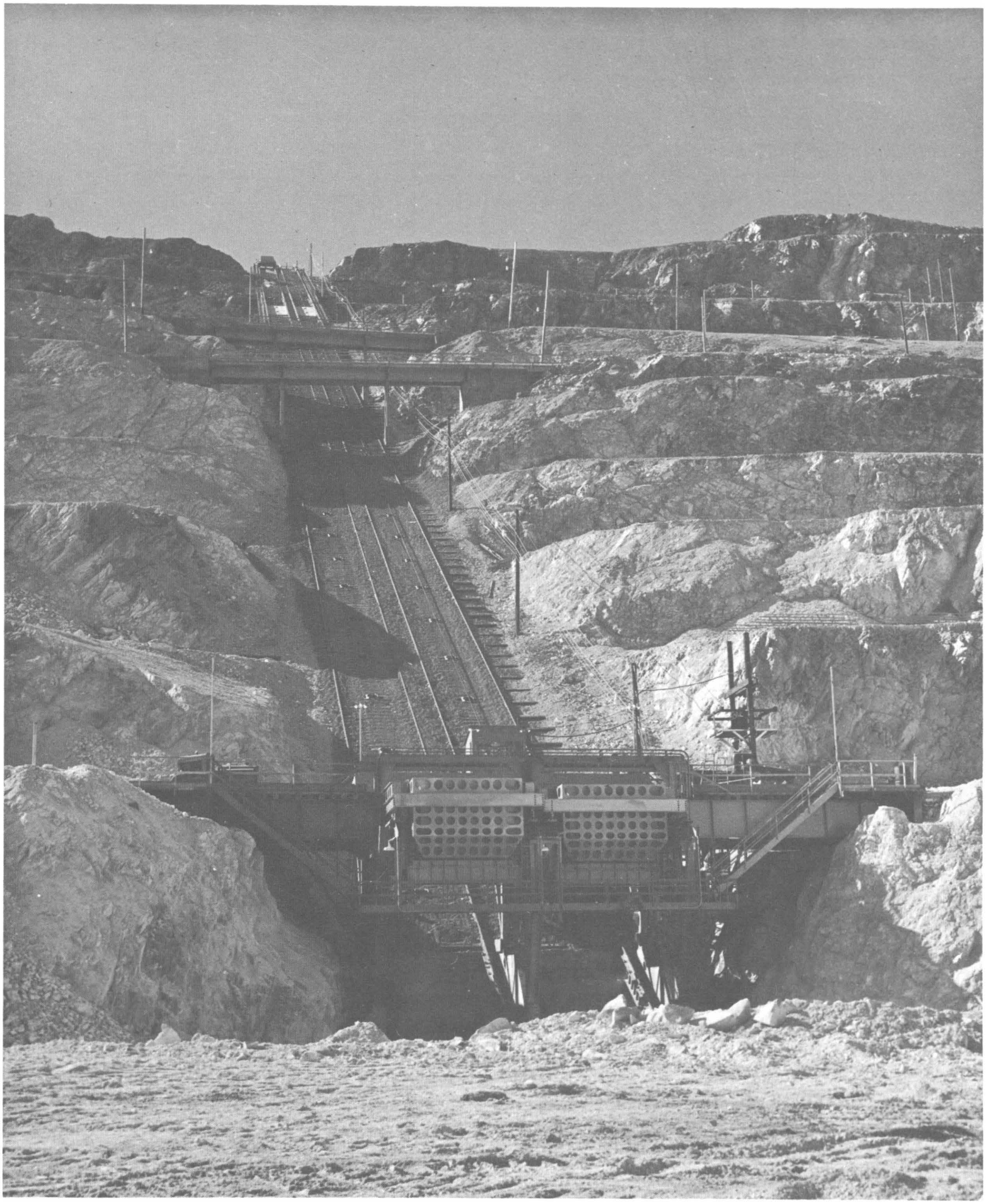


FIGURE 8.—Inclined Skip Hoist, Chino Mine, N. Mex.

(Courtesy, Kennecott Copper Corp.)

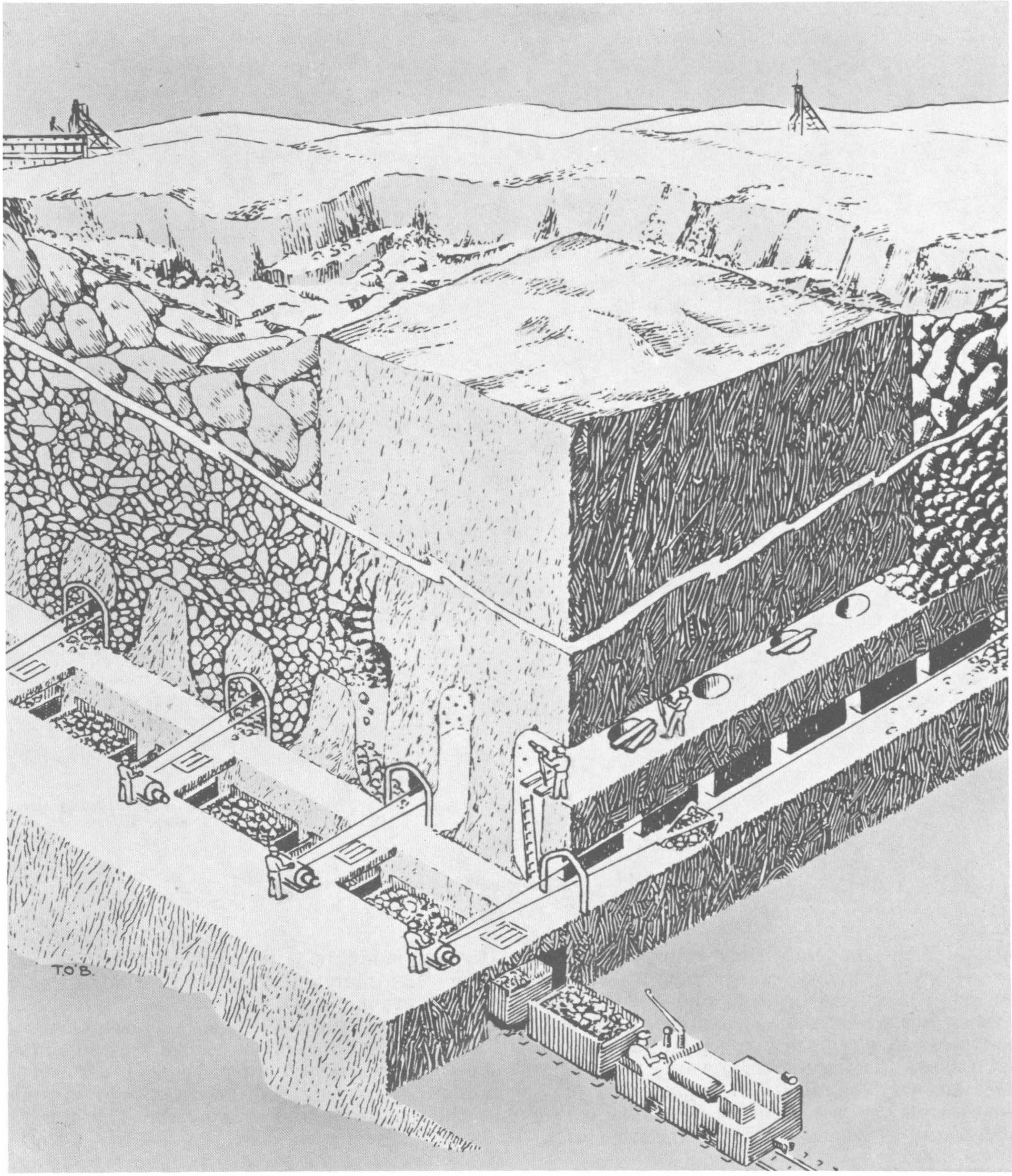


FIGURE 9.—Block-Caving Method.

(Courtesy, The Anaconda Company)

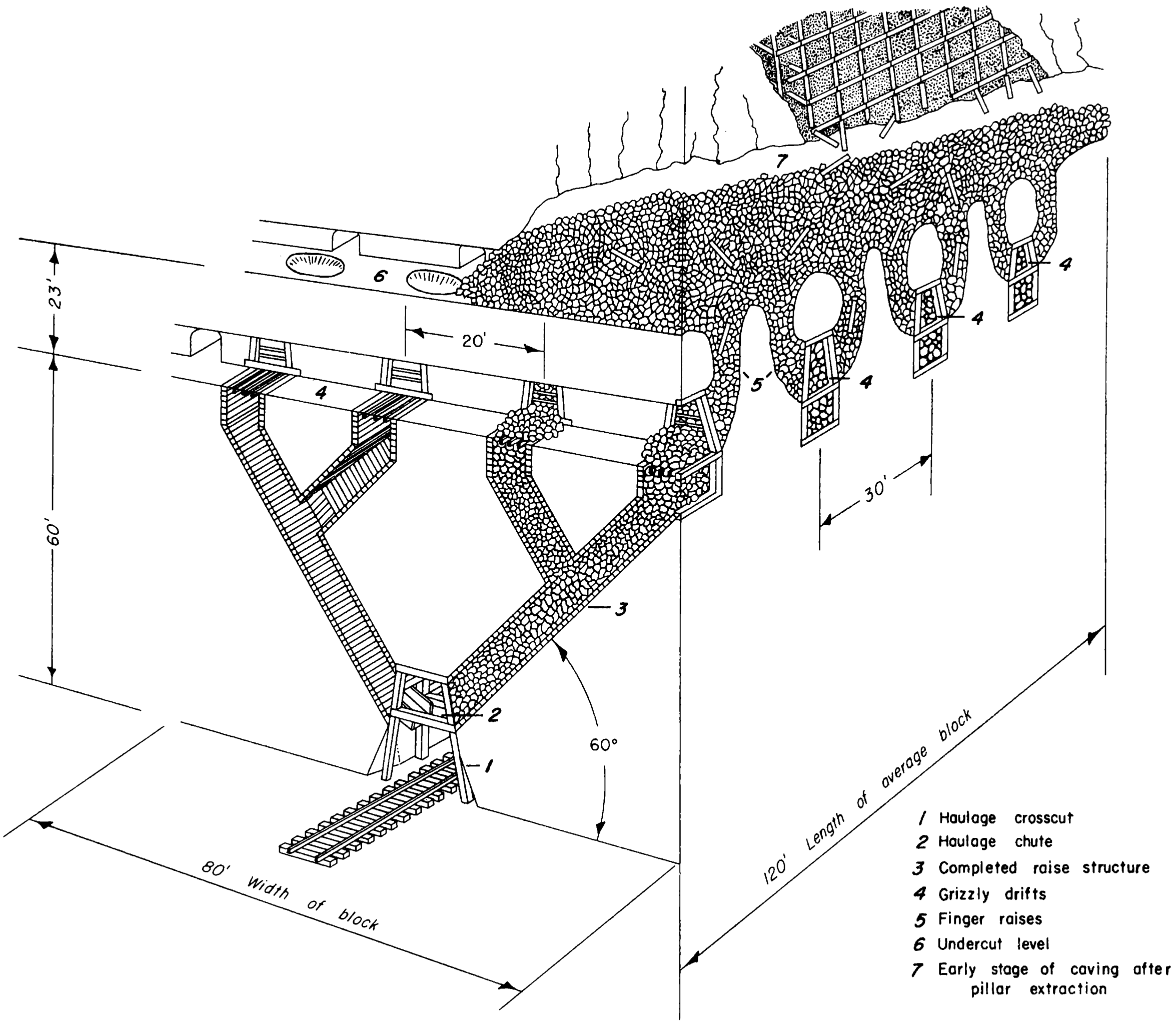


FIGURE 10.—Block Development, All-Gravity System.

bottom of the slice which has previously been covered with a floor or timber mat to separate the caved capping from the solid ore beneath and to prevent admixture of waste with the ore. As successive slices are mined and caved, this mat follows the mining downward, filling the space formerly occupied by the ore. The mat also controls the movement of the caved overburden and prevents dilution of the ore with barren capping.

Block-caving methods result in some loss of ore and a moderate dilution of ore with waste, but top slicing, although more costly, is capable of virtually complete ore recovery without dilution, hence is favored for ore bodies of somewhat higher copper content than those to which the block-caving methods are applicable. Top slicing is also more applicable to smaller and more irregular ore bodies than is block caving. It requires highly skilled miners, more manual labor, and more labor expenditures per unit of production.

Sublevel Caving.—This method resembles top slicing in that the ore is mined in horizontal slices in descending order, so that the overburden, or capping, will break up and subside as the ore beneath is removed. The fundamental difference is that the height of slices in sublevel caving is greater than for top slicing, allowing larger output, lower breaking costs, and use of less timber. This method, adapted principally for certain iron mines in the Lake Superior region, is rarely used in copper mining.

Supported Stopes

The term "stoping" is employed in its broader sense to mean excavating ore by a series of

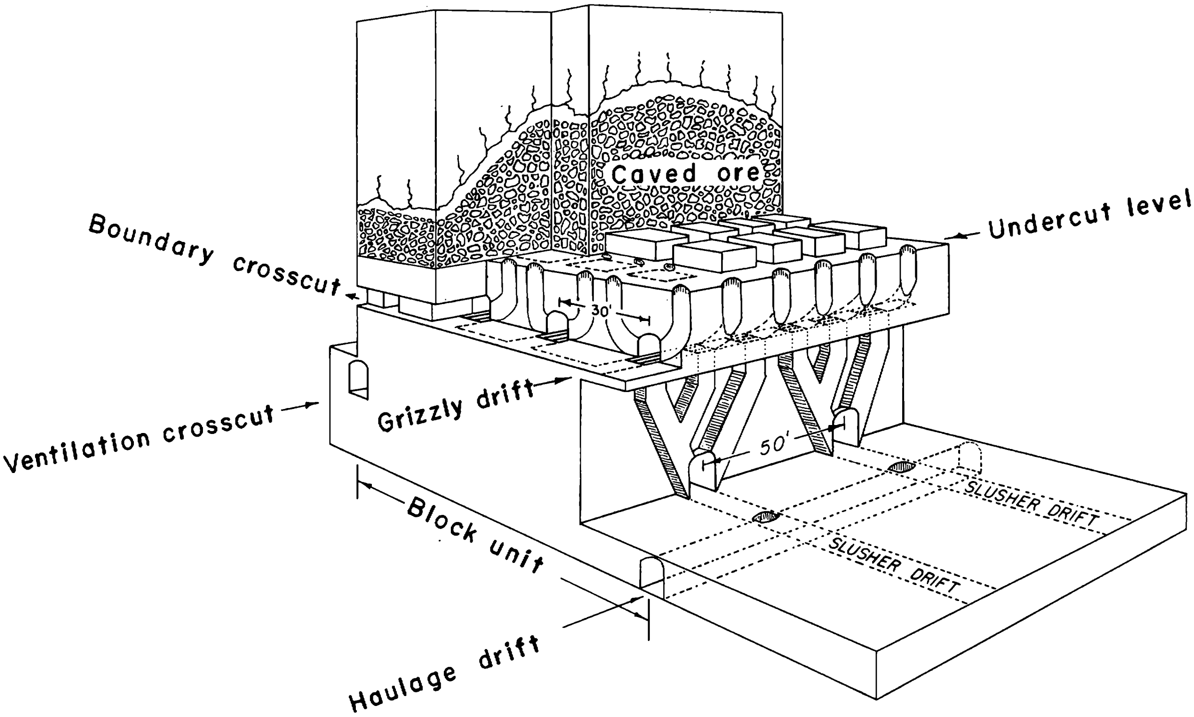


FIGURE 11.—Slusher-Gravity Block Three-Bench Raise Design.

horizontal, vertical, or inclined workings in veins or large irregular bodies of ore or by rooms in flat deposits. It covers breaking ore and removing it from underground workings (except those driven for exploration and development) and timbering, rock bolting, and filling stopes for support.

Basically, the stoping method or methods that can be applied to a given ore body depend on requirements for supporting the stope; the maximum area or span of back (roof) and walls that will be self-supporting during removal of the ore; and the nature, size, and interval between supports required to maintain the back and walls of the overlying and surrounding country rocks and overburden to prevent their movement and subsidence. Variations of the principal methods of stoping may be based on the direction or angle of workings, sequence of operations, or methods of handling broken ore.

Naturally Supported Stopes.—Naturally supported stopes are those in which no regular artificial method of support is employed, although occasional props, cribs, stulls, or rock bolts may be used to hold local patches of insecure ground. Walls and roof are self-supporting. The simplest form is the open stope, in which the entire ore body is removed from wall to wall without leaving any pillars. It is applicable to relatively small ore bodies, as there is a limit to the length of unsupported span that will stand without support, even in the strongest rocks.

In open stopes with pillar support, the length of unsupported span is controlled by leaving pillars of ore whose position and size are determined by localized ground conditions. Frequently it is possible to leave low-grade ore within the ore body as pillars, making possible more complete recovery of the higher grade ore.

Artificially Supported Stopes.—Artificially supported stopes are those in which installation of systematic temporary or permanent support of ground around mined-out areas is a part of the mining cycle.

Shrinkage Stopes.—In shrinkage stopes the ore is mined in successive flat or inclined slices, working upward from a level or the bottom of the block of ore. After each slice or cut, only enough broken ore is drawn off from below to provide working space between the top of the pile of broken ore and the back of the stope. Usually about 35 to 40 percent of the ore will be drawn during active mining in the stope. The remaining ore serves as a floor upon which to work in drilling the back for succeeding cuts and also provides temporary support to the stope walls. For this reason, shrinkage stopes are considered a form of artificially supported stope.

When active mining has been completed to the level above or to the floor pillar, the rest of

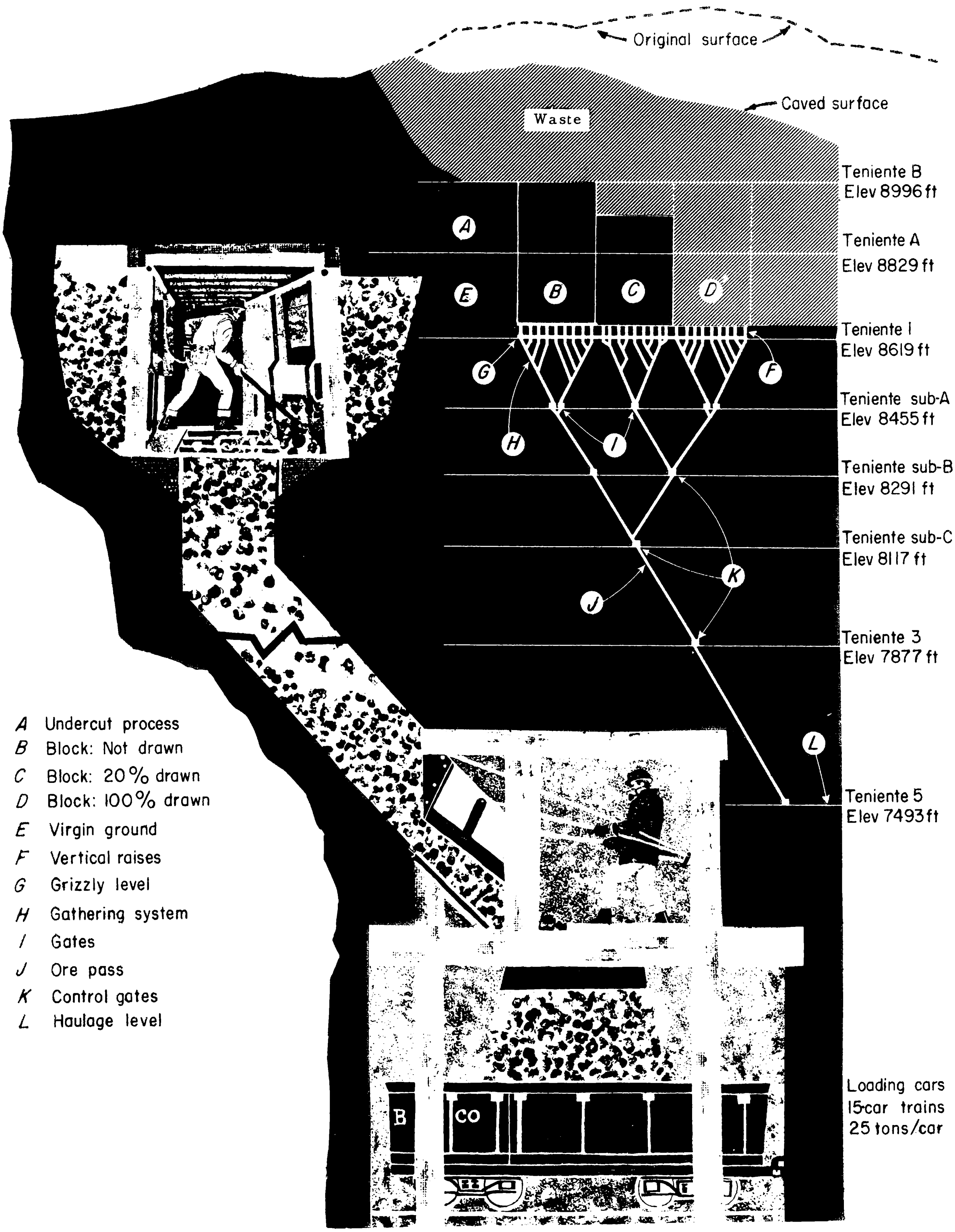


FIGURE 12.—Diagramatic Sketch of Block-Caving System of the El Teniente Mine, Sewell, Chile.

(Courtesy, Kennecott Copper Corp.)

the broken ore is drawn from below, leaving the stope empty. The stope may be filled with waste later to prevent general movement and subsidence or to permit mining of pillars left between stopes during the first mining.

Shrinkage stoping is applicable to bodies of ore enclosed between firm walls that will not slab or slough off to any extent when left standing for a considerable time. The method is applied most frequently to relatively thin, tabular deposits dipping at angles greater than 50° in which few waste inclusions occur and which have fairly regular walls.

One of the disadvantages of shrinkage stoping is the delayed recovery of broken ore that cannot be drawn until the entire block has been mined. Another is that there is more oxidation of sulfide ores than in systems having immediate withdrawal of ore. Oxidation may adversely affect metallurgical recovery or, in extreme cases, result in a mine fire.

Cut-and-Fill Stopes.—In cut-and-fill stoping the ore is excavated by successive flat or inclined cuts or slices, working upward from the level as in shrinkage stoping; but, after each cut, all the broken ore is removed and waste rock, sand, mill tailings, or other filling material is run within a few feet of the back, providing permanent support to the walls (fig. 13) and a working floor for the next cut. The term "cut-and-fill" implies a definite characteristic sequence of operations: (1) Breaking a slice of ore from the stope back, (2) removing the broken ore, and (3) introducing filling. The cycle is repetitive.

Cut-and-fill stoping is applicable to mining firm ore enclosed between two walls, one or both may be weak. In general, it is suitable for mining deposits too irregular for shrinkage stoping and deposits in which shrinkage could be employed if it were not for weak walls. Improved ore-handling and waste-spreading methods have extended the economic applicability of cut-and-fill stoping by comparison to shrinkage stoping, and the method has the

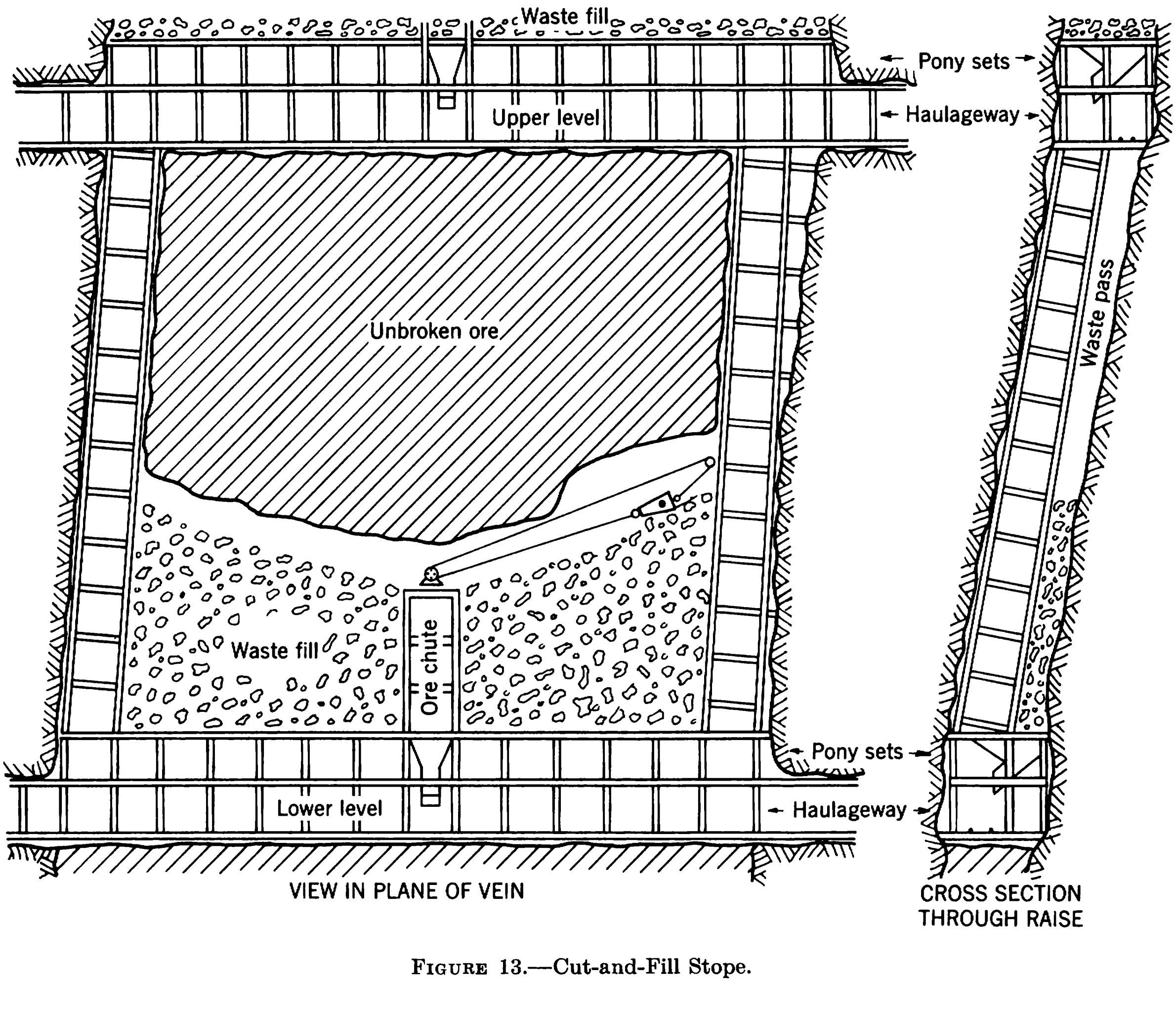


FIGURE 13.—Cut-and-Fill Stope.

advantage of greater selectivity, better working conditions, and greater safety.

Rock bolting provides a type of support that allows cut-and-fill stoping of heavy ore zones with weak and blocky hanging walls that otherwise would require square-set timbering. Rock bolting extends the time before ground failure, requires less time than timbering, permits exposure of the hanging wall for greater lengths and heights, and eliminates handling timber on the surface, in the shaft, and underground. All these factors contribute to increased production from fewer working places, thus reducing mining costs.

Timbered stopes.—Timbered stopes are those in which timber is used systematically for support. The most elaborate system of timbering is the square-set method (fig. 14), in which the walls and back of the excavation are supported by regular framed timbers forming a skeleton enclosing a series of contiguous, hollow, rectangular prisims in the space previously occupied by the ore and providing continuous lines of support in three directions at right angles to each other.

The ore is removed in small, rectangular blocks, usually just large enough to provide room for standing a set of timber. Ordinarily the stopes are mined in floors or horizontal panels one above the other, and the sets of each floor are framed into the sets of the preceding floor. Timbered stoping is usually accompanied by filling, and often in heavy ground the sets are filled with waste after they are installed, leaving only a small volume of the stope unfilled at any time. It has become accepted quite generally that, unless the ground is heavy enough to require filling for permanent support, the expense of timbering is not warranted, and other methods should be employed.

Timbered stoping is adaptable to mining regular or irregular ore bodies, where the ore and/or walls are too weak to stand—even over short spans—for more than a brief time, and where caving and subsidence of overlying rocks must be prevented. It is the most selective underground mining method, hence is particularly suitable for mining rich, irregular ore bodies.

CONCENTRATING

The metallurgical extraction processes used in producing copper metal are based on physical and chemical characteristics of the minerals in ore bodies, such as grain size, copper content, nature and content of byproducts to be recovered, and the type of impurities to be eliminated.

Low-grade, oxidized-copper ores usually are treated by leaching and precipitation (cementation) or electrolytic deposition of copper; some sulfide and oxide ores are sufficiently high-grade for direct smelting, but the bulk of all native or sulfide copper ores are first subjected to a physical separation of minerals by an upgrading process known as concentration.

Sulfide concentrates and high-grade ores are treated in a smelter in a series of pyrometallurgical steps to produce an impure (blister) copper, which is subsequently refined by pyrometallurgical or electrolytic methods. Native copper concentrates are smelted, and the copper is fire refined. In both smelting processes the gangue minerals and other valueless components are removed as slag. Byproducts are recovered at one or more of the various steps of concentration, smelting, or refining.

Concentration is the process of effecting physical separations of two or more minerals. Mineral dressing, ore dressing, beneficiation, and particularly milling are also part of the concentration process, having slightly different connotations. The plants in which mineral-dressing operations are conducted are known as mills or concentrators.

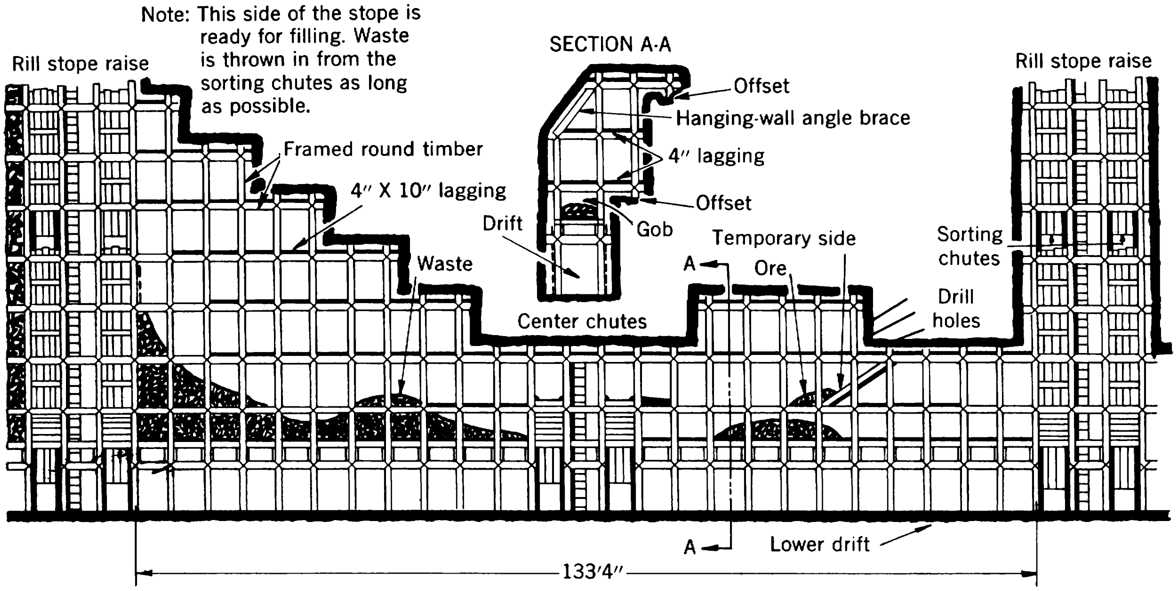
After liberation of the valuable minerals from the gangue, the separation of two or more minerals from each other is possible if they present critical differences in certain physical or chemical properties. Most important in concentration and separation of copper minerals from gangue are the chemical form, size, density, and surface characteristics of the several minerals in the ore.

The products of concentration are concentrates, containing the bulk of the valuable mineral, and tailings, containing gangue minerals. An intermediate product known as middling may be re-treated for further recovery of valuable minerals before final rejection as tailing.

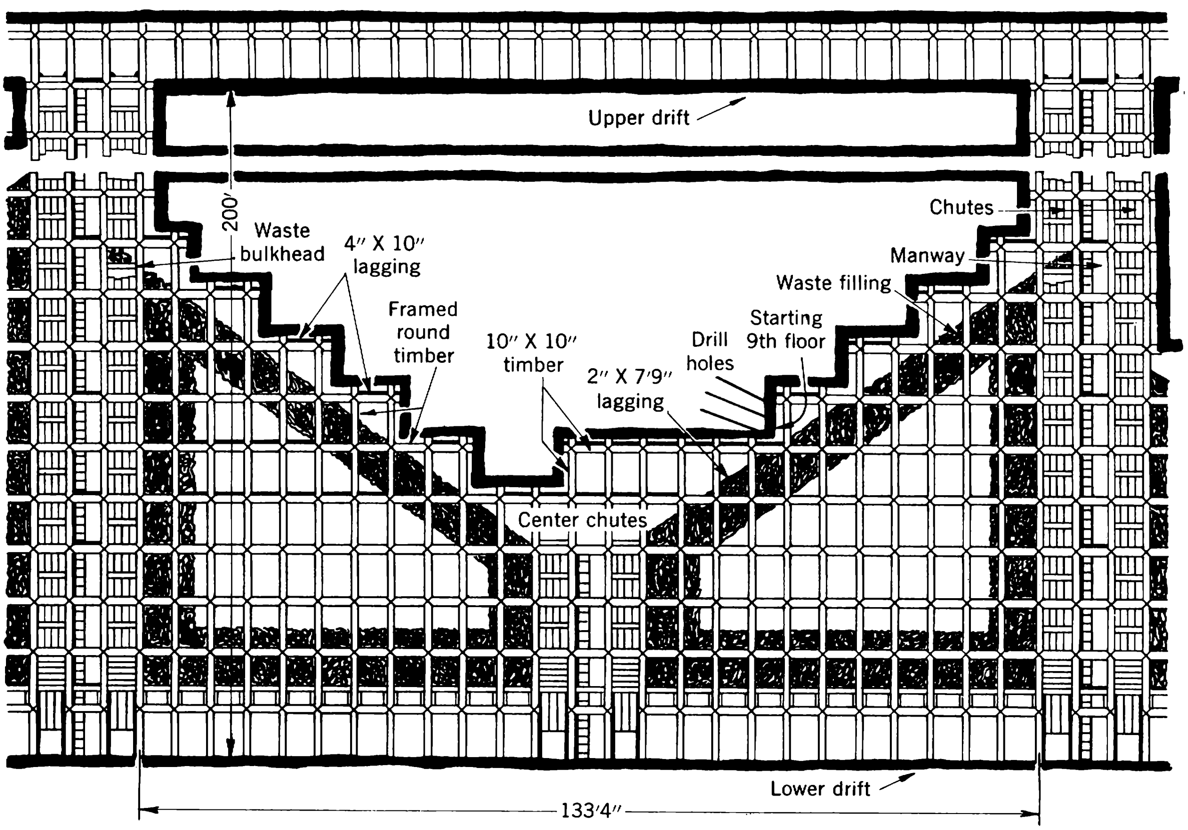
Concentration is less costly than smelting Furthermore, shipping costs to a distant smelter are reduced by producing a concentrate near the source of ore to avoid freight charges on waste associated with the ore.

Crushing and Grinding.—The first step in concentration is to crush and grind the ore to such a degree as to liberate the valuable minerals from the gangue minerals, thus the grain size of the ore minerals is an important controlling factor. Hardness, tenacity, brittleness, and structure influence the cost of grinding and the relative degree of sliming (production of extreme fines) of each mineral in an ore. Crushing and grinding are done only to the size necessary to liberate copper minerals from the gangue since sliming results in losses.

Most crushing plants for copper ores obtain size reduction in three steps. Primary crushing of ore as it comes from the open-pit or underground mining operation produces 6- to 9-inch



EARLY STAGE OF STOPING



STOPE COMPLETELY DEVELOPED

FIGURE 14.—Square-Set Stope.

pieces. This initial reduction is accomplished usually by one large gyratory crusher capable, at some operations, of crushing up to 2,500 tons per hour and the larger units can receive 60-inch boulders weighing 10 tons or more. The 6- to 9-inch product passes to several secondary gyratory or cone crushers where it is reduced to a maximum size of 1½ to 2 inches. Following screening for removal of material already reduced to wet-milling size, the oversize is passed through a tertiary stage of crushing in higher speed cone-type crushers. The product is screened, and the oversize is recirculated until it is reduced to about ⅝ inch.

Fine grinding is accomplished in rod and/or ball mills. Although it is possible to grind 2-inch-diameter feed to about 48-mesh (0.012 inch in diameter) in a single stage, grinding is usually cheaper for large tonnage if done in two or three stages when a high degree of comminution is required. Rodmills are used for coarse grinding, ballmills, for fine grinding. The newer concentrators built in the United States and South America use one open circuit rodmill, followed by two ballmills in closed circuit with rake classifiers, hydrocyclones or hydroscillators, and sand screws, to obtain a properly sized flotation feed.

Screens and classifiers play an important part in mineral dressing. Screens and grizzlies are used to bypass material already fine enough or to return oversize for recrushing. They are most efficient in size ranges greater than 10-mesh (0.065 inch in diameter); below this size various types of classifiers are preferred in most metallic mineral concentrators.

Classifiers are capable of separating finer sizes of materials into groups according to their settling rate in a fluid, usually water, or air. Of two particles of equal density but of unequal size, the larger will settle faster; of two particles of equal size but differing density, the higher density particle will settle faster. Chief applications of classification in modern ore-milling practice are in closed circuit with grinding mills to return oversize for regrinding. Classification also is used to prepare table feed in gravity concentration, but tabling plays a comparatively minor part in modern milling practices.

The more important accessories to ore concentrators are conveyors, bins, pumps, feeders, and filters.

Gravity Concentration.—Differences in the density of minerals form the basis of gravity concentration processes. The principal types of gravity concentration are: (1) Jigging, which depends on differences in the settling rate of minerals as they are carried horizontally by waterflow over a screen bed and subjected to a vertical pulsating action; (2) heavy-media separation methods, which depend on the use of a fluid sufficiently high in specific gravity or a suspension of a heavy mineral such as magnetite, galena, or ferrosilicon in water, to cause the gangue minerals to float and to allow the ore minerals to settle, or vice versa; (3) tabling, which depends on the differences in speed of travel of minerals of different sizes and density, as they are caused to flow in a stream of water or air transversely across an inclined, riffled surface that is subjected to longitudinal reciprocating motion.

Jigging, heavy-media separation, and tabling are used very little in copper-ore concentration, because most ores require finer grinding for mineral liberation than the minimum economic size limit of gravity methods. Most copper sulfide minerals are recovered by flotation. A pilot table, however, is often used as an indicator or guide to help control losses in a flotation circuit.

Flotation

Flotation is a process of wet concentration in which air bubbles are used to float one kind of particle from a mixture of two or more kinds of finely divided materials suspended in water. Certain minerals may be preferentially wetted by organic reagents in the presence of water so that they will adhere to air bubbles and float to the surface of the pulp. Other minerals, usually the gangue, are unaffected and remain suspended in the water.

The reagents that selectively coat the valuable mineral particles are known as collectors. In sulfide flotation these are usually xanthates or other chain hydrocarbons. Supplementing the action of the collectors is a group of reagents known as frothers whose function (in conjunction with agitation and aeration) is to create a myriad of small bubbles in the pulp. The bubbles attach themselves to the properly conditioned valuable mineral and rise to the surface to form a froth that may overflow or be removed mechanically. Frothers in sulfide flotation are usually alcohols, pine oil, or ring-carbon compounds, such as cresylic acid.

When two or more minerals of the easier floating type are floated together to form one concentrate, the process is known as bulk flotation. Differential flotation is the term used to describe an operation in which one or more minerals are depressed during flotation of one or more other minerals, or where several different minerals are floated successively into separate concentrates. The usual differential separations in copper milling are copper sulfides from pyrite, galena from sphalerite, and sphalerite from pyrite. Any one of the sulfides may be rendered more floatable than the others by the current surface modifications, and such modifications are obtained by using a class of reagents known as conditioning agents. Under this class are grouped the depressing, activating, and dispersing agents; the pH regulators; and the cleaning agents.

In general, sulfide-mineral particles coarser than 35-mesh (0.016 inch in diameter) cannot be effectively recovered by flotation; consequently, an ore that is to be floated must first be ground fine enough so that all, or substantially all, the desired mineral is smaller than this limiting size. This is aside from considerations of liberation, which may require even finer grinding.

To obtain a good recovery and a high-grade concentrate, several stages of flotation concentration are required. This is conveniently accomplished by employing successive agitating chambers or cells, so that the tailings from the first cell may pass progressively from one cell to the next as the original ore becomes impoverished in metal content. The concentrate from the first group of cells treating low-grade ores is seldom rich enough for a final product and is known as a rougher concentrate, which is re-treated or cleaned in one or more stages to produce a cleaner concentrate. In some instances, the rougher tailing may require regrinding for further liberation of minerals, and in other cases, it may be floated directly to produce a low-grade scavenger concentrate, which is often returned to the first rougher cell. The cleaner concentrate is dewatered in a thickener and a vacuum filter, and the dried concentrate is sent to the smelter. The plant tailing is conveyed by gravity flow or pumped to a settling pond. Where water recovery is required, the tailings are thickened, and the reclaimed water is returned to a large storage tank.

Figure 15 is the flowsheet of the Mission concentrator of the American Smelting and Refining Co., near Tucson, Ariz. This modern installation is one of the more recent worldwide. Figures 16 and 17 show the grinding and flotation sections of this mill.

With mixed ores, in which both sulfide and oxidized minerals occur, treatment depends on relative proportions of the two kinds of minerals. If sulfide minerals predominate, flotation is used, employing reagents that favor flotation of oxidized minerals. With such treatment, it is usually possible to recover more than 90 percent of the sulfide copper and 50 to 70 percent of the copper in oxides. If oxidized minerals predominate, the copper is usually recovered by leaching with sulfuric acid; ferric sulfate is an effective leaching agent when the sulfide portion of the mixed ore has significant value.

Dual Process.—When low-grade ores contain almost equal amounts of sulfide and oxidized minerals, combinations of leaching and flotation may be employed. In the Inspiration Consolidated Copper Co. Dual Process, the ore is first leached with sulfuric acid in the leaching plant to recover the oxide copper content, and the washed and drained residue is treated in the concentrator where, after fine grinding, the copper sulfide values are recovered by flotation.

LPF Process.—Along with conversion from underground to open-pit mining at the Ray Mines Division of Kennecott Copper Corp., the mill at Hayden, Ariz., was rebuilt to incorporate the leach-precipitation-flotation (LPF) process for recovering oxidized copper in the open-pit ore. This process converts copper oxide to metallic copper, which responds to recovery by flotation. The process starts by making a sand-slime separation of the rodmill discharge. The sands are leached in drums with dilute sulfuric acid and washed counter-currently. The washed sands are ground in ballmills for conventional, alkaline, copper sulfide flotation. The slimes are leached in a tank that received pregnant solution from sand leaching. Sponge iron is added to the slime pulp to precipitate copper, which is then recovered by flotation in an acid circuit. The LPF concentrate and the sulfide concentrate are joined and pumped to the smelter.

Segregation Process

There are oxidized and mixed oxide-sulfide ores that are not amenable to leaching with sulfuric acid or conventional flotation concentration. The success of acid-leaching oxidized ores depends largely on the amount of acid consuming constituents in the gangue. If the gangue contains significant quantities of calcite or other acid consuming minerals, acid leaching is infeasible. Where chrysocolla is the predominant oxide copper mineral, flotation is impractical because there is no commercial flotation process for recovering this mineral. However, research at the Federal Bureau of Mines Tucson Metallurgy Research laboratory demonstrated that the segregation process has merit for treating oxidized and mixed oxide-sulfide copper ores, regardless of the gangue constituents present.

The segregation process involves heating the oxidized or mixed oxide-sulfide copper ore with a halide salt, and a carbonaceous material, such as coke or coal, at approximately 1,400° to 1,500° F. Basically, the process proceeds in four stages: (1) Decomposition of sodium chloride and formation of hydrochloric acid; (2) the hydrochloric acid attacks the copper minerals to form volatile cuprous chloride; (3) the cuprous chloride is reduced to metallic copper on the carbon particles; and (4) the

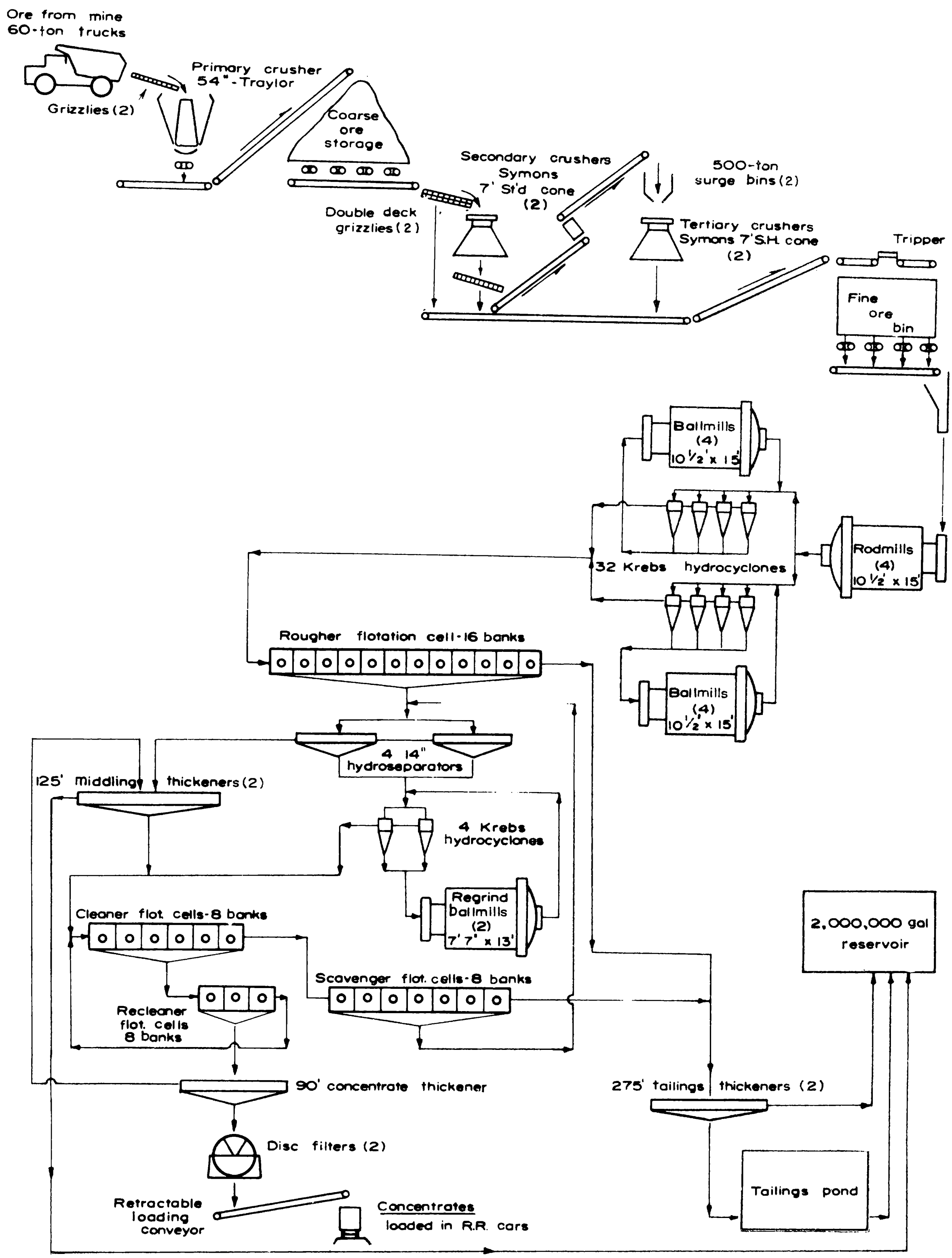


FIGURE 15.—Mission Mill Flowsheet.

(Courtesy, American Smelting and Refining Co.)

segregated copper is recovered by the conventional flotation process. Tests and results of pilot plant and commercial experience are described in a Bureau of Mines report and a journal article.[4]

HYDROMETALLURGY

Leaching is the term applied to the process of recovering the valuable metal or metals from an ore by dissolution with an aqueous solvent, leaving the gangue or waste material virtually unaffected. Subsequent recovery of the metal or metals from solution is effected through either chemical or electrolytic precipitation. For copper these processes are limited largely to copper-bearing materials that, because of grade, composition, or other considerations, are not amenable to concentration and pyrometallurgical extraction. Generally, hydrometallurgical methods are used to treat low-grade ores containing native copper, oxide, or mixed oxide-sulfide minerals because costs of other types of treatment are too high or the recoveries of copper are too low. Combinations of hydrometallurgical methods for recovery of oxide minerals coupled with flotation or sulfate roasting for recovery of the sulfide portion have been successful in treating some mixed ores.

Leaching

There are four principal methods used in leaching: (1) Leaching in place, (2) heap leaching, (3) leaching by percolation, and (4) leaching by agitation. The choice of method depends on disposition and grade of ore to be treated, as well as the character of the associated gangue.

Leaching in Place.—Ore bodies that contain sulfide minerals and that are shattered and broken so air and water have access to the ore are suitable for leaching in place. The copper sulfide minerals exposed are subjected to natural oxidation by alternate and intermittent contact with air and water to form water-soluble copper sulfate. The leach solution is accumulated in drainage tunnels driven under the ore body or in the lower workings of the mine. Leaching in place has been successfully applied in mines at Butte, Mont.; the Miami and Ray mines in Arizona; the Eureka mine, Ducktown, Tenn.; the Cronebane mine, County Wicklow, Ireland; and the Aznalcollar and Rio Tinto mines in Spain.

Heap Leaching.—Heap leaching is similar to leaching in place in that it depends on the natural oxidation of the sulfide minerals by continual contact with air and water. Some sulfide ores and mixed ores containing copper values too low grade to be processed profitably by any other method, but needing to be removed from the mine, can be treated by heap leaching. The process consists essentially of piling or dumping leaching ore, without crushing or other preparation, on an area having proper drainage to natural or prepared basins. When possible it may be advantageous to arrange the piles so that the coarser ore will be placed at the bottom and the finer ore on top, aiding ventilation and circulation of the solution. Leach solutions are directed over the piles and allowed to drain through the heap. The sulfide minerals that have been oxidized to sulfates are dissolved in the leaching solution, which collects in prepared basins. Copper is recovered from the pregnant leach solution by cementation on scrap iron. After removal of the copper, the spent solution is returned to the piles for another cycle of leaching.

This method is simple but the reaction is slow, and years may be required to obtain satisfactory extraction. Only large tonnages can be profitably treated by this method. The process has been the principal method of recovering copper at Rio Tinto, Spain, for hundreds of years. At one time there was about 20 million tons of ore, occupying 350 acres, undergoing treatment. In Arizona the method is used at the Lavender pit, Castle Dome, Morenci, Silver Bell, and Esperanza mines.

Percolation Leaching.—Percolation leaching is the method most widely used for commercial hydrometallurgical recovery of copper from large deposits of low-grade oxide ores. Ore charged to a number of leaching vats is successively treated with leaching solution, either by upward or downward percolation, or both. Usually the leach solution enters a vat at the bottom, percolates upward until the ore is flooded, is held there for a soaking period, and is then drained and advanced to the next vat where the process is repeated. The flow of the leach solution in this sequence completes a single cycle. The number of cycles necessary for optimum extraction depends on the solubility of the copper minerals in the ore. If six cycles are necessary for recovery of the copper from the ore, six charges or vats of ore would be undergoing simultaneous leaching.

Particle size and contact time, the two principal factors affecting leaching efficiency, are interdependent. Most copper ores to be treated by leaching are crushed dry because of the presence of soluble copper minerals, but dry crushing below ¼ inch becomes uneconomical. Higher grade ore may require crushing to

[4] Rampacek, Carl, W. A. McKinney, and P. T. Waddleton. Treating Oxidized and Mixed Oxide-Sulfide Copper Ores by the Segregation Process. BuMines Rept. Inv. 5501, 1959, 28 pp.
Freeman, G. A., Carl Rampacek, and L. G. Evans. Copper segregation at the Lake Shore Mine. J. Metals, May 1961, pp. 370–372.

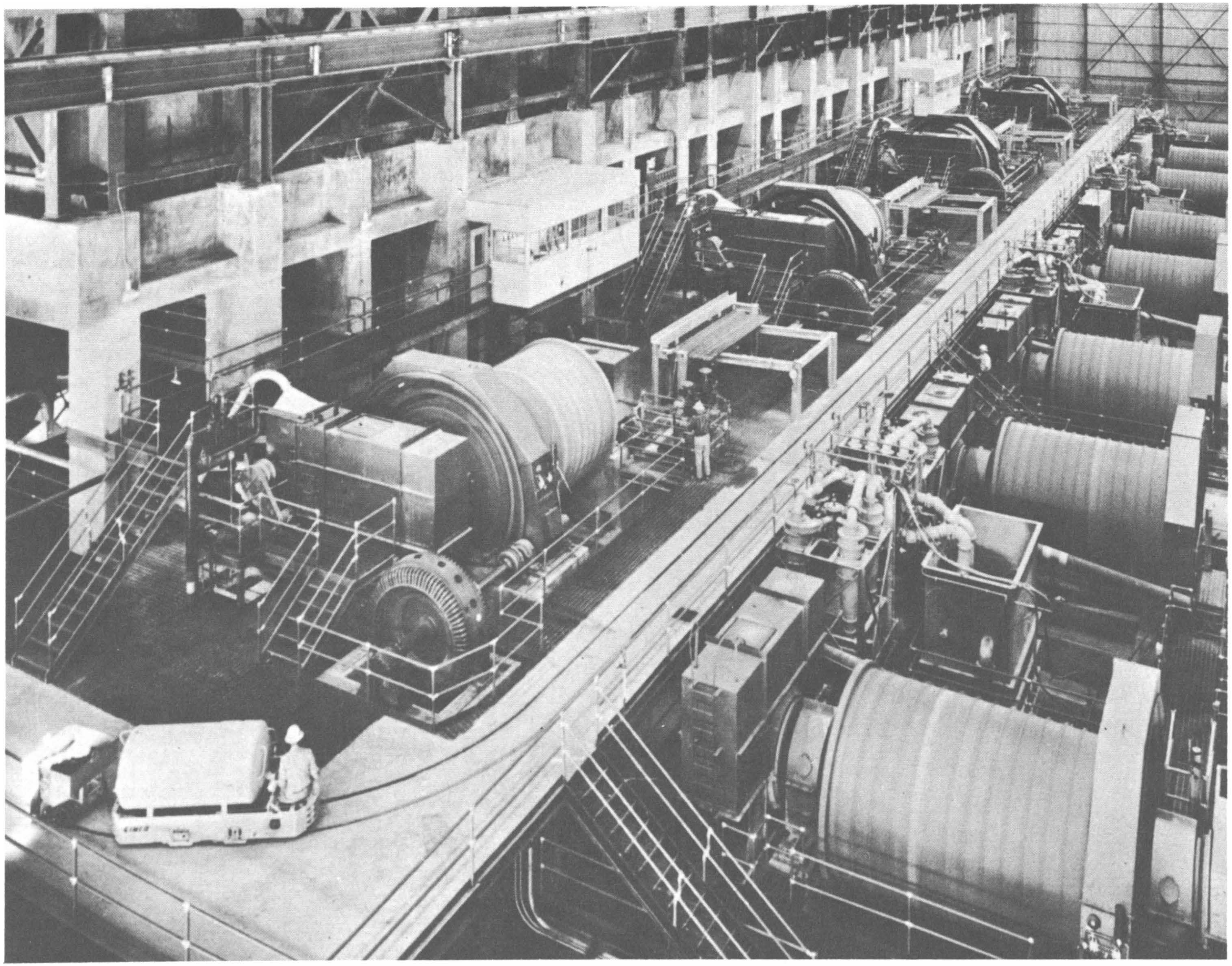


FIGURE 16.—Mission Mill Grinding Bay.
(Courtesy, American Smelting and Refining Co.)

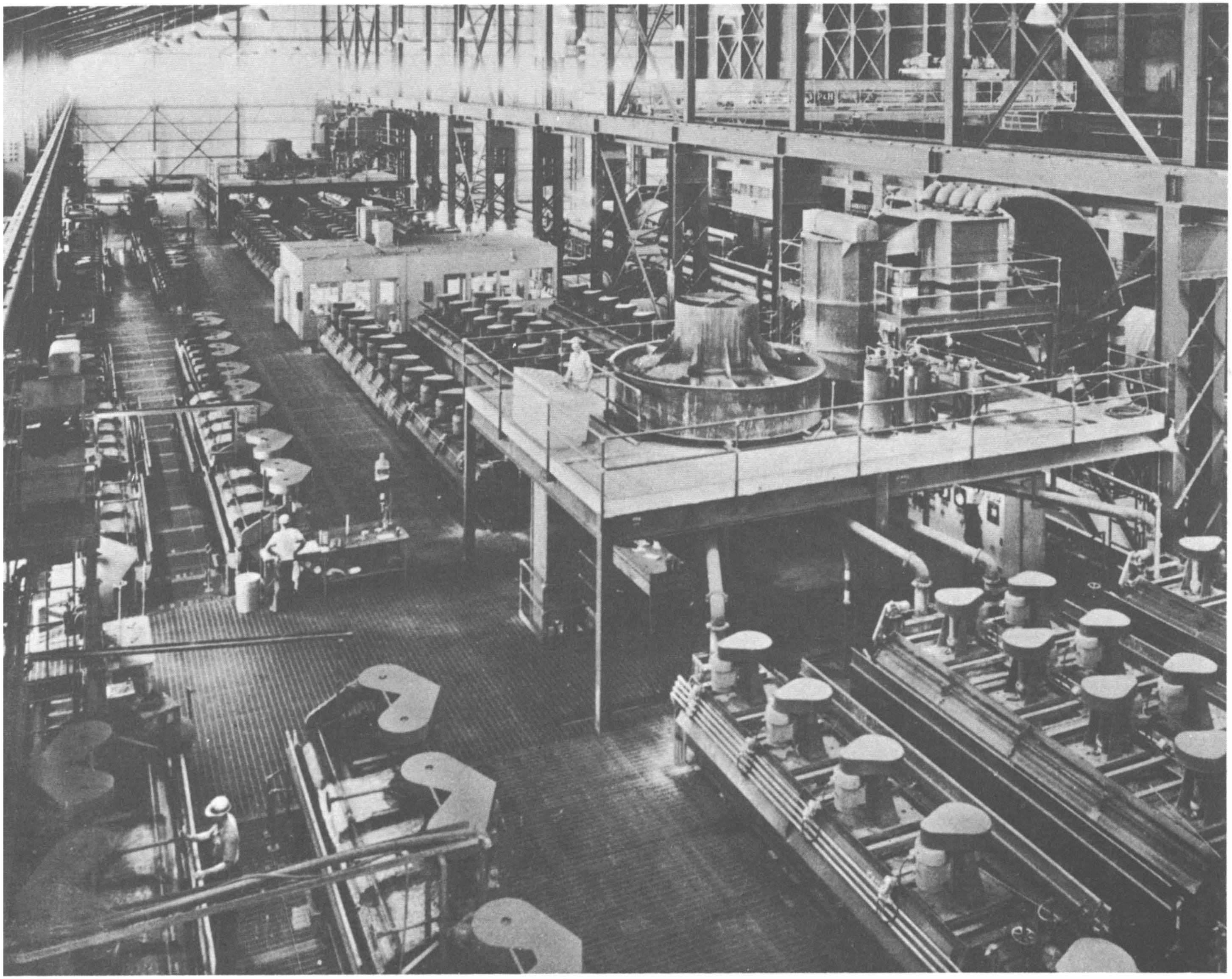


Figure 17.—Mission Mill Flotation Section.
(Courtesy, American Smelting and Refining Co.)

smaller sizes owing to grain size of the copper mineral and the degree of dissemination in the ore. Fine crushing or grinding is not only expensive, but the fine material produced reduces porosity in the vats and inhibits percolation of the leach solution. In fact, when fines or slimes are produced in crushing the ore, they are usually separated by classifiers and treated by suspension leaching methods.

Agitation Leaching.—Agitation leaching is applicable to those ores that cannot be effectively treated by percolation or to those operations where efficient extraction is required at a rapid rate. Dissolution of the copper minerals is effected by keeping finely divided ore particles in suspension in the solvent. Agitation is accomplished either mechanically or by forced air and must be strong enough to prevent settling in the tanks. The fine ore or concentrate may be leached on either a batch or continuous basis. For the batch process a charge of ore is agitated with the required amount of leach solution until optimum extraction is reached. In the continuous process, ore and leach solution are added simultaneously, but instead of effecting dissolution in a single tank, the ore-solution mixture passes from tank to tank, in series, until maximum extraction is obtained. Pachuca tanks with high lifts are convenient for this type of agitation. Separating residual gangue from leach solution and washing occluded solution from residual gangue are done in thickeners. Thickeners are standard equipment for separating a dilute pulp into a clear solution and a thickened pulp. When used in series, thickeners provide a convenient method for countercurrent washing.

Recovery

In current practice there are only two important methods for recovering copper from oxidized ores: (1) Direct leaching of ore followed by electrolysis of the leach solution or precipitation of copper from the leach solution with scrap iron (cementation), and (2) flotation of oxide minerals, leaching concentrates, and electrolysis of leach solution.

The choice of method depends largely on reserves and the size of operation planned. The oxide copper minerals in most ores are readily soluble in dilute sulfuric acid. Electrolysis of the leach solution produces refined copper with no further treatment required except melting for casting into shapes. The process also regenerates sulfuric acid which is recycled for leaching. The direct operating costs of producing copper by this method are said to be as low or lower than treating sulfide ores by flotation, smelting, and refining. Any departure from vat leaching-electrolysis usually is based on compelling economic or technical considerations.

Chemical Precipitation.—Chemical methods for copper precipitation are those not using electrolysis. While there are a number of theoretically possible precipitants, the only one that has found commercial importance is iron in the forms of scrap iron and sponge iron. This process of precipitation is termed "cementation" and the copper precipitate formed is called cement copper.

Precipitation may be carried out in various kinds of containers (launders, tanks, towers), depending upon the nature of the iron used.

The precipitation reaction,

$$CuSO_4 + Fe \rightarrow Cu + FeSo_4,$$

indicates that 1 pound of iron should theoretically precipitate 1.137 pounds of copper. If sponge iron is used as the precipitant, the amounts of iron required and cement copper produced approach the theoretical figures. If scrap iron is used, however, the nature of the scrap will regulate the amount needed and the grade of the cement copper produced. The type of scrap iron used at most precipitating plants is detinned and shredded tin cans, and about 1.4 pounds is used to precipitate 1 pound of copper. While the basic reaction for copper precipitation by iron is very simple, other reactions may occur during the operation that are related to the acidity of the solutions, the amount of ferrous and ferric iron and copper present, and the rate of flow. These affect iron consumption and the grade of copper produced. Free acid and ferric salts in solution can contribute to consumption of iron according to the following reactions:

$$H_2SO_4 + Fe = FeSO_4 + H_2, \text{ and}$$
$$Fe_2(SO_4)_3 + Fe = 3FeSO_4.$$

The advantages of this method are: (1) Simplicity of operation, (2) effective precipitation from all concentrations of copper in solution, and (3) precipitation not being affected by impurities in solution. Disadvantages are that (1) The process does not regenerate acid as in the electrowinning method; and (2) the cement copper assays are between 50 and 90 percent copper, requiring smelting and refining to be marketable as high-grade copper.

Precipitation From Ammoniacal Solution.—Copper dissolved in an ammoniacal solution forms complex cupric ammonium salt that hydrolyzes readily unless an excess of free ammonia is present. Simple heating to drive off excess ammonia converts the complex to the copper salt, which decomposes in solution with precipitation of copper oxide.

The only hydrometallurgical installation in operation utilizing an ammoniacal leach is that of the Lake Linden and Tamarack Divisions of Calumet & Hecla, Inc., at Hubbell, Mich. In treating ores or tailings, the coarser native copper is recovered by gravity concentration followed by classification and separation of plus 100-mesh sands for the ammoniacal leach. Minus 100-mesh material is treated by flotation for recovery of the fine native copper. The plus 100-mesh tailing, averaging less than 0.7 percent copper, represents about 10 percent of the original feed. A batch, downward percolation leaching method is used. Cupric ammonium carbonate is the active leaching agent.

Electrolytic Precipitation.—Electrolytic precipitation of copper from copper sulfate leach solutions, using insoluble anodes, is termed electrowinning and is the method used by several large producers for recovering copper. The principal advantages of the method are: (1) Electrolytically refined copper can be produced with no other treatment required; (2) sulfuric acid is regenerated, sometimes equal to or in excess of the amount needed for leaching, although usually some makeup acid is necessary; and (3) the smelting operation is eliminated.

Grunenfelder explains the reactions of electrorefining and electrowinning, as follows:[5]

Electrolysis can be considered as consisting of two equivalent oxidation and reduction reactions, the oxidation taking place at the anode, the reduction taking place at the cathode. In electrorefining, the mechanics of the reactions are simplified to the extent that the oxidation of an equivalent of metal at the anode, proportional to the amount of current passing (Faraday's law), is accompanied by the reduction of the same equivalent amount of metal ion at the cathode. Disregarding behaviors of impurities, the composition of the electrolyte remains unchanged, and the net cell reaction, ideally, is anodic corrosion and cathodic deposition of equal amounts of the same metal. Because there is no decomposition potential involved, the voltage required is mainly that needed to overcome ohmic resistance of the electrolyte, or $E=IR$. The process takes advantage of factors which influence resistance, such as concentration, temperature, etc., and thus optimum electrolytes and electrolyzing conditions are chosen.

In electrowinning, the net cell reactions are also equivalent oxidation and reduction reactions, but in this instance, since insoluble anodes are used, the oxidation and reduction does not take place on equivalents of the same material. Further, then, the source of material undergoing reaction must be the electrolyte.

Specificially, for the electrowinning of copper from an electrolyte containing copper as a sulfate solution, the $CuSO_4$ must undergo the oxidation-reduction reactions. This again represents the ideal condition with no complication of impurities that could be present along with the $CuSO_4$ in solution. If $CuSO_4$ is considered to ionize as Cu^{++} ions and SO_4^{--} ions, the reaction at the cathode is

$$Cu^{++}+2(e)=Cu.$$

This reduction reaction is equivalent to that taking place in electrorefining. At the anode the oxidizing reaction is

$$SO_4^{--}-2(e)=SO_4.$$

The sulfate radical is not stable and immediately reacts with water in the electrolyte to form sulfuric acid and oxygen according to the following reaction:

$$SO_4+H_2O=H_2SO_4+\tfrac{1}{2}O_2.$$

It will be noted that in electrolytic decomposition of a solution of $CuSO_4$ the solution will be depleted of one equivalent of copper for each equivalent of copper deposited at the cathode, the solution will be enriched by the formation of one equivalent of sulfuric acid, and one equivalent of oxygen will be liberated at the anode.

The voltage required for the electrolysis is not the simple IR drop as noted for electrorefining but includes, in addition to the IR requirements, enough added potential to decompose the $CuSO_4$, plus potential to liberate the O_2 formed at the insoluble anode. The latter is referred to as the gas overvoltage.

Since the net cell reaction is known, the reaction potential can be calculated.

$$CuSO_4+H_2O=Cu+H_2SO_4+\tfrac{1}{2}O_2.$$
$$\Delta H=+56{,}620 \text{ cal}$$

The reaction being endothermic, electrical energy equivalent to 56,620 calories of chemical energy must be supplied for the decomposition of one mole of $CuSO_4$.

The electrodes used in electrowinning are copper starting sheets for cathodes and some type of insoluble anode that will neither react chemically with the electrolyte nor be oxidized, either by the current or the oxygen liberated. Antimonial lead anodes are favored, particularly where chlorides and nitrates create no special problems. Anodes may be cast or of rolled sheet but are often of grid construction to reduce weight and lower anodic current density. Cell construction, electrical hookups, and the cathode sheets are similar to those used in electrorefining.

The power requirements for electrowinning are 8 to 10 times greater than for electrorefining but the power costs are largely offset by the lower labor costs. Anode handling and scrap remelting, which are major cost items in electrorefining, are at a minimum in electrowinning since the insoluble anodes may have a service life of 10 years.

The electrowinning process is used to recover copper from leach solutions by the Inspiration Consolidated Copper Co. in Arizona; Chile Exploration Co. at Chuquicamata, Chile; Andes Copper Mining Co., Potrerillos, Chile; Union Minière du Haut Katanga at Jadotville, Republic of the Congo; and Nchanga Consolidated Copper Mines, Ltd., Northern Rhodesia. Operating details for four of these plants are shown in table 12.

[5] Grunenfelder, J. George. The Hydrometallurgy of Copper. Ch. from Copper, The Science and Technology of the Metal, Its Alloys and Compounds. Am. Chem. Soc. Reinhold Pub. Corp., New York, 1954, pp. 317-318.

SMELTING

There are three main types of copper ores—native copper, oxidized, and sulfide. Since most of the world copper production is extracted from low-grade sulfide ores that require concentration, the dominant metallurgical processes for recovering copper metal are adapted to treating fine-grained sulfide concentrate. The usual concentrate consists mainly of copper sulfide, iron sulfide, and gangue, and the purpose of smelting is to separate copper from the iron, sulfur, and gangue. The strong affinity of copper for sulfur and its weak affinity for oxygen, compared with iron, sulfur, and other base metals of the ore, form the basis for the three major steps in smelting—roasting, reverberatory furnacing, and converting.

Direct smelting of oxidized ores in blast furnaces began losing importance after introduction of flotation, which produced a fine material not adaptable to treatment in blast furnaces. Since concentration of low-grade oxidized ores results in high tailings losses, direct leaching of such ores followed by cementation and reverberatory smelting of the precipitates is common practice.

The treatment of native copper ores of the Lake Superior district in Michigan departs from the general pattern in that there is no formation of matte and no converting step.

Roasting.—Roasting is a pyrometallurgical process of heating an ore or concentrate in an oxidizing atmosphere to effect oxidation reactions. The object of roasting sulfide ores or concentrates of copper is to oxidize sulfur and iron and to move volatile impurities such as antimony, arsenic, and bismuth. Copper and iron sulfides are among the easiest of the common metallic sulfides to convert to oxides, with minimum production of sulfates and other intermediates; furthermore, mixtures of copper and iron sulfides relatively free from inert compounds are readily ignited and will roast autogenously to 6 to 8 percent sulfur without further application of heat.

The amount of sulfur in the reverberatory furnace charge determines the grade of matte formed. Ores high in iron and sulfur may produce mattes too low in copper. The proportion of sulfur in such ores is reduced before smelting by roasting them under oxidizing conditions.

Roasting practice has developed along two principal lines—hearth roasting and blast roasting. Various types of multiple-hearth roasters are preferred in copper smelters to roast sulfide feed for reverberatory smelting. Roasting for copper blast furnaces is usually accomplished in moving-bed sintering equipment to agglomerate and partially roast fine-grained ores and concentrates.

The concentrate produced from some sulfide ores may be controlled at the concentrator to avoid roasting before reverberatory smelting. In some of the newer smelters roasters were not installed, and at some of the older ones the roasters are used as dryers. It is apparent that roasters are gradually being abandoned in copper pyrometallurgy.

Fluid-bed roasting, used at some plants for roasting copper ores is a new roasting technique adapted from the suspended-solids technique of the petroleum-refining industry. The method consists of partial suspension of solid particles in a gaseous stream. The gas velocities are such that size segregation of properly prepared feed will not occur. The entire fluidized bed, which is in turbulent motion like a boiling liquid, is substantially uniform throughout. Copper sulfides can be sulfatized by fluosolid roasting, making the copper soluble in water or weak acid. Calcines have consistently been obtained in which as much as 90 percent of the copper is water soluble, with an additional 5 to 9 percent soluble in 5-percent sulfuric acid. At the same time, close temperature control allows only 1 to 1.5 percent of the iron to go into solution.

Reverberatory Furnace Smelting.—Reverberatory furnaces are long roomlike structures from 80 to 130 feet long and 10 to 35 feet wide. Capacities range from 50 to 1,500 tons of charge per day. The fuel and charge are kept separate. Oil, gas, or pulverized coal is burned in a separate compartment from which the flame and hot gases pass over the ore. Heating of the charge is accomplished by radiation from the roof and side walls rather than by direct contact with the hot gases. There is little or no reaction between the gases in the furnace atmosphere and the material on the hearth; it is possible to get some oxidation of the charge by using a large excess of air for combustion, but this wastes heat and is seldom practiced. The principal chemical reactions that take place in the charge of a reverberatory furnace are between the various constituents to form a matte and a slag. Reverberatory slags are essentially mixtures of silicates and alumino-silicates of iron and lime. In many cases, the charge derived from copper-bearing materials is self-fluxing; but usually fluxes, such as limestone, are added to obtain a suitable slag. Analyses of typical concentrates, mattes, and

TABLE 12.—*Electrowinning of copper*

	Inspiration Consolidated Copper Co., Inspiration, Ariz.		Andes Copper Mining Co., Potrerillos, Chile		Union Minière du Haut Katanga, Katanga, Republic of the Congo	
Method of leaching	Upward percolation		5 to 6 days counter-current		Continuous agitation in Pachuca tanks.	
Leaching vats:						
Material of construction	Concrete, leadlined		Reinforced concrete, mastic and acid-proof brick lined.		7 rows of 4 Pachuca tanks, steel, lead lined.	
Length by width by depth	175'0"×67'6"×18'0"		105'0"×115'0"×19'6"		11' diam×27'5⅛" high.	
Average charge per tanks ... tons	9,000		8,603		5 tons/hr (dry feed).	
Circulation ... gpm	1,800		4 air lifts circulation 2,200, advance 800.			
Ore, percent:						
Copper	1.087		0.831		Flotation concentrates (oxides). 28.	
Copper, acid soluble			0.711		Practically 100.	
Oxide Cu	0.527				28 approximately.	
Sulfide Cu	0.560		0.120		0.2.	
Tailings, percent:						
Total Cu	0.148		0.249		0.5–1.	
Water-soluble Cu	Trace		0.024			
Oxide Cu, acid-soluble	0.014		0.126		0.5.	
Sulfide Cu	0.134		0.099		0.2.	
Extraction, percent:						
Total Cu	86.385		71.07		97.5.	
Oxide Cu	97.343		79.62			
Sulfide Cu	76.071		25.8			
	Starting sheets	Deposition tanks	Starting sheets	Deposition tanks	Starting sheets	Deposition tanks
Electrolyte to cells:						
Specific gravity		1.209	1.238	1.133		1.270.
Copper ... grams per liter	30–40	31.1	46.8	29.3	35–40	66.
Total H_2SO_4 ... do	120–150		166.6	30.0		
Free H_2SO_4 ... do		20.1			105	6.7.
Cl_2 ... do			0.003	0.07		
Total Fe ... do		20.5	3.18	2.24		2.5.
Ferric Fe ... do		5.7	0.10	0.22		1.5.
Ferrous Fe ... do			3.08	2.02		1.0.
Temperature ... °C	55	35.8	56.2	29.5		
Electrolyte from cells:						
Specific gravity			1.248	1.106		
Copper ... grams per liter		26.4	46.6	10.65		30.
Total H_2SO_4 ... do			167.6	60.4		
Free H_2SO_4 ... do		28.9				62.1.
Cl_2 ... do			0.006	0.08		
Total Fe ... do			3.30	2.10		2.5.
Ferric Fe ... do		12.0	0.05	1.16		1.3.
Ferrous Fe ... do			3.25	0.94		1.2.
Temperature ... °C		41.8	48.7	38.5		55.
Current:						
Total ... amperes					[1] 20,000	[1] 20,000.
Current density ... amp/sq ft	14–16	11.4	15.93	9.78	16	16.
Current efficiency ... percent		71.65	92.69	83.95	90–92	90–92.
Voltage per tank		2.16	0.359	2.066	0.6×3=1.8	2.05–2.2×3=6.1–6.6.
Copper ... kwh/lb		1.347	0.168	1.082	0.275	0.93.
Copper ... lb/kw-day			161.92	25.229		25.8.
Anodes:						
Material	Blister Cu	8 percent-Sb lead.	Blister Cu	83.5 Pb, 15.0 Sb, 1.3 As, 0.15 Cu.	Cast copper	6 percent-Sb hard lead.
Length, width, thickness		3'2"×3'4"×½"	3'3¼"×2'2½"	3'3¼"×2'2½"	3'9⅜"×2'9¼"×1¾".	3'9 15/16"×2'5⅞"×7/16".
Spacing		4.0"	4⅘"	3½"	4¾"=120 mm	3½"=90 mm.
Weight ... pounds	1,100	340	550–600	200	780	250.
Mode of suspension			Cast lugs	Cast lugs	Cast lugs	Copper bar, cast-in.
Life in days			35	Corrosion equals 2 lb of anode/ton of Cu deposited.	15–20	
Scrap ... percent	22.0		18		20–25	
Cathodes:						
Material	Rolled Cu		Rolled Cu sheet	Starting sheets	Cu blanks	Cu starting sheets.
Length by width by thickness	3'8"×3'6"	3'8"×3'6"	2'4¾"×3'7⅝"	2'4"×3'1½"	3'11½"×2'10¼"×3/16".	3'5¼"×2'9¼".
Weight ... pounds		100	80	68.48		110–120.
Mode of suspension		Punched loops	Riveted bars	2 loops	Riveted copper bars.	Punched loops.
Replaced after(?) days	1	7	1	8–12	12	6.
Weight starting sheet ... pounds	12–13	13–14	6.91	7.66	6–6½	
Percent starting sheets used for loops, scrap, etc.	15		20.27	Loops, 10.85	15	
Deposition tanks:						
Number	17–18	120	54	576	15	145.
Length by width by depth		33'0"×4'0"×4'3"	10'3"×2'10"×3'9".	10'3"×2'10"×3'9".	62'6"×3'2½"×4'2½".	62'6"×3'2½"×4'2½".
Number of anodes, cathodes	96, 95	98, 96	25, 24	34, 33	50×3	65×3.
Electric connection			Cast-rolled Cu Bus bars.	Cast and rolled Cu busbars.	3 groups series-electrodes in multiple.	([2]).
Material of construction			Reinforced concrete lined with 7 percent-Sb lead.	Reinforced concrete lined with 7 percent-Sb lead.	Reinforced concrete, mastic-lined asphalt.	([2]).
Circulation ... gpm		100	10	29–44		7.92.

See footnotes at end of table.

TABLE 12.—*Electrowinning of Copper*—Continued

	Chile Exploration Company, Chuquicamata, Chile
Method of leaching	Batch percolation
Leaching vats:	
Material of construction	Reinforced concrete lined with 4" of 27% asphalt sand mixture
Length by width by depth	150'×110'×(18.5' and 19.5')
Average charge per tank....tons	13,133
Circulation....gpm	3,000
Ore, percent:	
Copper	1.809
Copper, acid soluble	1.477
Oxide Cu	1.477
Sulfide Cu	0.332
Tailings, percent:	
Total Cu	0.343
Water-soluble Cu	0.030
Oxide Cu, acid-soluble	0.056
Sulfide Cu	0.287
Extraction, percent:	
Total Cu	81,963
Oxide Cu	96,357
Sulfide Cu	17,880

	Starting sheets		Deposition tanks			
	Commercial	Refined	1st stage, 70,093	2d stage, 19,491	Plating down, 3,638	Whole house, 93,222
Electrolyte to cells:						
Specific gravity	1.130	1.225	1.115	1.110	1.110	1.114.
Copper....grams per liter	38.921	52.10	24.96	20.28	17.36	23.69.
Total H_2SO_4....do	93.76	201.54	94.74	96.19	85.22	94.67.
Free H_2SO_4....do	35.38	123.39	57.30	65.77	59.18	59.14.
Cl_2....do	0.049	0.04	0.09	0.09	0.12	0.09.
Total Fe....do	2.81	3.44	2.87	2.82	2.69	2.85.
Ferric Fe....do			1.16	1.69	1.05	1.26.
Ferrous Fe....do	2.81	3.44	1.71	1.13	1.64	1.59.
Temperature....° C	28.3	47.6	32.6	34.2	33.4	33.4.
Electrolyte from cells:						
Specific gravity	1.127	1.225	1.110	1.105	1.095	1.108.
Copper....grams per liter	35.766	52.10	19.71	15.96	5.78	18.38.
Total H_2SO_4....do	93.75	201.54	95.51	94.98	85.22	95.07.
Free H_2SO_4....do	40.10	123.39	65.95	71.04	76.55	67.50.
Cl_2....do	0.049	0.04	0.09	0.10	0.12	0.09.
Total Fe....do	2.88	3.44	2.83	2.83	2.69	2.82.
Ferric Fe....do	0.73		1.88	1.95	1.70	1.88.
Ferrous Fe....do	2.15	3.44	0.95	0.88	0.99	0.94.
Temperature....° C	29.5	47.6	36.0	36.4	39.3	36.2.
Current:						
Total....amperes	25,319	25,080	24,538	23,155	26,957	24,538.
Current density....amp/sq ft	16.22	21.2	14.20	13.40	15.60	14.20.
Current efficiency....percent	86.89	84.79	85.53	84.05	81.13	84.87.
Voltage per tank	2.12	0.46	2.00	1.96	2.02	2.00.
Copper....kwh/lb	0.932	0.208	0.891	0.892	0.951	0.900.
Copper....lb/kw-day	25.76	115.42	26.80	26.91	25.24	26.67.
Anodes:						
Material	Pb-Sb-Ag	Soluble anode	Pb-Sb-Ag	Pb-Sb-Ag	Pb-Sb-Ag	Pb-Sb-Ag.
Length, width, thickness	4'2¼"×3'1¼"×7/20".	4'¾"×3'1¾"	4'1"×2'9"×7/20".	4'1"×2'9"×7/20".	4'1"×2'9"×7/20".	4'1"×2'9"×7/20".
Spacing....inch	3	4½	3	3	3	3.
Weight....pound	310	789	210	210	210	210.
Mode of suspension	Cu insert	Cast Cu lugs	Cu insert	Cu insert	Cu insert	Cu insert.
Life in days		19				
Scrap....percent		20				
Cathodes:						
Material	Cu blank	Cu blank	Cu sheet	Cu sheet	Cu sheet	Cu sheet.
Length by width by thickness	4'1"×3'1"×¼"	4'1"×3'1"×¼"	3'0"×4'0"	3'0"×4'0"	3'0"×4'0"	3'0"×4'0".
Weight....pound	150	150	150	150	150	150.
Mode of suspension	Riveted to bar	Riveted to bar	2 loops punched	2 loops punched	2 loops punched	2 loops punched.
Replaced after (?) days	Stripped daily	Stripped daily	5–8	5–8	5–8	5–8.
Weight starting sheet....pound	11	16	11	11	11	11.
Percent starting sheets used for loops, scrap, etc.	19	19	19	19	19	19.
Deposition tanks:						
Number, average	72.48	30.73	616	152	67.67	835.67.
Length by width by depth	19'2"×3'1"×4'10".	19'2"×3'11"×4'10".	19'2"×3'11"×4'10".	19'2"×3'11"×4'10".	19'2"×3'11"×4'10".	19'2"×3'11"×4'10".
Number of anodes, cathodes	63, 62	48, 47	73, 72	73, 72	73, 72	73, 72.
Electric connection	Whitehead	Walker	Whitehead	Whitehead	Whitehead	Whitehead.
Material of construction	Mastic-lined concrete.	Mastic-lined concrete.	Mastic-lined concrete.	Mastic-lined concrete.	Mastic-lined concrete.	Mastic-lined concrete.
Circulation....gpm	36.41	3–5	334	376	333.7	342.

[1] Two electrical circuits each of 80 tanks in series. Six motor-generator sets: 2×4,000 amp 500 volts (1 spare). Five generators of 4,000 amp, 20,000 amp for each circuit.

Source: Mantell, C. L. Electrochem. Eng., McGraw-Hill Book Co., Inc., New York, 1960, pp. 204–207.

slags at smelters in Montana, Utah, and Arizona are shown below:

	Cu, percent	Fe, percent	S, percent	SiO_2, percent	CaO, percent	Al_2O_3, percent
Concentrate	24.8	23	33	12.9	---	2.5
Matte	45.0	23	24	----	---	----
Slag	.56	42.5	----	34.5	5.8	6.3
Concentrate	31.3	22.7	29.8	14.5	---	.09
Matte	43.4	22.0	25.0	----	---	----
Slag	.43	34.5	----	39.2	6.8	4.8
Concentrate	23.3	24.2	31.0	9.4	2.4	2.4
Matte	31.6	35.0	25.0	----	---	----
Slag	.40	34.2	----	37.0	5	7.2
Concentrate	15.4	31.0	36.9	11.0	---	4.3
Matte	27.2	40.7	24.0	0.8	---	1.3
Slag	.34	36.1	1.3	37.6	3.5	9.6

The reverberatory furnace is constructed on a massive and heavily reinforced concrete foundation that supports the sides and end walls and encloses the furnace bottom. The hearth is 24 to 30 inches thick and is lined with a refractory material such as silica or magnesite brick. The sidewalls are usually of silica brick, but if a magnesite hearth is used a layer of chrome brick is laid to separate the acid sidewalls from the basic bottom. The more recent reverberatory furnaces have the Detrick-type suspended arch, which permits easy fettling and arch maintenance. Charge hoppers are arranged in a row above and along each side of the furnace. Slag is tapped from the upper end of the furnace into launders leading to slag cars; matte is tapped from near the burner end into ladles for transfer to the converters.

Blast-Furnace Smelting.—The copper blast furnace is used mainly for ores more than 1 inch in diameter, although fines may be treated if sintered. A few plants still use blast furnaces because they are useful under certain conditions, but they account for very little of the world copper supply.

The blast furnace is essentially a long, narrow, water-jacketed upright shaft. The length of the furnace varies considerably, being proportioned according to capacity. The size of a furnace is expressed in terms of the dimensions at the tuyère level. The width, being limited by ability of the blast to penetrate the charge, is usually 44 to 48 inches, though some furnaces are as narrow as 30 inches and others as wide as 56 inches. The molten products, slag and matte, collect and are drawn off at the bottom, and new material is charged at the top to keep the charge-level relatively constant.

Blast-furnace fuel is almost invariably coke, charged with ore and flux and ranging from 13 to 17 percent of the charge. The coke burden may be adjusted to control the degree of sulfur elimination, hence it is seldom necessary, unless sintering is required, to roast ores in advance of matte blast-furnace smelting.

Air under low pressure enters the furnace through tuyères near the bottom of the furnace above the hearth. The tuyères are pipes 4 to 6 inches in diameter, spaced 10 to 18 inches apart along both sides, and connected with a bustle pipe that carries the main air supply.

The lower part of the furnace walls usually consists of steel water jackets, while the upper part of the walls may be constructed of either refractory brick or a second tier of water jackets. In copper blast furnaces, the crucible is used as a collecting trough from which the matte and slag flow to a forehearth or settler in which the slag rises to the top and is removed almost continually.

Blast furnaces are still used at the following plants: Union Minière du Haut Katanga, Elizabethville, Republic of the Congo; The Rio Tinto Co., Spain; Mount Lyell M. & R. Co., Ltd., Tasmania; Tennessee Corp., Copperhill, Tenn.; Falconbridge, Ontario, Canada; Phelps Dodge Corp., Laurel Hill, N.Y.; and International Nickel Co., Coniston, Ontario, Canada.

Electric Furnace Smelting.—Electric smelting of copper concentrates to produce matte is used when the cost of electric power is less than coal or other fuels. The chemistry of the electrothermic reduction is essentially the same as in reverberatory smelting; interaction of the components of the charge is the same, with formation of matte and slag and elimination of some sulfur as sulfur-dioxide gas.

The Bolidens Copper Co. in Sweden operates an electric matte smelting furnace that is similar in design to the reverberatory furnace. It is 77 feet long by 20 feet wide with six Söderberg electrodes installed through the centerline of the roof. Each electrode is 3.9 feet in diameter and is connected to a 2,000-kva transformer for a total furnace energy of 12,000 kva.

Calcines from the roasters are charged directly into the furnace through charging pipes in the roof. Three tapholes for drawing off slag are at different levels at one end of the furnace. The slag, which is tapped almost continuously, flows through covered launders to a granulating plant where it is sprayed by jets of water; the mixture of granulated slag and water is pumped to the slag dumps. Matte is tapped at a lower level through three holes at the opposite end of the furnace. The matte averages approximately 35 percent copper; the slag, 0.3 to 0.5 percent.

Some advantages of electric smelting have been noted as follows:

1. Thermal efficiency is greater than that of a reverberatory furnace because there is no volume of high-temperature combustion gases carrying away much of the generated heat.
2. There are no combustion gases to dilute the sulfur dioxide (SO_2) gas, and the smaller amount of gas is much richer in SO_2.

3. Outstanding over the reverberatory furnace is the ability to reduce magnetite in hot and cold converter slags returned to the furnace. In the electric furnace the electrodes can be lowered to increase the heat of the bath; by adding fine pyrite and siliceous material, the magnetite (Fe_3O_4) is reduced to FeO which combines with the slag.

Converting.—Converting is the final stage in smelting copper sulfide ores or concentrates and is accomplished by blowing thin streams of air through the molten matte (product of the reverberatory or blast furnace) in a refractory-lined converter.

The first or white-metal stage of converting is rapid oxidation of the iron sulfide in the matte to iron oxide and sulfur dioxide. Enough silica is supplied to form an iron silicate slag. The copper remains as copper sulfide until most of the iron has been oxidized. When slagging is complete, the slag is poured off, leaving molten copper sulfide—known as white metal at this stage. Blowing is then continued in the second or blister stage to oxidixe the sulfur of the white metal, leaving metallic copper. The first stage is strongly exothermic and raises the temperature of the bath high enough to form slag and to provide enough superheating for the second stage, which does not liberate as much heat.

A low-grade matte produces a larger amount of slag to be retreated for copper recovery and requires more silica than a high-grade matte; but if the matte is too high in copper and too low in iron, too little heat may be liberated to maintain the process. Heat can be supplied with pulverized coal or fuel oil to convert copper mattes that contain as much as 60 percent copper. Table 13 shows analyses of matte treated and converter slag produced at forty worldwide copper smelters.

There are two principal types of copper converters, the Pierce-Smith and the Great Falls. Both types are mounted on trunnions for tilting to receive the charge and pour off slag and metal, and both have a row of tuyères in the rear connected with a wind box to introduce air into the charge. Of the 40 plants shown in Table 13, 29 use Pierce-Smith (horizontal) converters, 7 use Great Falls converters (upright). Most of the larger plants use 13- by 30-foot, Pierce-Smith converters, but 14 plants report having converters about 10 to 12 feet in diameter and about 20 feet or less in length. Figures 18 and 19 show the pouring of blister copper at United States and U.S.S.R. smelters.

Tuyères range in diameter from 1¼ to 2 inches; in the newer plants the larger sizes are preferred. They are placed 8 to 12 inches apart and high enough above the bottom to clear the level of the metal at the finish of the blow. Frequent punching of the tuyères is necessary, especially during the blister stage. Each tuyère is equipped with a special valve for punching the tuyère without dropping the air pressure and allowing the molten bath to run out through the tuyère. Mechanical tuyère punching is employed at some plants.

Air is supplied at 10 to 20 pounds per square inch, and the amount required ranges from 160,000 to 200,000 cubic feet per ton of blister produced from 40-percent matte.

Two types of converter linings are used in modern practice—basic (magnesite) and acid (silica). Basic linings are almost universally preferred, chiefly because of lower operating and maintenance costs. Basic linings have a much longer life than acid linings, converting 2,000 to 2,500 tons of copper per ton of lining, compared to 10 to 100 tons with the acid type. Other advantages of the basic lining are use of larger vessels, ability to convert low-grade mattes with relatively little lining consumption, and less handling of the shells. The disadvantages of the basic lining are excessive punching of the tuyères necessitated by formation of magnetic iron oxide about their mouths, greater time required for lining and repairing, and excessive blowing-out of fine, siliceous ore during charging of the flux.

Converter slag contains 2 to 5 percent copper and is returned to smelting furnaces for re-treatment, where its high-iron content is generally an aid to fluxing.

When the converter cycle is finished the converter is tilted to discharge the copper metal into ladles in which it is transferred to the anode furnace and casting machines. At small plants casting molds are assembled on trucks, which are passed in front of a launder, receiving the copper directly from the converter.

Due to the rough upper surface when solidified, the product of the converter is known as blister copper. The rough surface is a result of the expulsion of gases, largely air and sulfur dioxide, as the molten metal cools.

Blister copper contains most of the precious metals of the charge and minor quantities of certain other elements; hence it is invariably refined before being marketed.

A 13- by 30-foot, Pierce-Smith converter holds 200 tons of matte and at 1.2 cycles for 24 hours has a capacity of nearly 100 tons of copper per day on 37-percent matte. Within moderate limits, the capacity varies 5 tons with each 1-percent variation in matte tenor. A 12-foot-outside-diameter, Great Falls converter may take an initial charge of 10 tons of 40-percent matte and by four successive blows and charges may yield 20 tons of blister copper per 6 to 12 hours or 40 to 80 tons a day.

FIGURE 18.—Discharging and Charging Pierce-Smith Converters.

(Courtesy, the Anaconda Company)

Native Copper Smelting.—Although native copper is found in many deposits, it is only in Northern Michigan and Corocoro, Bolivia, that it occurs in large amounts. Special methods of treatment are required. In Michigan the ore is crushed in stamp mills and concentrated. Formerly, the concentrate was smelted in blast furnaces, but the present output is almost entirely treated in reverberatory funaces.

The furnaces resemble the cathode refining reverberatories (to be described hereafter) rather than those used for ore smelting. They are operated intermittently. In the roof are two charging holes, a small one near the fire

FIGURE 19.—Pouring Blister Copper at the Balkhash Copper Smelting Works, U.S.S.R.

(Courtesy, U.S.S.R. Embassy)

TABLE 13.—*Matte and converter slag analyses*

Smelter	Matte treated		Converter slag			
	Cu	Fe_3O_4	Cu	SiO_2	Fe_3O_4	Total iron
Electrolytic Refining & Smelting Co.	50	(?)	10	16	Mostly	40
Mount Isa	39	---	2.7	25.8	---	49.6
Mount Lyell	39	(?)	3	22	(?)	56
Mount Morgan	35	---	4	20	---	---
Union Minière	65	---	15–20	18	---	[1] 21.2
Falconbridge	[2] 11.4	16	[2] 1.7	21.8	18.1	50.5
Gaspé Copper	33	7–10	1.6	31	16	44
Hudson Bay	24.3	9.2	3.2	24	27.3	38.6
Noranda Mines	27	13	2	28	17	---
Braden Copper	50	3	3.5	22	20	50
Chile Exploration	50	4.5	3	28	18	41
Empressa Paipote	40–43	1.5	2–3.5	24–26	12.65	38
Norddeutsche	49	(?)	5	25	(?)	43
Indian Copper	48	(?)	6	25	(?)	44
Dowa	41.7	(?)	5.9	13.6	52.9	39.9
Furukawa	48	(?)	5.5	17.3	(?)	43.7
Mitsubishi	44.23	(?)	4.6	22.73	(?)	40.7
Mitsui	35	Ca 10	2.5	20	Ca 19.2	48
Nippon Hitachi	39.6	5	3.63	18.08	20	45.7
Nippon Sagano	41.38	---	2.9	21.05	Ca 15	50.9
Sumitomo	35.1	0.7	3.0	21.2	32.5	47
Mufulira	60–62	2.5	14.0	21	18.2	37.2
Rhokana	59.0	4.0	3.4	21	24	43
Roan Antelope	53	---	6	10	35	59
Sulitjelma	23–25	13.0	2.6	---	23	53–54
Cerro de Pasco	25.7	13.0	3.2	17.9	21	---
Messina	54.4	0.9	1.4	25.8	13.4	48.4
O'okiep	38–40	4	4	25	14	48
Rio Tinto	23	6.9	3.85	19.35	27.7	47.7
Boliden	36	---	4.8	27.6	---	37
Murgul Copper	22.7	(?)	2.4	20.4	---	48
Kennecott Chino	37.39	6.8	2.1	27.7	22.8	47
Kennecott McGill	26.09	8.42	2.85	24.2	19.1	47.1
Magma Copper	33.45	8.25	3.2	27.8	19	44.2
Bor	40–42	1.82	1.1	23.09	16.75	51.0
Plant A	22–32	10	4.5	22	29.5	48.5
Plant B	34.65	7	3.69	29.9	15.2	43.4
Plant C	21.5	---	1.25	27.5	(?)	53.0
Plant D	59	---	3	28	---	46
Plant E	37.15	---	3.76	24.1	7	47.7

[1] Slag contains also about 15 percent ZnO.
[2] Ni+Cu.

Source: Lathe, F. E., and L. Hodnet. Data on Copper Converter Practice. AIME Trans., Met. Soc., October 1958, v. 212, No. 5, pp. 603–617.

bridge for fine concentrates and a large one near the center for massive copper. The furnaces are coal fired, and their capacity may be 100 to 150 tons.

The mineral, together with slag from the refining furnace, some coal for reducing, and if necessary, some limestone flux, is charged into the furnace. It takes about 24 hours to melt the charge and skim the slag; the metal is then tapped to the refining furnace, which is placed at a lower level. The hearth is repaired with sand, and a new charge is introduced.

The refining furnaces are similar to the smelting furnaces, except for the charge holes in the roof—which are not required. If the copper is high in arsenic, the charge is treated with soda ash—which is blown below the surface of the copper. About 30 pounds per ton is needed to reduce the arsenic content from 0.3 to 0.01 percent. The arsenical slag may be treated to recover the arsenic as calcium arsenate. The oxidizing and reducing operations are similar to those used for treating cathode copper.

Metallurgical Smoke.—The metallurgical smoke produced in roasting, smelting, and converting copper, as well as in other pyrometallurgical processes, consists of gases, dust, and fume.

Of the gases commonly found in metallurgical smoke—nitrogen, carbon monoxide, carbon dioxide, water vapor, oxygen, sulfur dioxide, and sulfur trioxide—only the last two are harmful to vegetation. The sulfur compounds often are converted into sulfuric acid. Elemental sulfur also is being produced from flue gases by reduction with coke in a shaft furnace. When sulfur recovery is not feasible, smelter gases, after removal of dust and fume, usually are diluted copiously with air and discharged from a high stack to avoid damage to surrounding vegetation.

The amount of dust and its composition depend upon the type of material being treated; in general, dust consists of both original and decomposed or partly decomposed fine particles of ore, flux, furnace lining, and fuel.

Fume is that part of the solid material in a smoke that has been volatilized or sublimed and subsequently condensed when the gases are cooled in the flue system. The principal constituents are oxides of arsenic, antimony, lead, and zinc, as well as sulfuric acid and sulfates. Ordinarily, the fume must be recovered by special apparatus because it is exceedingly fine material; when recovered, it is mixed with the dust for re-treatment, and the mixture is known as flue dust, irrespective of its origin.

The two principal means of separating the solids from the gases before the smoke is dissipated into the atmosphere are baghouses and Cottrell electrostatic precipitators. Baghouses are not used in copper smelters owing to the high temperature and acid character of the gases generated in the reverberatory furnaces and converters. Before the dust-laden gases reach the principal collecting system, it is common practice to pass them through an expansion chamber in which the velocity is reduced and the larger solid particles drop out and into a waste-heat boiler for utilization of the heat. The gases often enter the flue at 2,000° F or higher.

The Cottrell process for removing suspended particles from smokes utilizes the fact that if an electrostatic charge is placed on these particles they will be attracted to an electrode carrying the opposite charge. Commercial Cottrell treaters are large chambers containing positive and negative electrodes; the positive electrodes, where the dust collects, have a large surface area and a small radius of curvature, compared with the negative electrode. The positive electrodes are usually pipes or plates, and the negative electrodes are wires or chains, carrying a difference in potential of 25,000 to 65,000 volts. Accumulated deposits adhering to pipes or plates are dislodged by rapping the electrodes at intervals with automatic hammers. The deposits fall into hoppers at the bottom of the treater chamber and are removed periodically.

Virtually any type of suspended material can be removed from a gas stream by Cottrell treaters, and the method has wide applications. It will remove all dust and fume found in copper-smelter smokes, as well as free sulfur trioxide. There is no important copper smelter in the United States or Canada that does not employ Cottrell treaters.

The treatment given to the dust and fume collected in copper smelters depends upon its composition. Most materials will be damped, sintered, or briquetted and fed back into the smelting circuit, normally at the reverberatory. The principal byproduct from smelter fume is arsenious oxide or white arsenic (As_2O_3), and virtually all the World supply of arsenic is a byproduct of copper and lead smelting. Where arsenic is present in any quantity in the smelter feed, it tends to accumulate in the flue system, because As_2O_3 is relatively volatile and is driven off in both the roasters and reverberatories. Crude arsenic-bearing dusts are subjected to repeated distillations and condensation until a commercially pure white arsenic is produced, and the residue is then sent back to the reverberatory furnace.

In addition to As_2O_3, small quantities of lead and bismuth may be separated in the arsenic plant, unless these dusts contain enough arsenic to warrant special treatment; however, they are usually returned to the smelting circuit, and the contained impurities are removed either in the slag or in the crude copper.

Autogenous or Flash Smelting.—The principle of flash smelting has been known for a long time; that is, exothermic reactions taking place on combustion of sulfide concentrates generate sufficient heat for continuous smelting of the concentrates and necessary flux into matte and slag. The process was first used on a commercial scale by Outokumpu Copper Mines, Ltd., at its smelter at Harjavalta, Finland, in 1949. International Nickel Co. of Canada, Ltd., started oxygen flash smelting of copper concentrate on a commercial basis in 1952, and the Ashio smelter of the Furukawa Mining Co. in Japan, adopted the Outokumpu system in 1956.

In the Outokumpu process, oxidation reactions take place in a vertical shaft. Proper proportions of preheated air and dried concentrate are fed into a burner on the top of the reaction shaft. The air and concentrate are effectively mixed in a burner and the resulting suspension directed vertically downward spreads over the whole shaft area. As the particles enter the hot shaft, ignition is instantaneous and the exothermic reactions raise the heat of the particles to the smelting temperature.

The particles collect in the molten bath in a settler, which is located horizontally below the reaction shaft. Iron oxide and silica from the feed react to form slag, and the drops of molten matte collect on the furnace hearth. The grade of the matte is controlled by the ratio of air to concentrate. The temperature of the furnace is controlled by altering the preheated air temperature. If the composition of the concentrate requires air preheat temperatures above those practically attained, the amount of extra heat needed can be provided by mixing fuel with the concentrates burned in the reaction shaft.

In the International Nickel Co. process almost pure oxygen is used instead of preheated air. The reaction velocity accomplished in the rich oxygen atmosphere permits the desired oxidation of the sulfide particles before they reach the molten bath.

Autogenous Converter Smelting.—The Nippon Mining Co., Ltd., at its Hitachi smelter in eastern Japan, developed a single-stage smelting operation for producing blister copper direct from copper concentrates in a converter using oxygen enriched air. Tests were started in May 1951, and commercial production using the process commenced in April 1958.

Concentrates produced from Hitachi mine ore are blended with imported concentrates and ores, then agglomerated, dried to 3 percent moisture, and charged to a converter with a relatively small amount of blast furnace matte. The charge is blown with oxygen-enriched air and the first reactions generate heat and produce copper matte and slag. Further blowing with oxygen converts the matte to blister copper, which is cast in anode molds and is sent to the refinery.

The converter slag formed in smelting the concentrates and converting the matte is skimmed and treated by flotation and the concentrate produced is re-treated in the converter.

Formerly, all copper ores and concentrates were treated in ten blast furnaces, but now only one blast furnace is used to supply origin matte for the converters, and only a small portion of the ores and concentrates processed is smelted in the blast furnace.

REFINING

Copper produced by smelting is too impure for most applications. This crude copper is classified as blister copper produced from matte, or black copper produced from smelting oxidized ores or native copper ores. It contains silver and gold and other impurities, such as arsenic, antimony, bismuth, lead, selenium, tellurium, and iron. The amount of these impurities will vary greatly depending on the character of the ore and the degree of elimination in smelting and converting.

There are two methods of refining copper, one by fire and the other by electrolysis. In general, electrolytic refining, which is more expensive, will be used when the amount of precious metals or the amount and character of the impurities present warrants. Most of the World production of primary copper is processed by electrolytic refining followed by melting of cathodes in fuel-fired reverberatory furnaces. The common sequence of refining operations is: (1) Fire refining of converter copper to produce purer and more homogeneous anodes, (2) electrolytic refining of the anodes to recover precious metals and remove impurities, and (3) a second fire refining to adjust the physical properties of the electrolytic copper to cast in shapes for use in industry.

Anode Furnace Refining.—Converter or blister copper is fire refined before casting to eliminate gases and impurities so that the anodes produced will be physically and chemically suitable for good electrolytic refining practice, which requires that the set or exposed surface of the casting must be flat. Impurities that weaken the casting must be removed so that the supporting lugs will have sufficient strength to resist breakage by the handling methods used.

The fire-refining process employs oxidation, fluxing, and reduction. It is based on the weak affinity of copper for oxygen, compared with that of the impurities. Compressed air at 8 to 10 pounds pressure is introduced under the molten metal surface through iron pipes, causing a bubbling and agitating action. This exposes the molten copper to the furnace atmosphere, and copper oxide is formed. The copper oxide dissolves in the metal bath, and reacts with the copper sulfide present, forming sulfur dioxide, which escapes from the melt; the copper oxide also gives up its oxygen to certain impurities, forming metallic oxides which combine with added silica to form slag. Sulfur, zinc, tin, and iron are almost entirely eliminated and many other impurities are partially eliminated by oxidation. Lead, arsenic, and antimony can only be removed in large quantities by fluxing. Oxygen is removed by reduction. Gold and silver and such impurities as nickel, bismuth, selenium, and tellurium resist fire-refining treatments almost completely and must be recovered or eliminated by electrolysis. Table 14 gives typical analyses of blister copper.

The reduction step is accomplished by partly covering the molten metal with coke and inserting green wood poles through the furnace door, forcing one end below the bath surface. As fast as a pole burns away it is fed into the furnace until consumed. Reducing gases formed by combustion convert the copper oxide in the bath to copper. The progress of reduction from about 0.90 percent oxygen to the required tough-pitch content (0.02 to 0.05 percent) is determined by appearance and microscopic examination of samples. A new method of

TABLE 14.—*Analyses of various types of copper for anode furnace*

	Ounce per ton		Percent									
	Au	Ag	Cu	Pb	Sn	Zn	Bi	As	Sb	Ni	Se	Te
Blister:												
1	0.01	2.4	99.1	0.01	Nil	Nil	0.00005	0.01	0.004	0.0003	0.005	0.01
2	.06	7.5	99.2	.015	Nil	Nil	.0003	.01	.005	.05	.04	.01
3	1.25	5.9	99.0	.008	Nil	Nil	.00003	.02	.005	.008	.007	.015
4	1.4	18.6	98.6	.05	Nil	Nil	.0015	.10	.03	.06	.04	.03
5	1.3	42.0	98.8	.15	Nil	Nil	.002	.15	.01	.30	.21	.01
6	3.2	195.0	96.1	.10	Nil	Nil	.001	.40	.25	.40	.30	.04
Black coppers:												
1	.15	6.9	91.1	.83	1.85	0.40	.001	.12	.09	1.27	------	------
2	.68	7.2	94.75	.55	.70	.35	.0015	.12	.18	.64	------	------
3	2.28	29.7	94.13	.75	.10	Nil	------	.22	.60	3.77	------	------
4	.02	8.4	96.52	1.00	.09	Nil	------	.04	.13	1.50	------	------
Miscellaneous:												
1	------	------	96–99	.1	.05	------	------	------	------	.1	------	------
2	------	------	93.5–96.5	1.0	.40	0.25	------	------	.01	.5	------	------
3	------	------	90.0–94.0	2.0	1.0	.5	------	------	.1	1.0	------	------

reduction using reformed natural gas has been developed by the Phelps Dodge Corp. for its three smelting plants in Arizona.

Two types of fuel-fired furnaces are used to refine blister copper for casting into anodes; a cylindrical tilting furnace which takes a molten metal charge and is usually located near the converters in smelting plants, and a reverberatory furnace designed for remelting and refining solid blister copper or high-grade scrap. Except for charging and melting, operations of the two furnaces are comparable. When cheap power is available, and refining the charge is unnecessary, electric furnaces can be used to melt the copper for anode casting.

The types of fuel used are pulverized coal, natural gas, fuel oil, and electric power. In the United States, the western refineries generally use natural gas when available, with oil as a standby; eastern refineries use oil or coal. As a fuel, coal has some disadvantages, and for this use it has been almost entirely replaced by oil.

Cylindrical tilting furnaces are lined with basic refractories of either burned or unburned magnesite brick. These refractories are most resistant to slagging actions. Refractories maintained by occasional spray coatings have given continual service for 7 to 10 years before complete replacement of the lining was needed. In reverberatory furnaces construction ranges from a basic brick roof to a complete lining of silica brick; some installations have basic lining in the sidewalls below the metal line.

Fire refining native copper, black copper, and secondary copper is similar to anode-furnace refining of blister copper; it is usually carried out in reverberatory furnaces. An oxidizing fusion is used to volatilize zinc and lead and to scorify manganese, iron, lead, zinc, nickel, cobalt, and some copper; the bath is blown with air to saturate it with cuprous oxide Cu_2O. At this time, the bath contains approximately 6 percent Cu_2O. The dissolved Cu_2O supplies oxygen for impurities in the molten bath, and these rise to the surface as slag. This slag is skimmed as rapidly as it is formed. The oxidation must be stopped as soon as the slag formation ceases, because the Cu_2O will then float on the surface, and considerable copper will be lost. The oxidation reaction is stopped by introducing enough reducing gases beneath the bath surface to remove the proper amount of oxygen to give the poured copper the pitch or set desired. Green wood poles usually are immersed in the bath to form the reducing gases. Following poling, the tough pitch copper is cast into commercial shapes for marketing.

Electrolytic Refining.—The first patents on electrolytic refining of copper were obtained by James Elkington in England in 1865–70; the Balbach Smelting and Refining Co. built the first electrolytic copper refinery in the United States at Newark, N.J., in 1883; and in 1893 there were about 30 electrolytic refineries in the world, 11 operating in the United States. Early electrolytic refiners found it virtually impossible to produce standard quality cathodes, and the copper was inferior to that produced by fire refining in the Lake Superior district. Using addition agents and improvements in the circulation of the electrolyte were important modifications that helped overcome early difficulties, but it required years to convince consumers that electrolytic copper could be produced regularly and uniformly with higher purity and conductivity than Lake copper. It was not until 1914 that electrolytic copper became the basis for price quotations.

Two systems of electrolytic-copper refining are employed—the multiple or parallel and the series. In the multiple system, separate anodes and cathodes are used, and the cathode deposit accumulates on a thin starting sheet of refined copper. The series system uses no cathodes, and the electrodes of impure copper serve as both anode and cathode; the copper dissolves from one side of each electrode, and the purified copper plates-out on the opposite side of the adjacent electrode. The multiple system is more widely used than the series system, largely because of the flexibility regarding the purity of the anode, the better recovery of precious metals, and the lower cost of casting and preparing the anodes. There is only one refinery now operating using the series system.

In electrolytic refining, copper is separated from other metals and impurities by electrolytic oxidation and is deposited as pure metal by electrolytic reduction in an electrolyte that is essentially a solution of copper sulfate and sulfuric acid. Anodes and cathodes are hung alternately at carefully spaced intervals in concrete electrolytic cells containing the electrolyte. When current is applied copper is dissolved from the anode and enters the electrolyte as $CuSO_4$ (electrolytic oxidation); at the same time an equivalent amount of copper plates-out of solution on the cathode (electrolytic reduction). Figures 20 to 22 are photos of electrolytic tankhouses, two in the United States, one in U.S.S.R.

Two types of reinforced-concrete electrolytic tanks (cells) have been used in recent installations. One is assembled from precast concrete slabs to form a row or tier of cells with partitions common to two tanks. The bottoms of these cells are usually made of heavy wood planks. The other type is the cast-in-place monlithic tier of reinforced concrete. All types of cells have a bottom outlet for removing electrolytic slime and may have another outlet for drawing off the electrolyte before removing slime. Antimonial lead is still favored for cell linings, but several types of acid-resisting plastic materials are being tested. Lead pipe and rubber tubing have been traditionally used for conveying electrolyte to and from the cells. However, polyvinyl tubing is replacing rubber in many tankhouses, and several new installations have polyvinyl plastic as a replacment for lead pipe and the lead lining of launders. Using plastics instead of lead eliminates conducting paths through which destructive current can stray from the electric circuit.

The copper sulfate-sulfuric acid solution used as the electrolyte can vary widely in chemical composition, specific gravity, and temperature and still give satisfactory results in producing high-purity cathode copper. The electrolyte constituents may be adjusted to compensate for accumulating anode impurities in solution. For example, sulfuric acid content can range from 150 to 220 g/l, but in most tankhouses it is maintained at 200 g/l, because this concentration has a high-electrical conductivity and usually avoids the anode polarization, resulting from lower solubility of impurity salts caused by high-acid content. Also, the copper content as sulfate may be from 40 to 55 g/l, but it is usually maintained at 45 g/l. This content insures pure copper deposition, yet allows for the presence of reasonable amounts of soluble impurities.

The copper content of the electrolyte tends to increase by 1.5 percent of the copper deposited. A sufficient amount of the electrolyte is continually diverted through plating-out or liberator cells equipped with lead anodes. This keeps the copper content of all the electrolyte at the desired level for deposition of normal high-purity copper. The temperature of the electrolyte can range from 120° to 150° F; at most plants it is held at 140° F or higher at the cell inlet to insure higher solubility and lower specific gravity, which facilitates movement of the electrolyte through the cell.

All electrolytic refineries introduce certain additions to the electrolyte to produce firm, smooth, cathode deposits free from entrapped impurities and to prevent sprouting growths which would cause short circuits with the anodes. Adding sodium chloride precipitates dissolved silver and improves the physical characteristics of the cathode. Certain organic additives promote a fine-grained, firm, cathode deposit free from growing protrusions for many days of plating. Animal glue, a complex protein, is recognized as the most effective organic addition agent. Other organic compounds which act as modifiers are used with glue, but they do not replace it entirely. Among these are casein, thiourea, Goulac, Bindarene, Avitone, Orzan A, and Separan. Glue additions range from 0.01 to 0.3 pounds per ton of cathode deposition, and the modifying agents are added in multiples of two, three, or four times the weight of glue.

Replenishing water evaporated from the electrolyte each day is a critical item in tankhouse operation. This daily evaporation amounts to 2 to 3 percent of the total volume of electrolyte being heated and circulated through the cells. Such loss must be carefully and continuously replaced, either with clean water or makeup solution recovered from washing cathodes and anode scrap, or from leaching and washing electrolytic slime. The makeup solution of water required must be thoroughly blended and kept warm, so that it will mix readily when added continuously to the circulating electrolyte. Diluted electrolyte due to improper addition of makeup solution or water will cause needlelike or whiskerlike growths on the cathode that may short circuit the adjacent anode.

Anodes.—Anodes used in multiple refining usually have a copper content of 98.5 to 99.6

733-740 O—65——9

FIGURE 20.—Electrolytic Refinery, Baltimore, Md.

(Courtesy, Kennecott Copper Corp.)

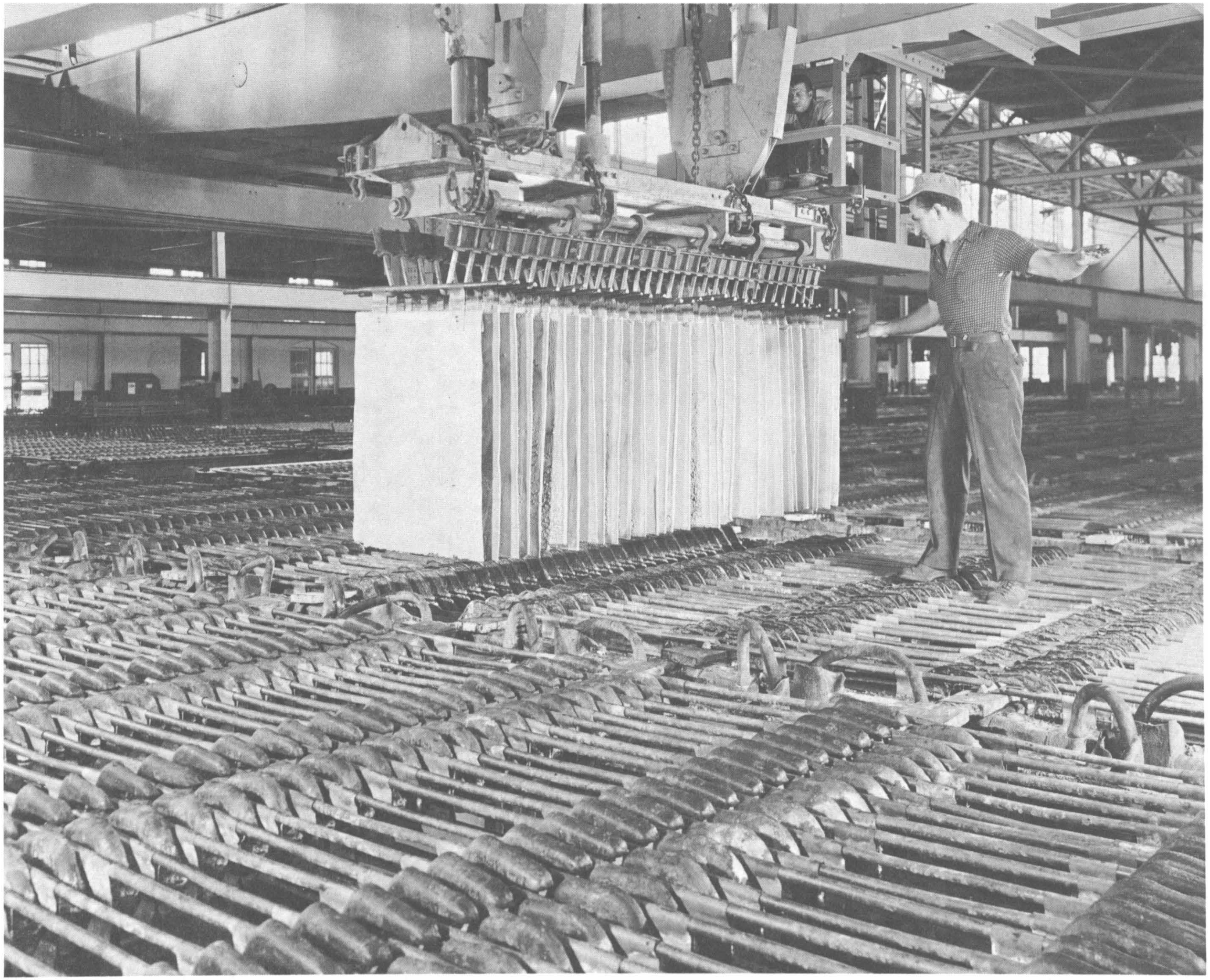


FIGURE 21.—Electrolytic Refinery, Perth Amboy, N.J.

(Courtesy, The Anaconda Company)

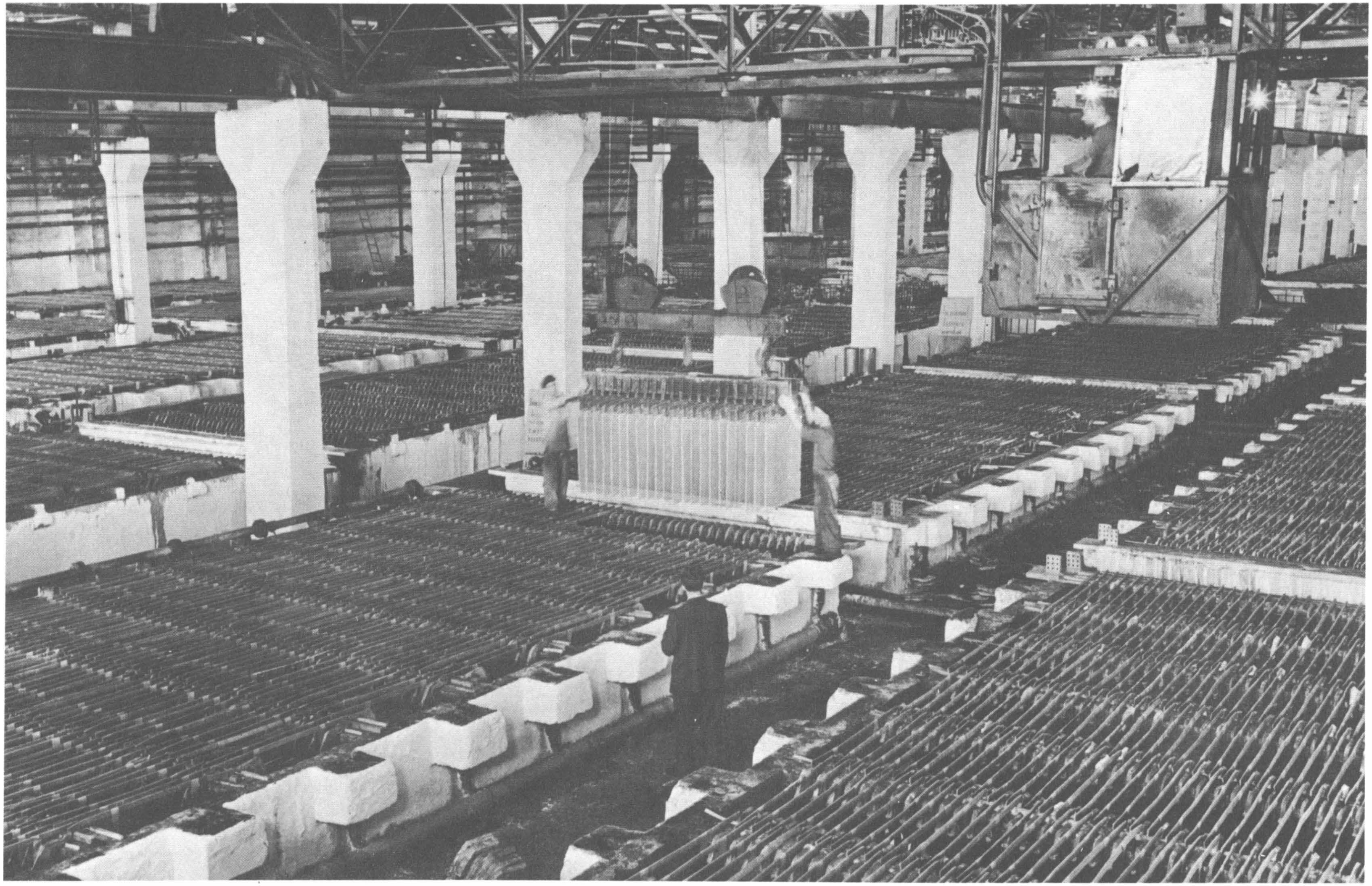


FIGURE 22.—Electrolytic Refinery, Noril'sk, U.S.S.R.

(Courtesy, U.S.S.R. Embassy)

percent (table 15), oxygen will range between 0.10 and 0.30 percent, and usually the percentages of the various impurities, exclusive of silver, are in the second or third decimal place. Silver plus gold seldom exceeds 30 oz/ton or 0.10 percent. Anode dimensions range from 27 to 36 inches in width, from 31 to 39 inches in length, and from 1¼ to 2 inches in thickness. Anodes are cast flat with two ears or lugs at the top end so they may be hung vertically in the tanks; the longer of the two lugs acts as the conductor for the inflow of current. Weight ranges from 400 to 700 pounds per anode. The life of the anode under electrolysis is from 21 to 42 days, leaving a scrap remainder of 12 to 20 percent. Scrap anodes are washed to remove slime and returned to the anode furnace for remelting.

Cathodes.—The starting cathodes used in the production cells are thin sheets of electrolytic copper deposited on oiled blanks of hard-rolled copper hung in special cells. After a 24-hour deposition, the starting sheets, 0.02 to 0.03 inch thick, are peeled from each side of each blank. Strips cut from these sheets are formed into loops which are attached to each sheet by punching or welding so that a copper rod can be threaded through them. The rods support the sheets when hung in the production cells and also serve as current conductors.

Electrolytic Process.—In the production cells, the starting sheets and anodes are properly spaced, and anode lugs and cathode-rod ends are checked for good current contact. Power is supplied from direct-current generators connected with the tanks by heavy copper conductors or bus bars in such a manner as to make the impure anodes positive and the pure-copper starting sheets negative. The current enters the anode bar, splits and passes through the anodes, through the electrolyte to the cathodes, and out the cathode bus bar. The cathode bus bar becomes the anode bus bar for the next tank.

With the electrolyte at the required level, temperature and rate of flow, current is applied and copper from the anode dissolves in the electrolyte and deposits on the cathode until the scheduled growth has been completed. Current is then shut off from the section of cells, the cathodes are withdrawn from the electrolyte by crane, thoroughly washed with hot water by immersion or spray, and loaded for transportation to furnaces or to the market.

In the process of deposition the anode impurities may dissolve in the electrolyte, float on the surface as slimes, or fall to the bottom of the tank—forming anode slime or mud. Of the soluble impurities that accumulate from normal corrosion of the anode, arsenic, antimony, bismuth, and nickel give most concern and necessitate closest control of the temperature and the copper and acid content of the electrolyte. Nickel remains almost entirely soluble; much of the arsenic, antimony, and bismuth form complex compounds which precipitate with the slime. Concentrations of nickel in the electrolyte can be tolerated to 20 g/l, and arsenic to 15 g/l, but antimony and bismuth become troublesome when they exceed 0.5 g/l. The anode slimes are removed and treated to recover their valuable elements, among which are selenium, tellurium, copper, silver, and gold. Operating data for United States and foreign electrolytic copper refineries are given in table 16.

Cathode Refining and Casting.—The usual fuel-fired furnace process involved in melting electrolytic cathodes for casting copper in refinery shapes is generally regarded as a refining process, because the copper during melting absorbs oxygen and sulfur that must be removed in the furnace before casting. Although the resulting product contains a slightly lower percentage of copper than the cathodes before melting, and the process is therefore not strictly one of refining, removal of sulfur and adjustment of oxygen content require practically the same steps as those used in fire refining.

Castings of tough-pitch copper must conform to certain requirements of composition, surface quality, and internal soundness to meet

TABLE 15.—*Analyses of anodes*

	Ounce per ton		Percent								
	Au	Ag	Cu	Pb	Fe	Bi	As	Sb	Ni	Se	Te
Anodes:											
1	0.01	2.40	99.60	0.01	0.06	0.0005	0.02	0.004	0.002	0.01	0.006
2	.06	7.5	99.55	.02	.024	.0001	.01	.01	.045	.04	.01
3	1.25	7.5	99.50	.012	.03	.0001	.004	.002	.018	.03	.01
4	.60	33.0	99.50	.013	.025	.001	.006	.005	.04	.03	.02
5	1.10	45.0	98.82	.18	.01	.0015	.15	.05	.25	.11	.06
6	2.10	58.0	98.65	.18	.012	.001	.16	.08	.28	.06	.02
7	3.5	91.0	98.51	.22	.015	.0015	.32	.24	.35	.05	.02
8	1.4	74.0	98.50	.32	.01	.001	.19	.06	.30	.15	.05
9	1.5	50.6	98.65	.19	.01	.001	.05	.04	.60	.20	.05
10	3.6	78.0	98.85	.08	.02	.009	.10	.17	.32	.05	.08

TABLE 16.—*Electrolytic refining of copper*

	American Smelting and Refining Company, Baltimore, Md.	American Smelting and Refining Company, Perth Amboy, N.J.	American Smelting and Refining Company, Tacoma, Wash.	The Anaconda Company, Great Falls, Mont.	Bolidens Gruyaktiebolag, Rönnskär, Sweden
Electrolyte:					
Specific gravity	1.265	1.275	1.25	1.28	1.25.
Percentage Cu	3.5 (44.3 g/l)	3.5 (44.6 g/l)	3.5 (43.75 g/l)	3.32 (42.7 g/l)	4.2 (52 g/l).
Percentage free H_2SO_4	15.8 (199.87 g/l)	16.5 (210.4 g/l)	17.0 (212.50 g/l)	14.4 (185 g/l)	1.4 (170 g/l).
Temperature, ° C:					
Cell inlet	60	60	62.8	55	62.2.
Cell outlet	55.5		58.9	48.9	58.
Circulation gpm	3.86	3.5–5.0	6.0	6.0	1.7.
Circulation apparatus	Vertical centrifugal pumps	Horizontal centrifugal pumps.	Vertical and horizontal centrifugal pumps.	Pohle air lifts	Horizontal centrifugal pumps.
Heating equipment	Lead steam coils in solution tanks.	Karbate tubular heat exchangers.	Lead tubular heat exchangers.	Lead steam coils in solution tanks.	Lead steam coils in solution tanks.
Addition agents, pound per ton of cathode:					
Glue	0.125	0.113	0.10	0.0365	0.10.
Goulac	0.625	0.452		0.096	0.03.
Others	HCl 0.5	NaCl 0.15	NaCl 0.13	NaCl 0.066	Thiourea 0.10.
Purification scheme:					
B.V.=blue vitriol (copper sulfate)		Segregation in Pyne-Green tanks.		Production by concentration.	
Lib.=electrolytic liberation	Lib. of Cu, As, Sb; removal of Ni, Fe, etc., by concentration.	Lib. of Cu, As, Sb; removal of Ni, Fe, etc., by concentration.	Lib. of Cu, As, Sb; removal of Ni, Fe, etc., by concentration.	Lib. of Cu, As, Sb; removal of Ni, Fe, etc., by concentration.	Lib. of Cu, As, Sb; removal of Ni, Fe, etc., by concentration.
Current:					
Amperes per cell	15,200	10,800	8,600–10,300	5,385	5,000–8,000.
Amperes per sq ft cathode	18.2	19.3	16.0	11.2	16–24.
Voltage per tank	0.230	0.230	0.200	0.250	0.30–0.35.
Conversion equipment ac to dc	Synchronous rotary converters.	Steam turbine generators	Motor Generator sets	Motor Generator sets	Motor Generator sets and mercury-arc rectifier.
Current, voltage, and kw of generators	954	1,500 and 2,500	1,110	600	400.
Generator amperage	8,670	12,000 and 20,000	6,000	3,000	4,000.
Generator voltage, max	110	150 and 160	185	200	90.
Current efficiency percent	93.2	94.5	93.0	93–94	92.
Kwh/ton Cu	196	181	209	209	320–400.
Pounds Cu/kw-day	244	265	230	230	150–120.

Anodes:					
Composition, percent Cu	99.43	99.+	99.0	99.49	99.3.
Length, width, thickness (inch)	38×34.5×1.5625	35.5×35.5×1.875	37.5×28×1.50	35.75×27.25×1.625	37.8×27.2×1.50.
Weight (lb)	700	670	530	440	375.
Mode of suspension	Cast lugs	Cast lugs	Cast lugs	Cast lugs	Cast lugs.
Anode spacing (inch)	3.875	4.25	4.0	3¾	4.75.
Life (days)	27	28	31	38	18.
Percentage scrap	18	16	18	16	20.
Starting cathodes:					
Length, width, thickness (inch)	41×37×0.031	36×37.5×0.025	38×29×0.031	36×28.5×0.025	39.75×28.4×0.024.
Weight (lb)	10.5	10.5	11.5	7	7–9.
Mode of suspension	1 wide loop	1 wide loop	Two 4-inch loops	2 small loops	2 small loops.
Finished cathodes:					
Replaced after (?) days	13.5	14	15	19	9.
Weight (lb)	285–300	300	210	185	155.
Manipulation of electrodes	Overhead cranes	Overhead cranes	Overhead cranes	Overhead cranes	
Deposition tanks:					
Materials of construction	Concrete, wood	Concrete, wood	Concrete, wood	Wood	Concrete, wood.
Lining	Lead	Lead	Lead	Antimonial lead	Antimonial lead.
Length, width, depth	13'5"×3'7"×4'1"	11'2"×3'6"×4'0"	99"–147"–174" long, 2'9" wide, 3'10" deep.	10'3"×2'10"×3'9"	9'10"×2'9.5"×4'1.25".
Number of anodes, cathodes	40, 41	30, 31	22, 23	32, 33	24.
Electric connection	Whitehead	Whitehead	Whitehead	5-cell cascade, 2 busbars each	Walker.
Amperes per sq in cross section	500	500	500	770	700–1,100.
Electrolyte inlet to cell	Top	Top	Bottom	Top	Top.
Anode mud:					
Percentage of anode	12.5	16.4	17	5.6	17.
Composition:					
Au (ounces per ton)	200	170–200	508	118.532	4.5.
Ag (do)	3,000	5,000–10,000	8,870	11,107.177	36.
Cu (percent)	25.0	22.0	1.5 (untreated, 18.0)	2.593	
Pb (do)	7.75	8.5	11.4	6.0	0.05.
Sb (do)				6.7	0.015.
S (do)				2.2	0.015.
Se (do)				4.9	0.2.
Te (do)				10.6	
Fe (do)				0.19	0.003.
As (do)				3.8	0.004.
Ni (do)				0.10	0.20.
SiO_2 (do)				4.0 insoluble	
SO_4 (do)					
Removed after (?) days	27	28	31	38	18.

See footnote at end of table.

TABLE 16.—*Electrolytic refining of copper*—Continued

	Canadian Copper Refiners, Ltd., Montreal East, Quebec	Cerro de Pasco Corp., Oroya, Peru	Electrolytic Refining and Smelting Co., Ltd., Port Kembla, New South Wales	The International Nickel Co. of Canada, Ltd., Copper Refining Division, Copper Cliff, Ontario	Kennecott Copper Corp., Garfield, Utah
Electrolyte:					
Specific gravity	1.25	1.21	1.24	1.280	1.25.
Percentage Cu	3.32 (41.5 g/l)	3.3 (37–40 g/l)	3.6 (45 g/l)	3.05 (39 g/l)	3.4 (42 g/l).
Percentage free H_2SO_4	16.53 (206.75 g/l)	10.5 (125–135 g/l)	1.4–1.5 (170–190 g/l)	16.10 (206 g/l)	1.6 (200 g/l).
Temperature, ° C:					
Cell inlet		55	60		
Cell outlet	62	50	54.4	65	
Circulation gpm	4.5	3.0	4	2.5–3	
Circulation apparatus	Horizontal centrifugal pumps.	Centrifugal pumps	Vertical and horizontal centrifugal pumps.	Vertical centrifugal pumps	Centrifugal pumps.
Heating equipment	Lead steam coils in solution tanks.	Karbate heaters (steam)	Lead coils, Karbate heat exchangers.	Lead steam coils in solution tanks.	Karbate tubular heat exchangers.
Addition agents, pound per ton of cathode:					
Glue	0.086	0.65–0.70	0.05	0.15	0.05.
Goulac				0.62	0.25.
Others	Avitone 0.071	HCl 2.00	Casein 0.05	NaCl 0.02	
Purification scheme:					
B.V. = blue vitriol (copper sulfate)	Production by neutralization and concentration.	B.V. production	B.V. production	Segregation in Pyne-Green cells.	
Lib. = electrolytic liberation	Lib. of Cu, As, Sb; Removal of Ni, Fe, etc., by concentration.			Lib. of Cu, As, Sb; Removal of Ni, Fe, etc., by concentration.	Lib. of Cu, As, Sb; Removal of Ni, Fe. etc., by concentration.
Current:					
Amperes per cell	18,000	6,000–6,500	4,300–5,000	11,800	15,000.
Amperes per sq ft cathode	19.59	16.66–18.00	11.4–13.2	15.9	17.8.
Voltage per tank	0.275	0.46	0.200–0.300	0.232	0.210.
Conversion equipment ac to dc	Motor Generator sets	Mercury-arc rectifier	Motor Generator sets	Motor Generator sets	Motor Generator sets.
Current, voltage, and kw of generators	675	2,600	750	960	1,000.
Generator amperage	5,000	6,500	5,000	6,000	8,000.
Generator voltage, max	135	400	145	160	125.
Current efficiency percent	96	94–97	90–92	96	95.
Kwh/ton Cu	205	480	280–300	192.7	175.
Pounds Cu/kw-day	233	100	190–168	249	275.

Anodes:					
Composition, percent Cu	99.41 Domestic 99.29 Noranda	97.5–97.9	99.32	99.18	99.40.
Length, width, thickness ... inch	36×36×1.50	26×36×1.625–3.0	31×34×1.50–1.75	36×36×1.375	39×35×1.625.
Weight ... lb	625	450–525	550–610	580	700.
Mode of suspension	Cast lugs	Cast lugs	Cast lugs	Cast lugs	Cast lugs.
Anode spacing ... inch	4	7.0	4.25	3.5	3.875.
Life ... days	24	24	42	28	27.
Percentage scrap	14	18–20	18	12.4	15.
Starting cathodes:					
Length, width, thickness ... inch	37×37.5×0.023	30×36×0.035	31×36×0.02	37×38×0.026	41×37×0.025.
Weight ... lb	13	11	7	12	11.2.
Mode of suspension	1 wide loop	2 small loops	2 small loops	2 small loops	1 wide loop.
Finished cathodes:					
Replaced after (?) days	8–12	8	14	13.7	13.5.
Weight ... lb	165–250	120	140–160	260	300.
Manipulation of electrodes	Overhead cranes			Overhead cranes	
Deposition tanks:					
Materials of construction	Monolithic concrete	Concrete	Concrete-wood	Concrete	Concrete.
Lining	Antimonial lead	Lead	Lead	Antimonial lead	Antimonial lead.
Length, width, depth	16′7″×3′7.5″×4′1.5″	15′0″×3′1″×4′6″	10′–9′3″×3′6″–3′6″×4′0″–3′ 5″.	11′3″×3′6″×3′9.5″	13′7″×3′7″×4′0″.
Number of anodes, cathodes	48, 49	24	24	38, 39	40, 41.
Electric connection	Whitehead	Walker	Walker	Walker	Whitehead.
Amperes per square inch cross section	450	600–650	538–625	524	375.
Electrolyte inlet to cell	Bottom	Top	Bottom	Bottom	Bottom.
Anode mud:					
Percentage of anode	16	45	20	8.3	15.
Composition:					
Au ... ounces per ton	520	1.0–2.0	5.79		1.523.
Ag ... do	4,439.27	160–250	10.62		17.138.
Cu ... percent	34.42			26.93	
Pb ... do		0.30–0.60	0.039	2.09	0.035.
Sb ... do		0.30–0.70	0.104	0.20	0.023.
S ... do		0.029		7.00	0.006.
Se ... do	20.66	0.016	0.022	14.50	0.047.
Te ... do	4.82	0.010	0.039	1.68	0.022.
Fe ... do		0.02	0.009	0.19	0.014.
As ... do		0.10		0.33	0.062.
Ni ... do		0.025		10.76	0.075.
SiO_2 ... do				0.63	
SO_4 ... do				8.55	
Removed after (?) days	24	24	14	28	27.

See footnote at end of table.

Table 16.—*Electrolytic refining of copper*—Continued

	Mount Lyell Mining and Railway Company, Ltd., Queenstown, Tasmania	Mufulira Copper Mines, Ltd., Rhodesia	Norddeutsche Affinerie, Hamburg, Germany	Outokumpu Oy, Pori, Finland	Phelps Dodge Refining Corp., El Paso, Tex.
Electrolyte:					
Specific gravity	1.20	1.23	1.25	1.23	1.25.
Percentage Cu	3.3 (40 g/l)	3.25–4.1 (40–50 g/l)	2.8 (35 g/l)	3.0 (37 g/l)	3.6 (45 g/l).
Percentage free H_2SO_4	10–12.5 (120–150 g/l)	16–10 (200–125 g/l)	13.2 (165 g/l)	1.6 (200 g/l)	18.4 (230 g/l).
Temperature, ° C.:					
Cell inlet	45–55	50–60	57.8	60	65.6.
Cell outlet			55	56.7	61.1.
Circulation gpm	5	3	4.4	4.5	4.5.
Circulation apparatus	Centrifugal pumps	La Bour centrifugal pumps	Centrifugal pumps	Horizontal centrifugal pumps.	Vertical and horizontal centrifugal pumps.
Heating equipment	Lead steam coils in solution tanks.		Steam coils	Lead tubular heat exchangers	Karbate tubular heat exchangers.
Addition agents, pound per ton of cathode:					
Glue	0.25–0.30	0.11	0.012	0.07–0.15	0.09.
Goulac	Casein 0.5–0.75	0.624.			
Others	Oil 0.1–0.2	HCl 0.34	Oil 0.020	Thiourea 0.11	
Purification scheme:					
B.V.=blue vitriol (copper sulfate)	Production				B.V. production by neutralization and concentration.
Lib.=electrolytic liberation			Lib. of Cu, As, Sb; Removal of Ni, Fe, etc., by concentration.	Lib. of Cu. As, Sb; Removal of Ni, Fe, etc., by concentration.	Fe cementation and discard.
Current:					
Amperes per cell	6,000–10,000	8,600	6,700	11,500	14,800.
Amperes per sq ft cathode	21–30	14.9	14.8	21.8	19.
Voltage per tank	0.400–0.450	0.205	0.260	0.290	0.185.
Conversion equipment ac to dc	Motor Generator sets	Motor Generator sets	Steam turbine gererator	Motor Generator sets	Motor Generator sets.
Current, voltage, and kw of generators	800	2–2,500 kw, 11,000 v ac generators. 10,000 amp dc at 20–120 v.	1,050	815	750.
Generator amperage	10,000	10,000	7,000	14,000	5,000.
Generator voltage, max	80	11,000	150	45	150.
Current efficiency percent	92–94	95	91	94	89.
Kwh/ton Cu	402–446		201	254	159.
Pounds Cu/kw-day	120–108	259.2	239	188	302.

Anodes:					
Composition Cu, percent	99.21	99.97	98.9–99.1	99.0–99.3	99.60.
Length, width, thickness, inches	36.75×27.5×2.75	36×36×1.25	34.625×26×1.344	36.50×35.50×1.50	36×36×1.5.
Weight, pounds	560	545	354	605	690.
Mode of suspension	Cu wire loops cast in corners	Plain cast lugs	Cast lugs	Cast lugs	Cast lugs.
Anode spacing, inches	5.5	4.5	3.547	4.75	4.
Life, days	18–25	28	25	21	26.
Percentage scrap	13	12–15	18	13–15	14.2.
Starting cathodes:					
Length, width, thickness, inches	38×30×0.02	37.25×37.875×0.025	36.25×27.875×0.024	37×37×0.025	37.5×37.5×0.025.
Weight, pounds	8	9.5	7.2	14	11.5.
Mode of suspension	2 small loops	2–4″ wide loops	2 small loops	1 wide loop	1 wide loop.
Finished cathodes:					
Replaced after (?) days	3–6	14	12.5	7	13.
Weight, pounds	95–125	245	154	176	290.
Manipulation of electrodes	Chain blocks and overhead crane.	Overhead cranes			Overhead cranes.
Deposition tanks:					
Materials of construction	Concrete	Precast reinforced concrete slabs.	Concrete	Concrete	Concrete.
Lining	Antimonial lead	Antimonial lead (6 percent)	Antimonial lead	Antimonial lead	Antimonial lead.
Length, width, depth	10′2″×2′8″×3′9″	12′6″×3′6″×3′9″	10′6″×2′8″×4′1″	11′10.5″×3′7.25″×4′0″	13′2.25″×3′7″×3′10″.
Number of anodes, cathodes	21,22	33,32	33,34	28,29	37,38.
Electric connection	5-cell cascade double jumper bar.	Walker	Walker	Whitehead	Whitehead.
Amperes per sq in cross section	500–830	460	645	600	400–600.
Electrolyte inlet to cell	Top	Bottom	Bottom	Top	Bottom.
Anode mud:					
Percentage of anode	35–40	0.12	12.1	9–13	2–3.
Composition:					
Au, ounces per ton	66	22	88	0.43	200.
Ag, do	373	3,700	3,650	10.29	9,000.
Cu, percent	73	35–43	16.5		20.0.
Pb, do	0.9		9.3	0.0046	10.0.
Sb, do	0.4		6.6	Trace	2.0.
S, do	9			0.005	
Se, do	3			0.017	
Te, do	0.6				12.5.
Fe, do	0.2			0.014	
As, do	0.08			0.008	0.5.
Ni, do	0.02			0.71	
SiO_2, do					4.5.
SO_4, do					
Removed after (?) days	18–25	56	25	21	26.

See footnote at end of table.

TABLE 16.—*Electrolytic refining of copper*—Continued

	Phelps Dodge Refining Corp., Laurel Hill, N.Y.	International Smelting and Refining Co., Perth Amboy, N.J.	Rhodesia Copper Refineries, Ltd., Nkana, Northern Rhodesia	Société Générale Métallurgique de Hoboken, Belgium	United States Metals Refining Co., Carteret, N.J.
Electrolyte:					
Specific gravity	1.24	1.28	1.210	1.285	1.22.
Percentage Cu	2.80 (34.72 g/l)	3.75 (48 g/l)	3.7 (45 g/l)	3.5 (45 g/l)	3.2 (39.04 g/l)
Percentage free H_2SO_4	18.00 (223.2 g/l)	17.0 (215 g/l)	9.9 (120 g/l)	17.5 (225 g/l)	16 (195.20 g/l).
Temperature, ° C:					
Cell inlet	50	60	65	55	55.
Cell outlet	47.5	55			
Circulation gpm	3.75	4	6 (5 imperial gallons)	3.8	3.
Circulation apparatus	Vertical and horizontal centrifugal pumps.	Vertical and horizontal centrifugal pumps.	Horizontal centrifugal pumps.	Vertical centrifugal pumps	Worthite centrifugal pumps.
Heating equipment	Lead steam coils in head tank.	Karbate tubular heat exchangers.	Lead steam coils and heat exchangers.	Lead steam pipes	Karbate tubular heat exchangers.
Addition agents, pound per ton of cathode:					
Glue	0.00009	0.15–0.032	0.098	0.020	0.065.
Goulac		0.60–0.200	Bindarene 0.127		Lignone 0.79.
Others		Casein 0.085		0.9	(50 percent solids).
Purification scheme:					
B.V. = blue vitriol (copper sulfate)	B.V. production by neutralization and concentration.		In process of design		Segregation in Pyne-Green tanks.
Lib. = electrolytic liberation	Lib. of Cu, As, Sb; Removal of Ni, Fe, etc., by concentration.	Lib. of Cu, As, Sb; Removal of Ni, Fe, etc., by concentration.		Lib. of Cu, As, Sb; Removal of Ni, Fe, etc., by concentration.	Lib. of Cu, As, Sb; Removal of Ni, Fe, etc., by concentration.
Current:					
Amperes per cell	414	7,500	9,000	1,500	10,700.
Amperes per sq ft cathode	18.4	15.5	15.0	14.5	14.8.
Voltage per tank	0.140	0.200	0.230	0.180	0.227.
Conversion equipment, ac to dc	Rotary converters	Motor generator sets; diesel generators.	Motor generator sets	Rotary converters	Motor generator sets, mechanical rectifier, turbo-generators.
Current, voltage, and kw of generators	750–500	2,400	990	1,837	1,500.
Generator amperage	2,400–1,800	8,000	10,000	10,500	12,000.
Generator voltage, max	360–325	300	110	175	150.
Current efficiency percent	70	92	92	96–97	90.
Kwh/ton Cu	151	176	197	150	182.
Pounds Cu/kw-day	318	273	244	320	264.

Anodes:					
Composition, Cu ... Percent	99.5	99.40	99.78	99.00	98.90.
Length, width, thickness ... inch	.56 x 12 x 0.5625	37.5 x 28.5 x 1.5	37 x 36 x 1.25	35.5 x 35.5 x 1.5	36 x 36 x 1.25.
Weight ... pound	112	490	550	605	525.
Mode of suspension	Punched lugs, rings	Cast lugs	Cast lugs	Cast lugs	Cast lugs.
Anode spacing ... inch	1.8125	4	4.375	4–3.5625	3.5.
Life ... days	27	30	30	30	28.
Percentage scrap	14	13	20	10	16.5.
Starting cathodes:					
Length, width, thickness ... inch	Series system, deposit on anode.	38.5 x 30.25 x 0.025	37.5 x 37.5 x 0.031	37 x 38 x 0.030	37 x 38 x 0.025.
Weight ... pounds	94–99	8. 5	10	13.2	10.5.
Mode of suspension	Series systems, deposit on next anode.	2 small loops	2 small loops	2 small loops	2—4″ loops.
Finished catnodes:					
Replaced after (?) days	27	16–14	15	15	14.
Weight ... pounds	94–99	215	220	270	225.
Manipulation of electrodes	Overhead cranes	Overhead cranes	Overhead cranes	Overhead cranes	Overhead cranes.
Deposition tanks:					
Materials of construction	Concrete	Concrete	Concrete-wood	Concrete	Concrete-wood.
Lining	Asphalt	Antimonial lead	Antimonial lead	Lead	Lead.
Length, width, depth	16′0″ x 5′4″ x 5′2″	10′0″ x 2′10″ x 4′0″	12′6″ x 3′7.5″ x 3′11.5″	11′5.875″ x 3′5.438″ x 3′8.5″	11′0″ x 3′6″ x 3′7.75″.
Number of anodes, cathodes	102 cells of 5 anodes per tank	30, 31	32, 33	34, 35–38, 39	37, 38.
Electric connection	Series	Walker	Whitehead	Walker	Walker.
Ampere per sq in cross section	225	600	450	520	535.
Electrolyte inlet to cell	Bottom	Bottom	Top	Bottom	Bottom.
Anode mud:					
Percentage of anode	5.8	8	2.8	12–16	18.
Composition:					
Au ... ounces per ton	100	58	13.4	10–60	200–400.
Ag ... do	2,000	2,350	1,452	5,000–7,000	8,000–11,000.
Cu ... percent	30.0	25.5	43.55	2–3	12–15.
Pb ... do	9.75	12.2	0.91	30	10–15.
Sb ... do	4.0	4.4	0.06	3.5	4–8.
S ... do			6.55	5.5	
Se ... do	8.0	7.0	12.64	2.5	5–8.
Te ... do	1.0	4.2	1.06	0.5	2–4.
Fe ... do			1.42	0.2	
As ... do	1.25	4.6	0.29	2.2	2–3.
Ni ... do		0.3	0.27	0.3	1–2.
SiO_2 ... do	1.70		6.93	7–10	
SO_4 ... do				15	
Removed after (?) days	27	30	100	15	28.

Source: Mantell, C. L. Electrochemical Engineering. McGraw-Hill Book Co., New York, 1960, pp. 150–157.

established commercial standards. The surface should be flat to slightly crowned, finely wrinkled, and free from ridges or edgewise depressions. Other surfaces must be free from laps, cold sets, inclusions, and protrusions. Internally there should be no blowholes or cracks. The molten metal must be properly conditioned with respect to gas content and amount of gas-forming elements. The means for pouring the molten metal into the mold must permit a quiescent transfer so as to avoid surface defects. Temperature range, pouring speed, and mold design will determine the rate of solidification and the internal structure of the casting.

Refinery shapes are of two classes: Regular shapes—consisting mainly of horizontally cast wirebars, ingots, and ingot bars—and special shapes—including vertically cast wirebars, cakes and billets. Large-scale casting operations use specialized equipment integrated with the melting furnaces. Molds for horizontal casting are traylike, with the major axis in the horizontal plane. In service, they are kept within the desired temperature range with bottom water sprays. Such molds are used largely for wirebars, ingots, and ingot bars. Vertically cast shapes are produced in molds having the mold pocket in the vertical plane so that the set surface of the shape is of minimum area. Molds of this type are used chiefly in producing billets, cakes, and wirebars (fig. 23).

The melting of cathodes in electric furnaces eliminates the refining steps necessary in reverberatory furnaces. At one plant selected cathodes are melted in an induction furnace under a reducing gas atmosphere for casting oxygen-free copper wirebars, cakes, and billets. Two other refineries melt the cathodes in electric arc furnaces that are capable of producing copper of negligible oxygen content owing to the normal reducing atmosphere in the furnaces. These furnaces, however, are equipped with draft systems, permitting a controlled quantity of air to pass over the molten baths, and the copper absorbs some oxygen by the time it flows from the furnaces. The molten copper picks up more oxygen during its passage through the launders to the holding furnaces, and by casting time the oxygen content is at the desired 0.03 to 0.04 percent for tough-pitch copper.

A special feature of refineries that melt cathodes in electric furnaces is the integrated continuous and semicontinuous casting equipment for forming wirebars, billets, and cakes. The principle of continuous casting, although not new, has been developed for the commercial production of refinery shapes in the last 15 years. In the process, molten metal is fed into one end of a mold or forming enclosure, and solid metal is continuously withdrawn from the other end at a speed regulated by the rate of solidification. This method of casting was used only for deoxidized and oxygen-free copper until 1958, when the American Smelting and Refining Co. (A.S. & R.) perfected equipment for semicontinuous casting of tough-pitch copper cakes.

The cake casting operation at the A.S. & R. Perth Amboy, N.J., plant is unique and is based on use of water-cooled graphite molds which, because of their heat transfer properties and lubricating qualities, are adaptable for continuous casting.

The casting unit has dual, water-cooled, graphite molds mounted on a reciprocating carriage suspended over a 32-foot well. Copper is poured through a funnel arrangement into each mold. As the castings solidify they are lowered continuously through the molds by a hydraulic ram at controlled speeds and pass through high-pressure water cooling sprays. Tough-pitch copper cakes are cast in 25-foot lengths, with cross-sectional dimensions of 5 by 25 inch, 5 by 30 inch, or 5 by 36 inch.

Wirebars, billets, and cakes of oxygen-free, high-conductivity copper are cast by a continuous process at the United States Metals Refining Co., Carteret, N.J. Wirebars and small billets are cast in one machine having water-cooled, vertically split copper molds that are vibrated horizontally at about 1,200 cycles per minute. This vibration produces rapidly recurring pressure on the solidifying metal and prevents surface rupture as it is withdrawn. A second machine produces billets up to 8 inches in diameter and cakes in two sizes, 4 x 13 inches and 3½ x 26 inches. The one piece copper mold in this machine reciprocates in a vertical direction, moving downward with the casting about 1½ inches and turning quickly to its upper position by a cam mechanism. The low frequency of relative movement between mold and metal and lubrication prevents surface rupture of the castings.

FABRICATING

The term fabrication, as applied to the metal industries, refers to shaping and finishing refined metals and alloys from bulk forms into standard shapes, sizes, temper, and finishes required by manufacturers of finished articles or by construction industries.

Copper and copper-base-alloy products consist of strip, sheets, plates, rods, shapes, tubes, bus bars, commutators, print rolls, and wire and are fabricated in numerous sizes, shapes, and dimensions.

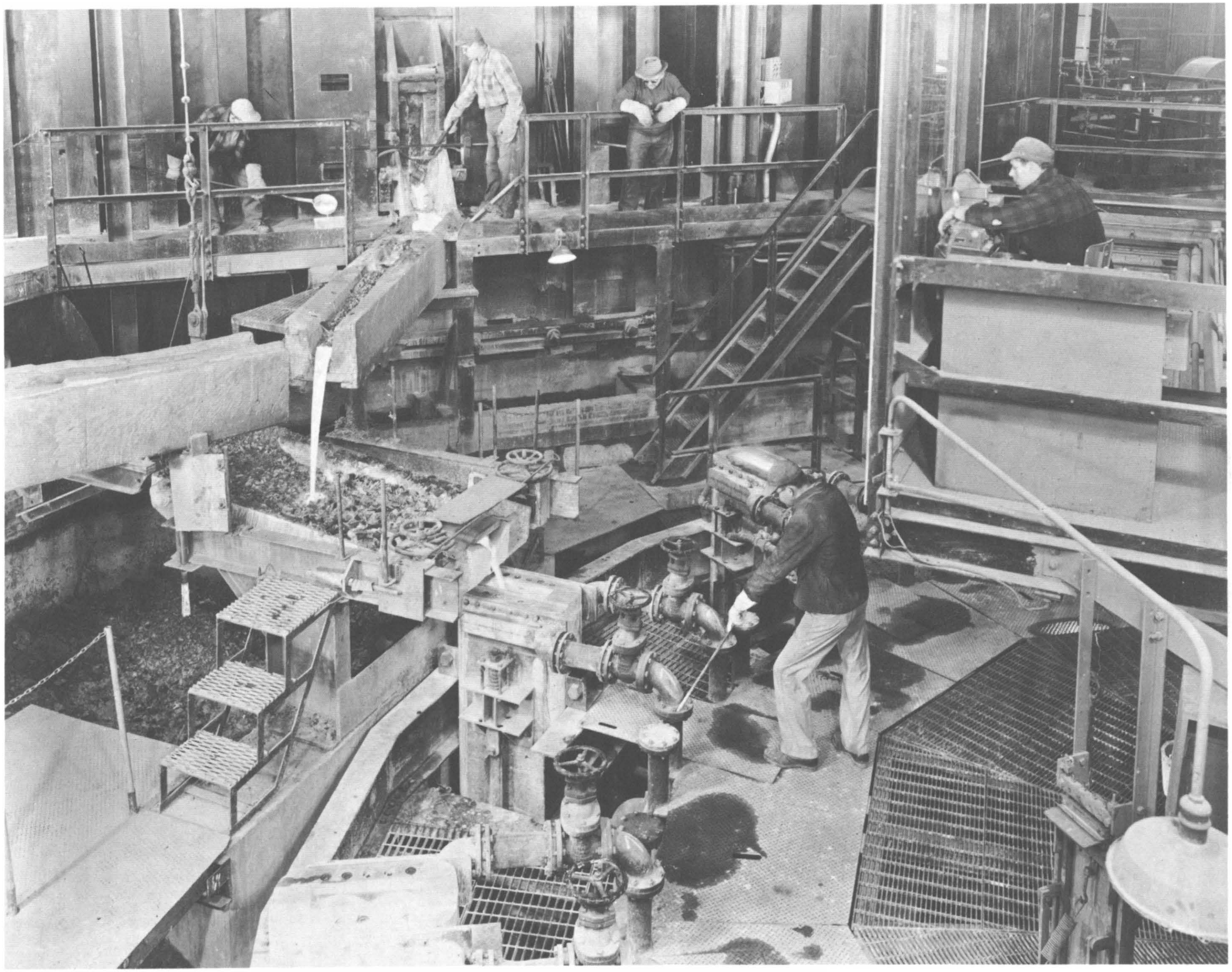


Figure 23.—Vertical Casting of Copper Cakes.

(Courtesy, The Anaconda Company)

The group of companies manufacturing these products is generally referred to as the copper and brass industry. A list of the companies fabricating copper and brass in the United States, the locations of their plants, and the products manufactured are given in chapter 7.

The copper-wire fabricators are a separate group of manufacturers. Methods of production are more or less standardized, but may vary between two companies producing the same article and also between two plants within the same company or organization. Many types of machinery and equipment are utilized in manufacturing copper and alloy products. They are generally of standard design. In a few cases, specially designed machinery is employed for specific purposes.

Fabricators receive their refined metals from the refineries in carlots as cathodes, ingots, billets, slabs, cakes, or bars. The scrap used by fabricators originates mostly from processing various products; remaining requirements are obtained from secondary manufacturers and scrap dealers.

Melting Furnaces and Casting

The melting furnaces used almost exclusively by the fabricators of copper and copper-base-alloy products are electric induction furnaces of the low-frequency type. In copperplate mills, reverberatory furnaces are generally used.

Induction Furnaces.—Low-frequency, induction-melting furnaces came into use from 1915 to 1920 and soon displaced the older practice of melting in coal- or coke-fired graphite crucibles in all important operations. Induction furnaces, now in general use, are made in various sizes, ranging from 80 to 500 kw input with single coil furnaces and 1,000 kw with dual coil furnaces. Pouring capacities vary up to 10,000 pounds. In many instances double-slot (two inductor tubes serving one bath) furnaces are used to reduce the melting time. Essentially, both types are crucible melting furnaces in which a ring of molten metal surrounds one leg of an iron transformer core. The primary winding of the transformer is connected to an alternating-current supply. Current passing through the primary is magnified in the single-turn secondary in direct proportion to the ratio of turns, which in this case equals the number of turns in the primary. In a typical furnace, current of about 30,000 amperes is developed, which heats the ring of metal—owing to its electrical resistance.

The secondary loop is so designed that the effect of magneto-motive force generated by the high current creates a circulation from the secondary to the crucible and back. Thus, the overheated metal in the secondary is continuously replaced by cooler metal from the crucible, causing the charge to melt rapidly.

The electrical characteristics of the furnaces depend on the molten resistivity of the alloy melted, and the resistance of the single turn secondary loop as well as the primary coil. The reaction of both primary and secondary are important, as well as mutual positioning of both with respect to the core.

Refractories.—The refractory lining of an induction furnace must have low-electrical conductivity to avoid short-circuiting between the primary coil and the molten loop of metal forming the secondary. This precludes using silicon carbide, but most other common industrial refractories may be employed, such as fire clay, alumina, magnesia, chromite, silica, and mullite. The principal criterion for selecting one or more of these refractories is the refractory cost per pound of metal or alloy melted, which is a function of replacement cost, principally labor, versus operating life. In a furnace averaging 600 pounds or more per hour of pouring capacity, the life of the lining is considered satisfactory if it lasts for the pouring of a half million pounds of some highly refractory alloy such as cupronickel, although a life 10 times as great is not unusual with some of the more easily melted, low-temperature brasses.

Furnace Operation.—When a furnace is first placed in operation, linings, after a low-temperature drying period, must be partly vitrified by careful heating with a torch until they are well above a red heat and preferably as high as 2,500° F. This may take 15 hours. About half a normal charge of molten metal is then added to more than fill the secondary loop and to complete the secondary circuit. The current is then turned on, and melting will proceed normally upon addition of unmelted material.

A furnace is usually charged in the following manner: First, a layer of scrap of the same composition as the metal to be poured (for example, brass) is placed in the bottom of the crucible. The high-melting constituents of the charge, such as copper, together with part of the zinc and the heavy scrap are added so that these will gradually be melted. The balance of zinc is added when the melt has nearly reached its pouring temperature. When all these are melted, the furnace is skimmed of impurities and dross through the door, and the surface on the metal is covered with fresh charcoal to prevent further oxidation. Since the customary pouring temperatures are 200° F higher than the melting temperatures, the current is left on until a pyrometer in the molten metal indicates that the pouring temperature is reached; the charge is then poured.

Owing to its chemical activity, zinc acts somewhat as a deoxidizer. When other alloys that do not contain zinc are melted, some other deoxidizer usually is added, such as manganese-copper or phosphor-copper.

All of the molten metal cannot be poured from a furnace of this type, as the secondary ring would be broken; thus, it is customary to pour about 60 percent of the contents. The balance acts as a reservoir of molten metal (commonly referred to as a button), which not only assists in continuing the melting but tends to maintain a uniform composition of the heats poured. The pouring temperatures range from 1,850° to 2,450° F, depending upon the alloy being cast.

In addition to charcoal, fluxes are frequently used to further protect the surface of the metal during pouring. These vary considerably in composition; ordinary table salt is the material most generally used, and borax and soda ash are used extensively. A handful of one of these is added to the molten charge, either before or after zinc is added, or immediately before pouring.

Reverberatory Furnaces.—Reverberatory melting furnaces usually are used for casting large copper slabs or cakes to be fabricated into plates. Although electric furnaces of sufficient capacity are now available, two factors detract from their usefulness—the nature of the plant scrap, requiring considerable preparation, such as cutting into small pieces to fit the charging door, and the need to leave a considerable poundage of molten metal in the furnace to cover the ducts, making it difficult to adjust the composition when a change in the alloy is necessary.

The hearth of a reverberatory furnace slopes from the charging door down to the discharge, or taphole. Because of its location, the complete melt is used, and a change in the alloy can be made conveniently.

After discharge, the taphole is plugged with a mixture of moist fire clay and fine coal. When the melt is ready, a ladle is lowered into a pit under the taphole, and a pointed iron bar is driven through the clay plug. The metal flows into the ladle, and from this it is poured into molds of various sizes and styles.

Reverberatory furnaces can be fired with either coal, oil, or gas, depending on cost and availability.

Casting.—Copper and copper-base alloys are cast in the following forms: Round billets for processing into tubes, rods, and shapes; slabs for rolling into strip; and cakes for rolling into sheets and plates.

Cannon Molds.—The simplest kind of mold for casting round billets, either for use in piercing or extrusion processes, is the old cast-iron cannon mold. This name no doubt originated because they look like cannons that are hung by trunnions from racks and point skyward. The breech consists of a removable cast-iron plug, and the metal is poured into the muzzle. After the pouring operation, the mold is lifted off the billet by an overhead crane; then the same crane picks up and removes the cooled billet. Cannon-type, air-cooled molds usually are of single-cavity design and can be made to cast billets 2 to 10½ inches in diameter in various lengths to 75 or 80 inches. Cannon molds have been replaced largely by the water-cooled type.

Book Molds.—Slabs are cast in hinged-type molds, generally referred to as book molds or Lawton-type molds. Book molds can be used for casting slabs 2½ to 14 inches wide, 1½ to 2 inches thick, and as much as 75 inches long. They are not recommended for slabs weighing more than 250 or 300 pounds.

Heavy Cake Molds.—Molds used for casting heavy cakes to be rolled into plates are essentially of two types—the flat or open-poured and the vertical or top-poured. The flat-type mold is made of cast iron or copper in various shapes (square, rectangular, or octagonal) and sizes. The vertical mold is made in one piece, of special cast iron, has four sides but neither top nor bottom, and is set on a copper stool that acts as a bottom. The sides taper slightly in all directions to remove the casting more easily. A vertical mold has a hot top built of refractory brick. Hot tops are used when casting metal having heavy shrinkage and are not generally used on metals having comparatively small shrinkage. It is usual to use a flat or open-poured mold when casting alloys having small shrinkage either with or without partitions to alter the shape. Vertical molds are used for metals with heavy shrinkage.

Water-Cooled Molds.—Water-cooled molds began being used in the early 1930's and came into general use in the early 1940's. A cast slab for cold rolling now averages from 600 to 1,000 pounds and for hot rolling from 1,000 to 4,000 pounds.

Water-cooled billet molds are made of cast iron and have a cylindrical copper-tube insert around which water circulates.

Water-cooled billet molds are made for sizes from 2 to 10½ inches in diameter and from 50 to 120 inches in length. In diameters to 4 inches they can be made in double- or multi-cavity designs, whereas in larger diameters they usually are made in single-cavity designs. The molds are mounted vertically during pouring

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and usually may be unloaded by tipping horizontally.

Slab molds have copper faceplates about 1 inch thick, are held in a cast-iron water jacket, and open like a book.

The water-cooled mold design, similar to the Junker, is made to cast 500- to 5,000-pound slabs in widths to 42 inches, in thicknesses from 2½ to 10 inches, and in lengths to 96 inches.

Water is circulated through the molds at approximately one-half gallon per minute per pound of metal cast. The temperature of the inlet water is controlled and ranges from 100° to as high as 220° F, depending on the size and shape of casting, on the alloy, and on plant practice.

Continuous Casting.—Continuous casting can be defined as a process wherein liquid metal enters one end of a mold continuously at a substantially uniform rate and solid metal emerges simultaneously from the other end.

Virtually all the tonnage in production is confined to three processes, each producing castings of any desired length without stopping. The three process—stationary mold, vibrating split-mold, and reciprocating-mold—have these factors in common: Water-cooled copper, copper-alloy, or graphite molds; mechanical means for withdrawing or controlling the billet speed through the mold; and traveling saws to cut the casting into desired lengths without stopping the continuous pouring.

The stationary mold process is one in which the mold remains fixed; the molten metal enters at the top and emerges at the bottom as a solid, continuous casting. A mold of this type usually is one piece and rather short. This process is used for copper and alloys difficult to cast by more conventional methods.

The vibrating split-mold process consists of two water-cooled mold sections that together form the contour of the casting. These sections are mechanically opened and closed laterally, with a small gap, and at high frequency. The molten metal, entering at the top, solidifies, is withdrawn at constant speed, and is cut into the desired lengths by integral saws. This process is used principally for casting copper.

In the reciprocating-mold process, the liquid metal is underpoured from a reservoir furnace through a downspout and discharged underneath the surface of the liquid metal ,in the mold. The mold has a downward and upward motion. The downward motion is synchronized with the speed of the billet, and the upward speed is about three times that of the downward speed. The total travel of the mold is about three-fourths of an inch in each direction. This process is used principally for copper-zinc alloys.

Semicontinuous Casting.—Castings are also made by a semicontinuous variation of the reciprocating mold process. In this type of casting a vertically withdrawable, close-fitting copper stool is first placed in the mold cavity. The pour is then started, and the mold is allowed to almost fill. At this point the stool withdrawing mechanism—usually hydraulic—is activated, moving the stool downward at a uniform adjustable rate equivalent to the rate of molten metal entering the mold. The length of billet is limited by the design of the withdrawal mechanism, usually ranging from 100 to 180 inches. Two or more billets may simultaneously be cast using a single withdrawal mechanism.

In the foregoing processes, further cooling is necessary after solidification. This subsequent cooling is either by direct application of water sprays or by secondary cooling jackets.

The linear-casting rate of these machines ranges from 6 to 60 inches per minute, depending on the alloy and cross-sectional area. The principal application of continuous casting is in large units, but the process is also applicable to small units for some alloys difficult to cast by other methods.

The metallurgical advantages of these processes are less segregation, high density, and absence of shrinkage porosity. Operational advantages include straight-line continuous production, lower pouring temperatures, elimination of butt or gate scrap, exact lengths delivered to the mill, greater uniformity of composition, and economy. Disadvantages are high-initial cost and lack of flexibility of alloy charges.

Most of the tonnage produced by continuous casting is as billets, slabs, and bar for standard fabricating processes.

Heating and Annealing.—In fabricating copper and copper-base-alloy products the metal may be heated for hot working, for reworking, for strain relief, or to obtain the final temper.

No specific rules can be made for establishing hot-working or annealing temperatures. They can be formulated only after all contributing factors of each job are known and considered, as affected by variations in equipment and operating methods.

Heating preparatory to hot-working usually requires higher temperatures than annealing for cold working. Most metals and alloys have a relatively wide hot-working range, but some have a narrow range. The working temperature depends on the material and the type of operation and may vary from about 1,200° to 2,000° F. In this temperature range the metal is more plastic than at atmospheric temperature.

Annealing consists of heating metals between cold-working operations, usually after a 30-percent or greater reduction has been made either by drawing or rolling. The cold working of metals results in strain and distortion of the grain structure with an accompanying increase in hardness and a decrease in ductility. In progressive cold working, a point is reached at which further deformation cannot be made economically or without structural damage to the metal. To restore the ductility for further cold working, the metal must be annealed by heating to a temperature where it recrystallizes, and the grain is changed to the proper size and shape. Annealing is also done after the last stage of cold working to obtain the desired temper or hardness or to relieve the strains in the metal to eliminate season cracking. This is generally referred to as relief annealing.

When copper that contains oxygen is to be annealed, the hydrogen in the atmosphere must be kept to a minimum to reduce the danger of embrittlement. Embrittlement results when the hydrogen in the atmosphere combines with the oxygen in the copper, forming water vapor under pressure and resulting in minute ruptures in the metal.

Commercial copper is one of the easiest metals to anneal, and yet it maintains a clean bright surface. Copper, of course, will readily oxidize at elevated temperatures to form cuprous or cupric oxide. Cuprous oxide is reddish or rose color and cupric oxide is jet black.

Materials are annealed in various forms. Tubes and rods are in straight lengths and in coils; strip metal is in flat strips and rolls; and sheets and plates are in flat form. Wire is annealed in coils, on spools, and in some instances in strands.

It is usually not practicable to anneal different sizes or kinds of material in the same charge because of different rates of heating and variable final temperatures.

Many types of equipment are utilized for heating and annealing. Selection of the size and type of furnace for a given application depends primarily on the particular heating process involved, the expected rate of production, and the most efficient means of moving the material to, through, and from the furnace.

The fuel may be oil, gas, or electric power—depending on cost, availability, and the furnace design. Gas or electricity is preferred, when economically available, because closer control of temperature is possible, and less surface scale or oxides are formed—resulting in less pickling and cleaning.

Heating Furnaces.—Furnaces for heating before hot working are selected to suit the forms to be heated and are usually side-fired, having oil, gas, or combination burners.

Furnaces for heating round billets may be the simple rolldown type, the conveyor type, or the push-through design. The hearth in the rolldown furnace is built on a slope, which allows the billets to roll from the charging end to the delivery end by gravity.

The conveyor-type furnace for heating piercer billets, 3 inches in diameter and 50 inches long, has a selective feeding mechanism, in which billets are laid down in bundles on rails adjacent to a chain-operated lifting device—incorporating star wheels for selective disposition of billets one at a time to a screw-fed conveyor. This type of furnace is built to handle billets to 8 inches in diameter. The billets are moved through the furnace by a screw-feed conveyor, and the surface of the billet is continuously exposed to the heat—assuring uniform heating.

A variation of the conveyor furnace is the so-called walking-beam type, in which bars or billets are intermittently moved forward mechanically by plates or arms which, moving in a vertical plane, emerge from the slots in the furnace bottom, move forward, withdraw below furnace bottom, and return to the starting point. Bars are thus picked up from the furnace floor, carried forward a few inches, and deposited again on the floor.

The push-through-type furnace for heating copper wire bars consists of a chain conveyor on which the bars are placed. As the conveyor moves forward, the leading bar is placed in a selective jaw-clutch, feeding device, which in turn delivers the bar to a table in front of the charging end of the furnace. Hydraulically operated pushers are employed at the charging end for pushing the material through the furnace. The bars rest on heat-resisting alloy rail while being pushed through the furnace. At the discharge end an extractor mechanism is utilized to remove the heated bar from the furnace. The heated bar is conveyed or is carried on a buggy to the rolling mill.

Annealing Furnaces.—Annealing furnaces are either of the batch or the continuous type. The nature of the material being handled, tonnage requirements, and operating conditions ordinarily will determine the type to be employed.

In the batch furnace, the materials usually are loaded on pans in comparatively high and broad stacks and pulled in and out of the furnace by cables. In such stacks, under ordinary conditions, the outer layers are the first to reach temperature, and the center of the stack is last. Also, on cooling, the outer layers are the first to cool. This results in a longer total heating and cooling cycle than is required in a continuous furnace.

In a continuous furnace, the material usually is loaded one layer high and conveyed through the furnace by driven rollers or other conveyance. This results in uniform distribution of heat above and below the metal.

An increasing number of furnaces with special atmosphere-controlling equipment are being used. When a specially controlled atmosphere is used during annealing of copper and alloys, a much cleaner metal surface is obtainable, resulting in a lower cost for cleaning and pickling. Controlled atmosphere may be produced with many different types of equipment, depending on the desired results. For bright or clean annealing, an inert-gas atmosphere usually is employed.

Another variation of the batch furnace is the bell type. Material to be annealed is piled upon a base, and a closed-top, cylindrical sheet metal retort is lowered over the charge. The lower rim of the retort fits in a water or sand seal in the base, thus effectively excluding air. A nonoxidizing gas is admitted to the charge area through the base, and after a purging period to displace air, an electric or gas fired heating bell is lowered over the retort, and heat is applied for a suitable period. At the end of the heating period the heating bell is removed; and the retort and its contents are allowed to cool by radiation, usually expedited by a water spray on the surface of the retort.

Cooling.—To obtain a clean or bright surface on annealed metal, the material must be cooled before being exposed to the air; usually, this is done in a separate chamber after leaving the heating chamber.

Cooling is best accomplished by rapidly circulating the furnace atmosphere through cooling devices around the material. Special water-cooled radiators have been developed for this purpose and have proved highly satisfactory. With the proper equipment, cooling may be accomplished in approximately twice the time required for heating. Some of the less-efficient cooling devices require greater intervals, up to two and one-half or three times the heating period.

Seamless Tubes

Tubes are produced largely by two methods—hot piercing or hot extrusion; both systems begin processing with a solid-cast cylindrical billet. The method of producing tubes by drawing a blank into a shell is not extensively employed. Cast shells are used for producing tubes with an outside diameter of more than 6 inches.

Preliminary forming by piercing or extrusion is followed by stages of cold drawing. Between the drawing operations, annealing and pickling take place.

The major steps in tube production may be classified as follows:

1. Preliminary forming by—
   a. Piercing.
   b. Extrusion.
2. Pointed (before drawing).
3. Cold drawing, annealing, and pickling in steps.
4. Straightening by—
   a. Roll.
   b. Medart.
   c. Block.
   d. Hand.
5. Finishing.

Piercing.—In forming tubes by piercing, the preheated billet is forced over a mandrel, by cross rolling, to form a shell. The temperature to which the billet is heated is determined by the composition of the metal and ranges from 1,100° to 1,600° F.

Extrusion is forcing the preheated billet under compression to pass between a die and a mandrel. The metal is preheated to a temperature sufficient to keep it in a semiplastic state, a range from 1,200° to 2,000° F, depending on the material.

No general statement can be made concerning the total cost of making tubes by piercing compared to extrusion. The number of billets that can be pierced per hour range from 60 to 70, requiring 1 or 2 operators; by comparison, from 20 to 140 billets can be extruded per hour, depending on alloy size and weight, and 4 to 6 operators are required. Extrusion generates widely varying percentages of scrap, whereas piercing produces very little.

All grades of commercial copper, the alpha copper-zinc alloys with less than 0.01 percent lead, the alpha-beta copper-zinc alloys with lead to one percent, naval brass, and leaded naval brass are readily pierced. Temperature ranges for piercing alloys are small, and close temperature control is required. If the billet is too hot, cracks may form on the inside of the tube, causing rejection; a cold billet would either retard the operation or stick in the machine. Initial billet temperatures for piercing range from 1350° F for naval brass to 1600° F for red brass and electrolytic copper.

The essential mechanical parts of a piercing mill, known as a Mannesmann machine, are two main driving rolls, a small guide roll, and a piercing mandrel or arbor (figs. 24 and 25). The driving rolls are shaped like two sections of a truncated cone, with their bases welded together, forming a ridge in the center of each. The rolls are set at an angle, so that these high points of the roll take the path of a screw thread. When the billet is entered in the rolls, and the rolls are rotated, they grip the billet in such a way as to force it ahead through the rolls just as a thread on a screw draws a nut down when the screw is turned.

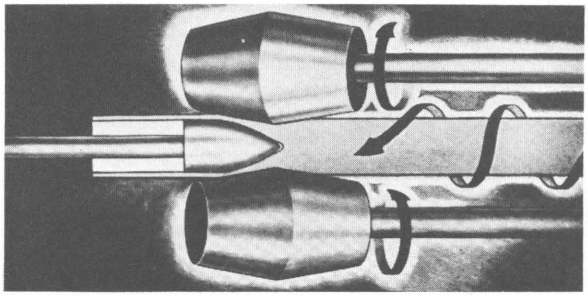

FIGURE 24.—Principle of Mannesmann Process.

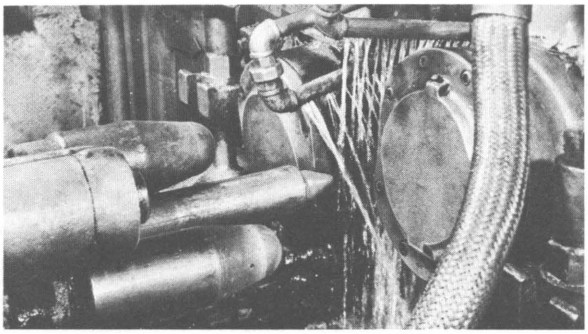

FIGURE 25.—Mannesmann Machine.

The guide roll is placed in the opening between the two driving rolls and well below the centerline. The centerline at the billet as it is being pierced must be below the centerline of the main driving roll, to keep the billet from jumping out through the opening at the top. The guide roll may be either straight or ground to a shape similar to the driven rolls.

The mandrel or arbor is a long bar of steel carrying a high-speed steel point at one end; the metal is rolled over that end to form a shell. The other end of the bar is held firmly in a swivel, so that the bar can rotate freely but cannot be withdrawn until the latch that holds it in place is released.

In addition to these essential parts, certain guides are necessary for the billet entering and the shells leaving the rolls. It is quite necessary to keep these guides in first-class condition to prevent scratching or tearing the surface of the metal; any such action would produce defects in the surface of the finished tube.

Diameter and length of the rolls are determined by the size of the billet to be pierced. Power requirements are determined by the size and speed of the mill. Two men are required to operate most piercing mills, but some of the newer mills are so arranged that they can be operated by one man.

Extrusion.—Extrusion is an intermediate operation to rough-form material from the cast state to a form approximating that of a tube, rod, or shape.

Certain alloys can be extruded much more readily than others because of lower resistance to deformation in the hot condition. For example, starting with an alloy containing 55 percent copper, the required extrusion pressures are at their lowest point. As the copper content is increased, the metal remains quite readily workable in the hot condition until an alloy containing approximately 63 percent copper is used; beyond this content the required pressure increases rapidly.

It was formerly considered impractical to extrude metal containing 66 percent or more of copper, but now, with increased pressures available and better knowledge of metallurgy, almost any of the copper alloys can be extruded.

Extrusion machines.—Extrusion machines are both vertical and horizontal; however, horizontal machines are generally used. The process of extruding tubes, rods, or shapes is similar, but the arrangement of certain parts of the machine is different. The die mechanism, including the die, is the same for all, while the container and the container liner are the same in principle. The container liner is backed by the container to provide greater strength. Differences are in the dummy block, the ram, and the piston moving through them. For tube extrusion, a second piston and ram within the main piston and ram are employed. The inner ram is called a mandrel and passes back and forth in the main ram independently. The dummy block has a hole through the center, through which the mandrel passes.

The ram varies from 7 to 10 inches in diameter and is backed by a large hydraulic cylinder, approximately 30 inches or more in diameter. The ram acts upon the dummy block, which in turn transmits the pressure to the billet. The ram is slightly smaller than the dummy block. The thin shell of the metal which pushes back around the circumference of the dummy block does not prevent the ram from being withdrawn at the end of the extrusion cycle.

Extruded tubes.—The great advantage of extrusion over other methods of producing tubes is that it lends itself to production of tubes of various alloys that cannot be pierced, and it also yields a dense shell that is substantially free from physical defects. The greatest weakness in extrusion is the difficulty of producing a concentric shell. A commercial extrusion operation should produce a shell with a wall thickness within 10 percent of perfect concentricity. Figure 26 is a picture of an extrusion press.

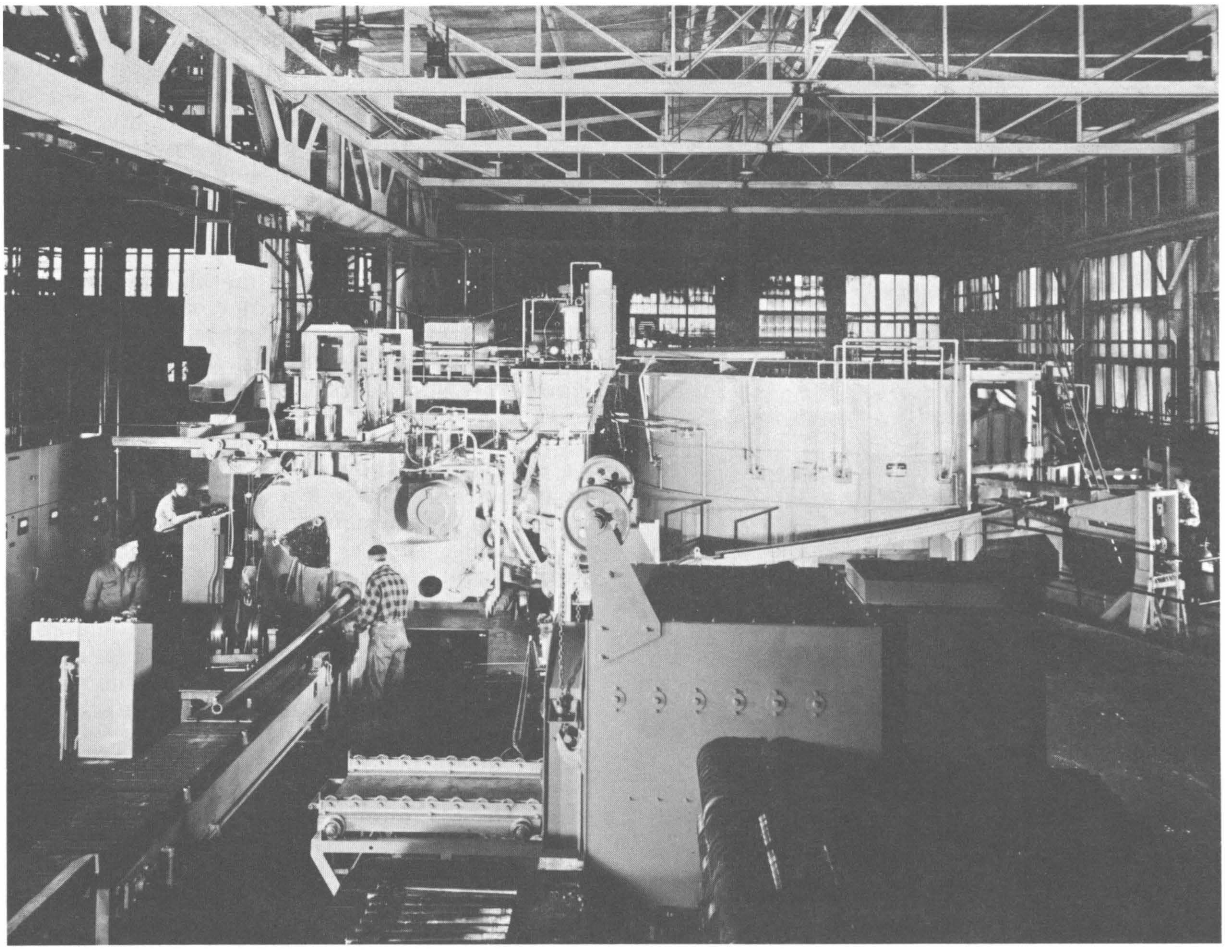

FIGURE 26.—Extrusion Press.
(Courtesy, Anaconda American Brass Co.)

After the tube has been extruded, it is sprayed or quenched in a tub of water. Then it is pickled; the ends are trimmed; and it is examined superficially for blisters and core. The front end of the extruded shell or tube usually is off gage, and it is common practice to cut it back or to use it for the point for the subsequent drawing operation.

Pointing.—The object of pointing is to prepare tubes for drawing. Pointing is a cold-working operation, and the conical point is from 8 to 10 inches long. The diameter of the point is prescribed by the size of the dies through which the tube must be drawn on the draw-benches. A tube is usually pointed to such a diameter that a point can be used for two or more draws, after which the tube is usually too long for redrawing and must be cut into shorter lengths. The previous points are also cut off, as they are usually too large for further use.

The smallest diameter to which a given tube can be pointed depends upon the alloy, temper, outside diameters, and gage. The more ductile an alloy and the softer its temper, the smaller it can be pointed. In some instances, the gage limits the extent to which the tube can be pointed, because as the end of the tube is swaged, its walls thicken; providing the alloy and temper will allow, a point diameter will be reached that will close up that end of the tube. Pointing the tube further is likely to overtax the machines and may yield points that will break during subsequent drawing operations.

After the tubes have been properly pointed, they are cold-drawn on bull blocks or draw-benches. Tubes cold worked on tube-reducing machines do not require pointing.

Drawing.—Whether the preliminary forming is by piercing or extrusion, tubes are finished to gage by cold working and annealing in stages.

Cold drawing reduces the outside and inside diameters and at the same time reduces the wall thickness and circular area of the tube. The inside diameter, as a rule, is reduced slightly less than the outside diameter, and the operation results in a smooth-finished surface inside and outside. During this operation the metal becomes hardened; hence, at intermediate stages the tubes are annealed.

Tube drawing to finished size on drawbenches is normally accomplished by one of four methods (1) Drawing over a fixed mandrel or plug; (2) drawing by sinking through a die with no mandrel on the inside; (3) drawing on and with a mandrel on the inside, causing the mandrel or arbor to travel through the die with the tube; and (4) drawing with a so-called floating plug. This plug is not attached to a plug rod. It is free within the tube and is composed of two cylindrical sections, differing in diameter and joined by a tapered shoulder. During drawing the forward motion of the tube forces the plug up to the die, its smaller diameter portion within the die defining the inner wall of the tube. The tapered shoulder to the larger diameter of the plug prevents the plug from being sucked through the die with the tube. The floating plug was originally developed for drawing tube in coils on a bull block where it is not possible to use a plug rod.

Tubes are also finished to size on bull blocks and on tube-reducing machines. Bull blocks are being employed more extensively owing to the demand for long, coiled lengths. Tube-reducing machines employ dies with tapered grooves. The dies are rocked back and forth over the tube, compressing the metal of the tube against a mandrel that governs the inside diameter. The tube is fed through the dies intermittently and rotated so as to distribute the working action over the entire circumference of the tube.

The drawing cycle of the draw bench is as follows:

1. The tube is threaded, tail first, over the plug and plug-rod, which is anchored in the back end of the bench.
2. The pointed end of the tube is then passed through the die, where it is grasped by the jaws of a carriage.
3. The carriage pulls the tube through the die over the plug. The size and shape of the plug determines the inside diameter of the tube, and the size and shape of the opening in the die determine the outside diameter of the finished tube.

The drawbench consists of a horizontal frame that has a mechanical drive at one end, a die through which the tube is drawn, and a tailstock at the other end. An endless, square-linked chain passes through the center, lying in a channel at the top of the frame and returning beneath the bench and over an idler at the opposite end of the bench. The chain sprocket is driven by a variable-speed motor. A carriage equipped with jaws to grip the pointed end of the tube runs on tracks along the top of the drawbench and is automatically engaged with the continuous chain. Modern drawbenches are constructed to draw one or more tubes simultaneously.

The benches are rated in pounds of pull, corresponding to the rated capacity of the main chain and die stand. Common ratings are 1,000 to 300,000 pounds, although some benches are rated as low as 500 pounds.

The smaller benches are used for drawing capillary tubing or items even as small as hypodermic-needle stock, while at the other extreme the larger benches are used to work tubes to 16 inches in diameter.

Figure 27 illustrates a drawbench in operation.

Tube straightening.—Straightening is done after drawing to finish size or after the last anneal, to eliminate any general or local curvature resulting from mill processing. After straightening, the finished tubes are cut to specific straight lengths or furnished in coils or straight lengths.

Straightening may be done by one of four methods, depending on the size and temper of the finished tube.

Roll straightening.—Roll straightening is done in a machine equipped with 8, 12, 16, 20, or more rolls, with a semicircular circumferential groove to fit the size of the tube to be straightened. The rolls are arranged in tandem and staggered and adjusted so that as the tube is passed between them it is sprung back and forth slightly by the rolls. Each set of eight or more rolls is divided into two groups. One group springs the tube back and forth in a horizontal plane and the other group in a vertical plane. Of each group, only one side is power driven; the other side revolves freely. With proper adjustments, any hooks, bows, or crooks in the tubing can be straightened. Cross-roll straighteners employing five or six rolls are also used.

Medart straightening.—In Medart straightening, two power-driven rolls are used, one with a straight surface and the other with a concave surface. The two rolls are contraposed at vertical angles. Between and below the center of the rolls is a babbitt guide. Once the tube is started in the rolls, the machine propels it through, rotating it and effecting a straight tube. This method of straightening makes possible the manufacture of copper tubing with a satisfactory spiral bending temper. The tubes are annealed before Medart straightening, which in turn hardens and stiffens the annealed tube. The machine also imparts to the tube a peculiar finish resembling a polish.

FIGURE 27.—Draw Bench.
(Courtesy, Anaconda American Brass Co.)

Block Straightening.—Block straightening is a manual operation performed on tubing that cannot be rolled or Medart straightened because lengths are too short; diameters, too large; or gages, too thin. Also, tubing that needs to have only a slight crook removed can be conveniently block straightened. One end of the tube is anchored, and the remaining part of the tube is sprung to a degree that will remove any bends.

Hand Straightening.—Another manual method, hand straightening, ordinarily is used for straightening tubes more than 3.5 inches in diameter. One end of the tube is rested on a low horse, and the other end is raised above the floor to a height that will spring the tube straight when it is dropped or forcefully thrown down. Tubes also are straightened by placing the ends on blocks and moving a hand-operated hydraulic press along the length of the tube.

Rods and Shapes

Copper-base alloy rod usually is produced by extrusion and processed to finish by cold working. Some rods are hot-rolled in mills equipped with grooved rolls; the slightly rough hot-rolled surface may be ground or turned on a lathe. In some instances rods are cold rolled from cast billets to finish.

Practically all brass rod is produced by extrusion. Extruded rods are round, hexagonal, or square cross sections. Rods as small as $\frac{5}{32}$ inch in diameter may be extruded in particularly soft alloys, but standard practice is not to extrude rods smaller than $\frac{7}{16}$ or $\frac{1}{2}$ inch in diameter.

Rod smaller than $\frac{3}{4}$ inch in diameter is usually extruded through a multiple-hole die, and it is generally coiled hot as it comes from the extruder. Larger diameters to $1\frac{1}{4}$ inch are extruded through a multiple-hole die in straight lengths. Diameters larger than $1\frac{1}{4}$ inch are extruded through one-hole dies.

Shapes consist of a variety of simple and complex cross sections and sizes (fig. 28). Extrusion is often the only economical production method, as it produces shapes with good surface, free from porosity, that have uniform properties. Extrusion subjects the metal to high pressures and a thorough working, which develops a dense, fine-grained structure. Successful extrusion of complex shapes depends mainly on die design. Rod dies are similar to tube dies and are subject to the same conditions.

The major steps in rod or shape production may be classified as follows: (1) Extrusion; (2) pointing; (3) cold drawing, pickling, and annealing in steps; and (4) finishing.

Extrusion.—Extrusion machines are similar to those used to fabricate tube, except that they use a solid ram and dummy block and do not need a mandrel. The extrusion operation is essentially the same as for tube extrusion. The billets are received from the plant-casting shop and vary in diameter and length, depending on the alloy and the size and number of pieces to be extruded. Inasmuch as the rods and shapes are solid, it is unnecessary to have two independent rams, as is the case in tube extrusion.

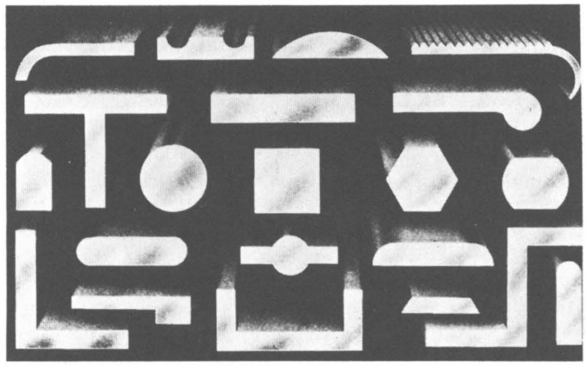

FIGURE 28.—Extrusion Shapes.

Because pressure is exerted against the billet, there is no place for the metal to go, except out the hole in the die; it therefore flows through this hole, forming a rod or shape having the exact contour of the die opening, except for cooling shrinkage; allowance is made for this in die design.

Generally, at the end of the extrusion operation, a butt of 2 or 3 inches is left. To make certain that the rod after being extruded does not contain core for a part of its length, all rods are given a nick and break test, so that the fractured surface can be examined for possible flaws. A saw cut may not disclose a core defect.

The extruded rod or shape after leaving the extrusion machine carries a light oxide film that is readily removed by pickling.

Pointing.—All rods and shapes are pointed before receiving a drawing operation. The pointing is accomplished in a swaging machine, by machining, or rolling, or by a combination of these procedures. The point must be small enough in diameter so that it may be inserted through the drawing die.

Drawing.—Rods and shapes are brought to final dimensions, or to form a shape that cannot be extruded to the finished form, by one or more cold drawings or sizing operations with suitable intermediate annealing and pickling stages when necessary. The final temper of the rod is controlled by the amount of reduction in area and annealing. The machines used for drawing rods and shapes to final dimensions are bull blocks, drawbenches, or continuous-rod drawing machines.

Bull blocks are used for both intermediate and final drawing on small-diameter rod. The block has provisions for a die and a rotating drum on which the material is coiled.

Drawbenches used for drawing rods or shapes are similar in design and capacity to those described for tubes. A carriage or tongs, having a hook or grip jaw, grips the pointed end and draws the material through the die, reducing it in diameter or changing its form.

A continuous rod machine consists of a preliminary straightening unit, drawing unit, cutting-off device, and final straightening and polishing unit. It has definite advantages over the drawbench, as it automatically reduces the cuts to a specified length in one operation and only one operator is required (fig. 29).

Finishing.—Rods finished to size on drawbenches or bull blocks receive one or all of the following operations: Annealing, straightening, cutting to length, chamfering, and coiling. Shapes usually are straightened and cut to length after drawing or sizing.

Rolling: Strip, Sheets, and Plates

Rolling is the process used to reduce the cross section of a material by compression between two cylindrical rotating bodies, known as rolls. By successive rolling operations, ductile metal can be reduced to an almost unlimited extent, provided that the ductility of the metal is not destroyed by work hardening. In fabricating copper and copper-base alloys, rolling is applied principally to flat shapes, including strip, sheet, and plates. The selection of roll materials is based largely on the desired surface hardness, which varies with the alloy and the class of work for which the rolls are designed.

The classification of flat-rolled products varies somewhat in the trade, but, in general, flat metal to 20 inches wide is referred to as strip, and that wider than 20 inches is classified as sheet; metal thicker than 3/16 or 1/4 inch is called plate. Rolled products less than 0.006 inch thick are termed foil.

Rolling may be either hot or cold, depending on conditions. Rolling mills are designated two high, three high, or four high, according to the number of rolls.

The actual rolling is conducted in several stages to reduce the metal thickness progressively. Annealing, milling of the surface of alloys after the first rolling cycle, pickling, and edge trimming may be necessary at various points.

Hot Rolling.—There is no essential difference in principle between hot and cold rolling, but in hot rolling, advantage is taken of the fact that certain metals and alloys become more malleable at elevated temperature. Copper, for example, is extremely malleable at temperatures between 1,200° and 1,700° F. Maximum reductions per pass are limited by the diameter of the rolls and the horsepower applied. In hot rolling copper, about 90 percent total reduction is usually taken in 11 or 13 passes, that is, from 4 5/8 inches to 0.200 inch. With brass alloys that may be hot-rolled, the total reductions and number of passes vary at different plants, depending largely on the thickness of the original casting, which will range from 3 to 5 inches. It is common with brass alloys to hot roll to 0.5 inch for convenience in subsequent surface-milling operations, which become slow and expensive if the gage is too light. Provided the metal or alloy is ductile and malleable while hot, the only factor limiting total possible reduction is the ability to retain the internal heat of the slab; this heat is constantly being lost by radiation and transmission to the rolls and runout tables during hot rolling.

Copper-zinc alloys containing 65 percent or more copper can be successfully hot-rolled, provided certain impurities are held to small traces. Lead is the most harmful of the common impurities in its effect on hot rolling these alloys, because it precipitates at the grain boundaries during solidification after casting, and at the normal rolling temperature of 1,300° to 1,600° F it is present in the molten state, markedly lowering cohesion of the grains. Lead should, therefore, preferably be restricted in these alloys to not more than 0.03 percent. Below 65 percent copper, lead can be permitted in gradually increasing quantities to 2 or 3 percent in alloys of 58 to 60 percent copper without harmfully affecting the hot-working qualities, owing to the presence of the highly plastic beta phase in the alloy. Copper-aluminum, copper-tin, copper-silicon, and other combinations of these alloys can also be successfully hot-rolled, provided harmful impurities are kept to a minimum.

The physical structure of the cast slabs is also important in hot rolling. A long, columnar, grain structure produced by high-temperature pouring and slow cooling is undesirable; cohesion of this structure is less than in the more equiaxial type produced by lower pouring temperatures and more rapid cooling. A columnar structure possibly tends to produce intercrystalline fissures, which develop into surface cracks as the structure is changed from a vertical to a horizontal position during the rolling operation.

The harmful effects of structure are most pronounced during the first three or four passes; once recrystallization takes place, the slabs become more homogeneous and malleable.

From the above considerations, it is obvious that applications of hot rolling are limited to

FIGURE 29.—Automatic Rod Drawing, Finishing, and Cutting Machines.
(Courtesy, Anaconda American Brass Co.)

specific metals and alloys and large masses that retain heat long enough to permit reduction to the required gage; this can be brought about by using large castings or high-speed rolling on tandem mills.

Because slabs have a tendency to spread in width during hot rolling, resulting in stresses on the edges, it is desirable to use edging rolls with the hot mill. These edging rolls serve doubly in maintaining accurate width and in working the edge structure to prevent edge cracking.

The principal advantages of hot rolling may be summarized as follows: (1) Less power consumption for equivalent reduction; (2) heavier reductions per pass; (3) greater total reduction before annealing is necessary due to self-annealing properties of the hot metal; (4) flexibility in width of casting due to ability to cross roll; (5) faster flow of metal down to milling gage for quick delivery.

Cold rolling.—In contrast to the limited application of hot rolling to alloys with a closely controlled analysis, it is possible to cold-roll almost any brass or bronze alloys that have any degree of malleability, provided the reductions are controlled within the limits of malleability of each particular alloy. Cold rolling, therefore, is not only more suitable for a wider variety of alloys but, in addition, finds great application in high-speed rolling of strip products.

The cold-working property of metal depends on its mechanical properties, principally tensile strength, hardness, and ductility. Ductility is particularly necessary, since without it no cold work can be done; however, strength is also an important factor. Ductility is highest and strength lowest in fully annealed metal; therefore, such material has the greatest capacity for cold working. The effect of cold working is to increase the tensile strength and elastic limit and to reduce the elongation and reduction of area.

When any metal or alloy is subjected to deformation at a temperature below the recrystallization temperature, it becomes more resistant to flow; with increasing deformation a point is finally reached when further working produces brittleness, and the material begins to crack. In cold rolling, the rate of deformation is frequently very high, and cracking first appears at the edges of the strip, the zone of least support. These cracks form along planes at an angle to the direction of rolling, indicating that the metal fails under shearing stresses. When this state is reached, the internal structure of the crystal grains has been completely altered and is in the form of long fibers. These fibers differ in appearance, depending on the structure of the bar before cold rolling and on the type of alloy. If the structure before rolling is in the cast condition, some indication of the original coarse structure will be present, unless the reduction has been at least 50 percent. If the bar has already been rolled and annealed, the initial structure would be much finer and consequently more readily obliterated by cold rolling. Under microscopic examination at high magnification, it will be seen that the fibrous structure consists of greatly elongated crystals that have been caused to slip along cleavage planes. This condition is accompanied by a considerable increase in hardness. This fibrous structure must be converted to a homogeneous equiaxial condition by annealing at a suitable temperature for a given length of time. The material will thus be reduced to its original soft condition ready for further rolling.

Metal is finished with some degree of rolled or drawn temper, that is, cold work having been applied as a final operation, or in some degree of annealed temper, with an anneal as the final operation. For sheet and strip the amount of cold rolling is conventionally expressed in B&S (Brown & Sharpe) gage-numbers reduction. The tempers represented by these gage numbers are:

Temper Designation:	*Approximate B&S-numbers reduction in thickness, following last anneal*	*Approximate percent reduction in thickness, following last anneal*
Light cold rolled	½	6. 0
Quarter hard	1	10. 9
Half hard	2	20. 7
Three-quarter hard	3	29. 4
Hard	4	37. 1
Extra hard	6	50. 1
Spring	8	60. 4
Extra spring	10	68. 6

Cold rolling can be performed on single two-high and four-high mills or on tandem mills of various types and combinations. Cold rolling shows to the best advantage in high-speed strip production, and output speeds as high as 1,000 feet per minute have been obtained on mills equipped with automatic blockers, although such speeds may require somewhat lighter reductions. Experience indicates that a speed of 400 feet per minute on copper or brass 0.003 to 0.010 inch thick can be satisfactorily maintained with a reduction of at least 30 percent per pass with good control of gage and flatness. Little is to be gained by increasing speed if this is done by sacrificing the amount of reduction that can be obtained. However, with development of better coolants of soluble oils, applied through pressure jets; by hydraulic control of roll pressure, operated by automatic gages; and by various other improvements, there is no reason to believe that the limit of rolling speeds has been reached.

The principal advantages of cold rolling over hot rolling are: Greater variety of alloys that

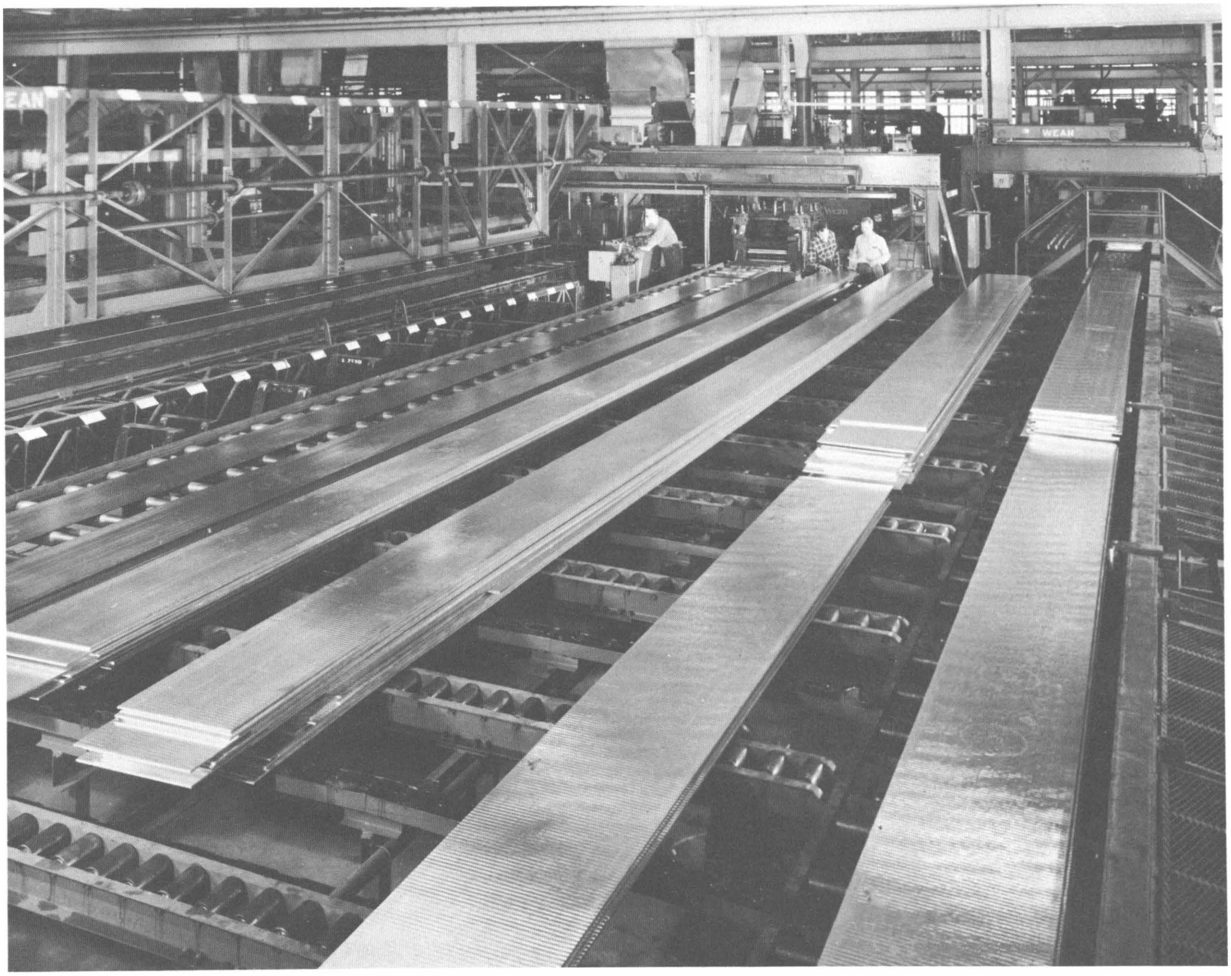

FIGURE 30.—Hot-Breakdown Rolling, Scalping and Conveying Copper and Brass Plates.

(Courtesy, Anaconda American Brass Co.)

can be rolled; no heating required before breakdown; better surface quality; less expensive roll maintenance; and better gage control, making for greater precision in subsequent operations.

Using first-class equipment in both cases and weighing all factors except purity of alloys, it would appear from cost data that hot rolling is preferable for alloys equally suited for either process. In a highly diversified mill manufacturing relatively small tonnages of a large variety of alloys, cold rolling would be preferable, owing to its flexibility. In a mill producing large tonnages of copper and simple hot-rollable alloys, the preference would be toward hot rolling.

Rolling Operations

Rolling operations are commonly divided into three stages: (1) Breakdown, (2) rundown, and (3) finishing.

Breakdown Rolling.—Breakdown rolling is the operation of breaking down the coarse, cast structure of the slab or cake to a heavy-stock point, when the rundown operation begins. There is no definite demarcation between the end of the breakdown and the beginning of the rundown operation, but in brass rolling the breakdown operation is usually considered as taking the metal from the cast thickness of 3 to 5 inches in hot rolling or $1\frac{3}{4}$ to $2\frac{1}{2}$ inches in cold rolling to a gage from 0.4 to 0.6 inch.

In hot rolling, the metal is not annealed during this rolling stage; in cold rolling two or three anneals may be necessary. After the brass is rolled to 0.4 to 0.6 inch, approximately 0.010 to 0.015 inch is scalped off the top and bottom surface of the slab to remove any of the cast surface remaining after rolling. Figure 30 illustrates the hot-breakdown rolling, scalping, and conveying system.

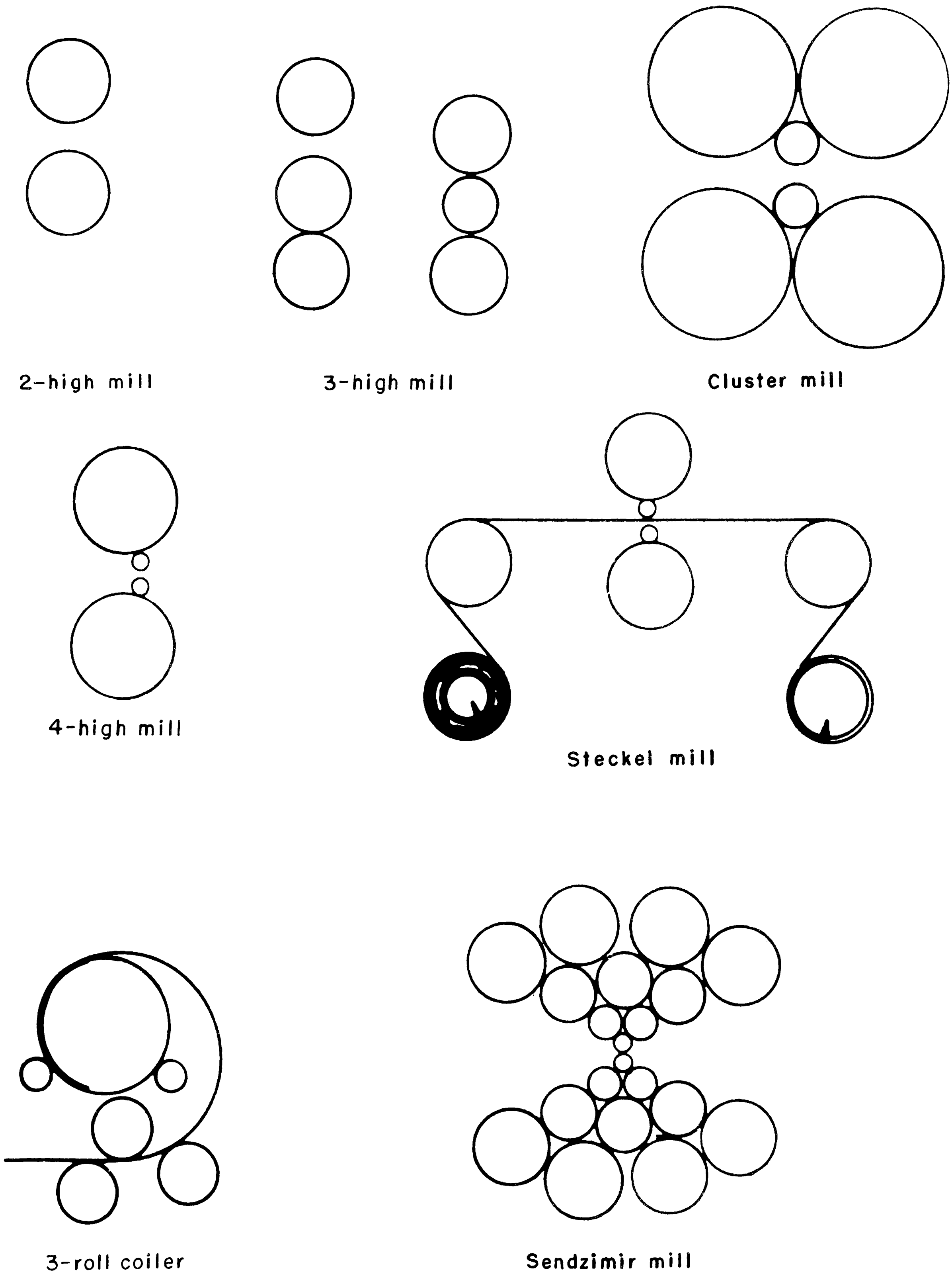

FIGURE 31.—Roll Arrangements.

The three-high mill, when equipped with three rolls of the same diameter, is used for breakdown and sometimes for rundown. The metal receives a reduction when traveling in one direction between the lower and center roll, and in the other direction between the center and upper roll. A lifting table is necessary to raise the metal for the returning reduction pass between the center and upper roll. Maintenance costs are high for this type of equipment, and it is being replaced by the two-high reversing mill for breakdown and the four-high mill for rundown.

Rundown Rolling.—The three-high mill, when equipped with a small-diameter center roll, is used for rundown and finish rolling.

Contact friction is largely a function of roll diameter and the metal thickness reduction ratio per pass. To reduce friction, it is desirable to use small-diameter rolls. Small rolls, however, will deflect easily under the roll pressures and it is, therefore, necessary to provide stiffness with larger-diameter supporting or backing rolls.

It has been found that, as the working rolls are decreased in diameter, the power requirements are lowered, and the ratio of reduction may be increased; since it is possible to reduce the metal more between anneals without cracking the edges. This also reduces the number of annealings required.

Those considerations led to development of mills utilizing small-diameter work rolls, such as the cluster mill, Steckel mill, Senzimir mill, and four-high mills. Diagrams of the roll arrangements of various mills are shown in figure 31. Senzimir mills have become very popular in the United States since 1950. The first application of four-high mills for producing sheet copper in the United States was in the late 1920's, and they have since been widely adopted for rundown and finish rolling of strip and sheet.

A four-high mill, as the name implies, consists of four rolls, one on top of another. The middle two are the work rolls, between which the metal is reduced in thickness. The other two are backup rolls and support and lend rigidity to the work rolls. The backup rolls usually run idle; the work rolls are driven. The work rolls are considerably smaller in diameter than those in an ordinary two-high mill.

The three-high mill, incorporating a small work roll, acts on the same principle as the two small working rolls in a four-high mill, that is, it reduces the area of contact between the roll and metal.

The three- and four-high mills are generally used for rolling in one direction only. The initial cost of a three-high mill is less than that of a four-high mill.

Rundown rolling is usually done cold and begins where breakdown rolling ends, taking the metal down several gages closer to the finish gage, depending on finishing requirements. Annealing and pickling operations may be introduced at various points during the rundown operations.

After breakdown sheets may be rolled hot either in single sheets or in packs of two, three, or four sheets. Plates may be rolled hot or cold.

Figure 32 illustrates cold rundown and finish rolling of close tolerance strip metal, such as automobile radiator copper.

Finish rolling.—Finish rolling may consist of several operations from rundown to finish gage. The metal is annealed and pickled at various points between. Rolling terms used to describe the finishing between anneals are ready-to-get-ready, ready-to-finish, and finish. Final rolling determines the finish gage and frequently the temper and flatness.

Pickling Equipment

Pickling is done in several types of machines. For heavy-gage metal the continuous-type machine is employed. Metal is fed into a roll leveler through troughs containing the pickle solution, which is recirculated; through troughs containing water (cold or hot), to wash off the acid remaining on the surface; and through brushes and driers. It is coiled as it leaves the machine.

For metal 0.030 inch and thinner, the pull-through-type machine is employed. The starting end of the coil of metal is attached to the end of the previous coil and is pulled through the pickling solution, cold and hot water wash, brushes, and drier and wound into coils on spindles at the delivery end of the machine.

Metal is also pickled on racks in tubs, so that the flexibility inherent in a batch-type operation may be utilized.

In general, pickle solutions are mixtures of sulfuric acid, nitric acid, potassium bichromate, and water.

Copper and copper alloys are generally pickled in 5- to 10-percent sulfuric acid at room temperature to 125° to 150° F. Various other pickling solutions are also in use.

Finishing Equipment

Finishing equipment may consist of slitters, shears, roller levelers, stretcher levelers, and saws.

Slitting is done to bring rolled metal to finished width. The machine used for slitting

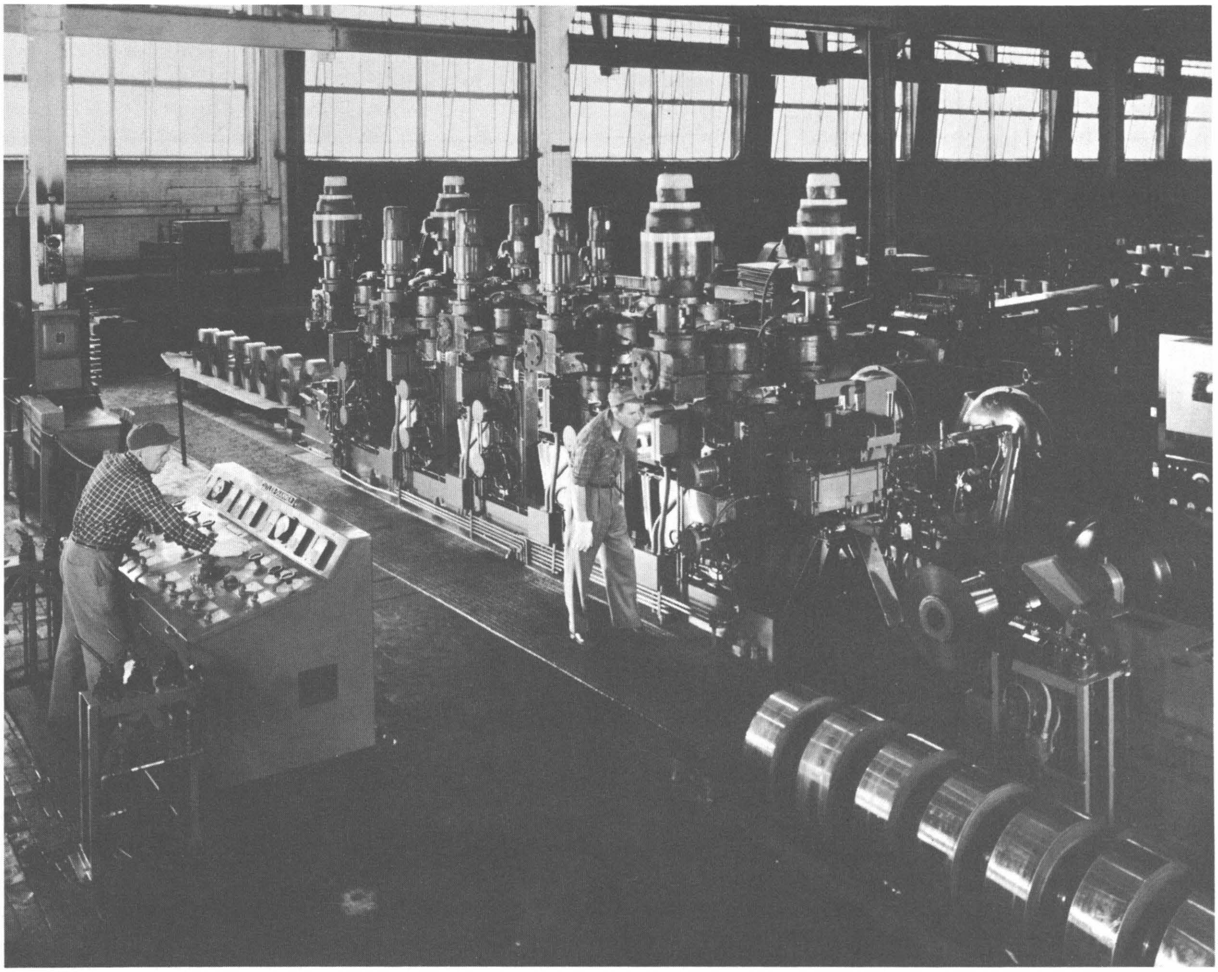

FIGURE 32.—Rolling Close-Tolerance Strip Metal.
(Courtesy, Anaconda American Brass Co.)

consists of rotary cutting shears mounted on two parallel shafts, which are rotated in opposite directions and driven by a motor through suitable reduction gearing. The rotary cutters are from 2 to 16 inches in diameter and from ⅛ to ¾ inch thick. A coiler or winder mechanism at the exit end of the slitter is used for rewinding the slit width.

Shears are used for cutting sheet metal to finished size and for flat strips. Metal to be sheared is flattened before cutting to size by passing it through a roll leveler consisting of five to nine or more rolls. Roll levelers are also used to straighten and flatten strip material.

Examples of Rolling Practice

Rolling-mill practices are determined by the form and composition of the product; the final gage, temper, surface requirement, and quality; and the type of equipment available.

Breakdown practices are closely similar for all types of rolling; variations are degree of reduction, choice of hot or cold rolling, and other factors.

Strip metal is cold-rolled after breakdown to finish. The number of roll passes, anneals, and pickling operations is determined by the methods employed, the machinery and equipment utilized, and by the layout.

Sheets of copper or brass may be hot- or cold-rolled, after breakdown to finish in single sheets or in packs of two or more. Soft sheet copper may be cold-rolled to finish, with one intermediate annealing and one finish anneal. If cold-rolled temper is required, it is obtained by one light pass on a dry roll. When accuracy of final gage for sheet copper is not essential, as average weight per square foot, the practice of hot rolling to finish is sometimes followed.

Sheet brass, when hot-rolled after breakdown, is usually taken only to the ready-to-finish gage and is then cold-rolled to finish in single sheets on dry rolls. Owing to the difficulty of milling wide brass sheets after the breakdown operation, it is the usual practice to scalp the surface of the casting before rolling, when the surface is smaller.

Rolling alloy plate is the same in principle as sheet rolling; that is, the castings are scalped before rolling, brought to the size by cross rolling and finished either hot or cold, depending on the physical requirement. After rolling to gage, they are flattened through heavy roll levelers. Plates for such items as condenser heads are frequently cut to specified shape by a band saw or on a boring mill as a final operation.

Electrolytically Deposited Copper Sheet

This is pure electrolytic copper foil, deposited as a thin, continuous roll on rotating drums directly from the refinery electrolyte. It is produced in thin gages and wide widths, in continuous rolls. It is used for printed circuits for radio, television, and other electrical apparatus. Bonded to other materials, it is used in building applications for dampproofing, weatherproofing, heat sealing, vapor sealing, ridge flashing, electrostatic shielding, gaskets, capping, cable-wrapping, reflectors, and decorative applications. Figure 33.

Wire Fabrication

Wire is fabricated by hot rolling wirebars or by hot extrusion of billets into rods about ¼ or 5/16 inch in diameter, which are then cold-drawn through various stages into wire. Extrusion is usually employed when alloy rods are produced.

After the wire is drawn to finish size, it may be either shipped bare or receive one or more of the following operations: Enameling; tinning; stranding; or insulating with rubber, paper,

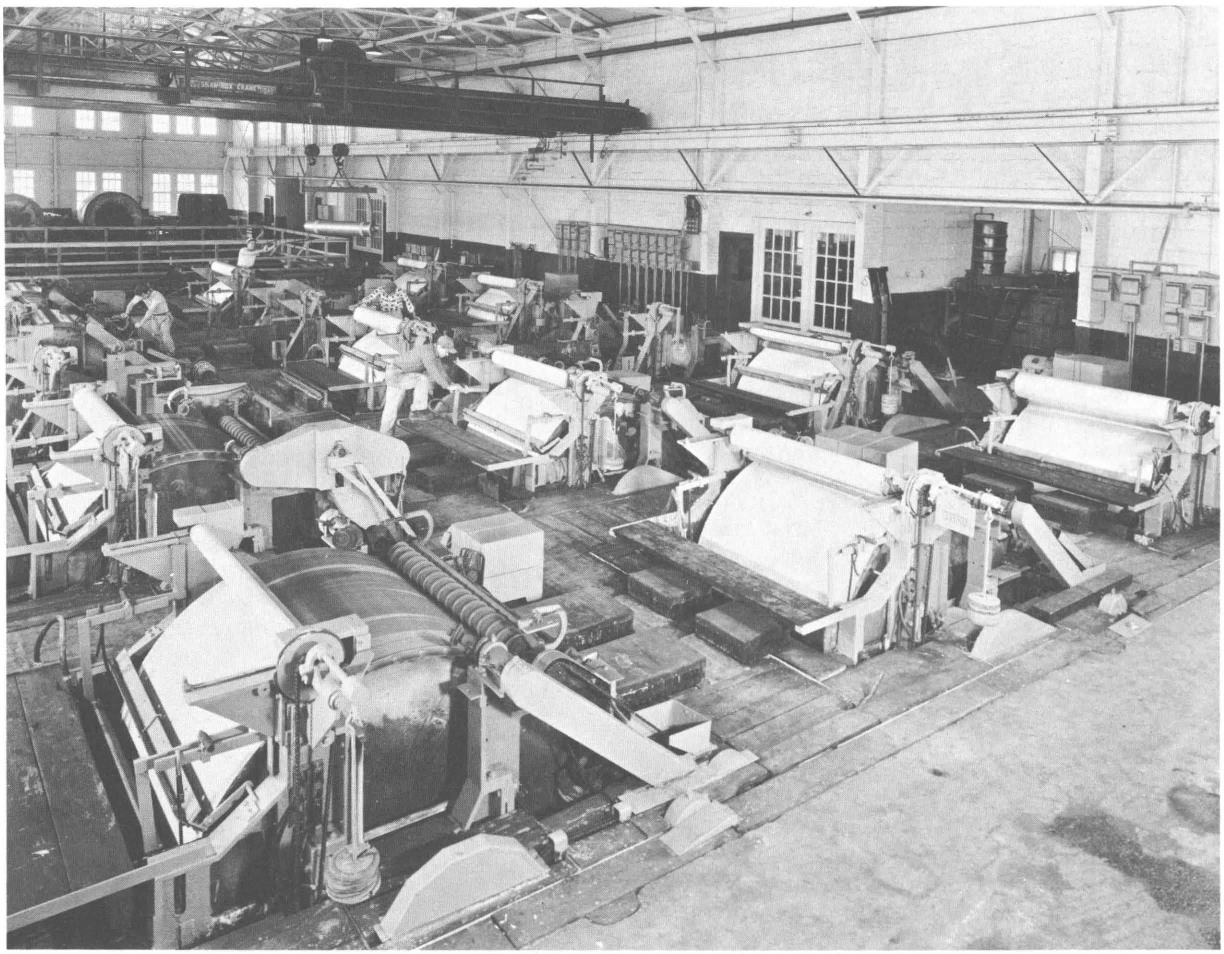

FIGURE 33.—Electrolytically Depositing Thin Copper Sheet.

(Courtesy, The Anaconda Company)

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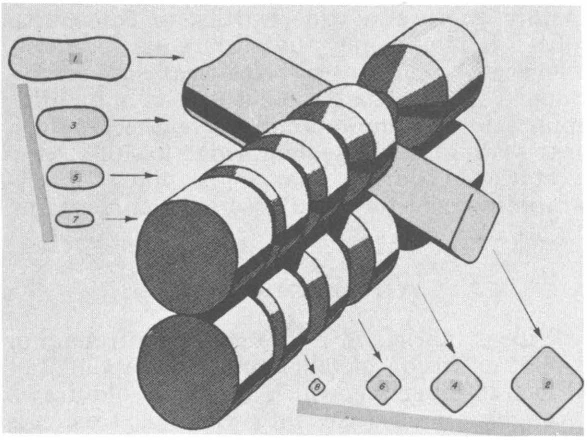

FIGURE 34.—Breakdown Rolling of Wirebar to Rod.

plastic, glass fiber, silk, or cotton. These operations are not described herein.

The major steps in wire production are as follows: Preliminary forming by rolling, extrusion, cold drawing, pointing, pickling, and annealing; finishing by enameling, tinning, or insulating.

Preliminary Forming by Rolling.—The wirebars used for rolling into rods for further fabrication into wire weigh about 250 pounds each, as received from the refineries. After heating to a predetermined temperature the bars are delivered to a breakdown mill.

Wire-rod rolling mills are designed to effect thorough hot working of the metal coincident with size reduction. In the breakdown mills the initially square section of the wirebars is progressively changed to an elongated hexagon, an oval, a square, an oval, and finally to a square. See figure 34. In the rundown and finishing mills, square and oval shapes alternate until the final round section is formed. In addition, the rod is given a 90° twist between successive passes, which is done automatically with twisting guides.

The breakdown mills are followed by a succession of rundown and finishing mills to complete reduction of the wirebars to wire rods.

The mills may be arranged in a straight line or train. A typical train consists of one three-high breakdown mill; one or two two-high rundown mills; and eight or more two-high intermediate and finishing mills.

Modern production requirements have led to development of a tandem arrangement of mills. A typical tandem assembly comprises one three-high breakdown and eight two-high intermediate and finishing mills, and four coilers. This arrangement is primarily for producing ¼-inch round rods. Rounds can also be coiled off at intermediate sizes between ¼ and ⅞ inch. To facilitate coiling rods of various diameters, two of the four coilers are movable, and two are stationary.

Wire-Drawing Benches.—Wire-drawing benches usually are used for making drafts on wire beyond the capacity of ordinary continuous-drawing machines and are especially useful for heavy work, as well as for meeting numerous demands that arise when only one or two drafts are required on finer sizes. Wire-drawing benches consist essentially of vertical spindle blocks arranged in a continuous frame with a single main drive. In the general operation of a wire-drawing bench with draw-out motion, the wire (which has first been pointed) is inserted through the die, gripped from the opposite side by tongs, pulled through the die, and fastened to the block. The block is set in rotation by a foot treadle, and the finished product is delivered in coil form. The draw-out motion is a device for pulling a short length of wire through the die and up to the die block. For the convenience of the operator, the draw-out motion should not run more than 20 to 30 strokes per minute, depending on the size of the bench.

In the operation of a bench without draw-out motion, the end of the wire rod after being inserted through the die is gripped by a hand-wedge grip that is attached to the block while it is not in motion. This arrangement, which operates semiautomatically, dispenses with any independent draw-out motion by tongs or other means.

Continuous-Drawing Machines.—Various types of continuous-drawing machines equipped with multiple-die arrangements, and combinations are used in large-scale wire drawing practice. As many as 21 dies have been used.

Bus Bars and Commutators

Bus bars, commutators, commutator segments, and other shapes and forms used by the electric industry are produced by hot rolling and cold working to finish size.

The major steps in producing these products may be classified as follows:

1. Preliminary forming by hot rolling.
2. Pickling at various stages.
3. Pointing before drawing.
4. Cold working by either:
   a. rolling.
   b. drawing.
5. Annealing at various stages.
6. Finishing by:
   a. Straightening.
   b. Edging.
   c. Sawing.
   d. Stamping.

The equipment and procedures are similar to those already described for corresponding stages of rod and wire production.

Print Rolls

Print rolls are used to print various designs on fabrics and for other printed matter. The rolls must be fine grained, have good surface and uniform properties, and be free from all porosity. Print rolls are made by hot extrusion. Solid-cast billets of various diameters and lengths, received from the refineries, are heated to a predetermined temperature and extruded into a solid round to a diameter somewhat larger than the desired finished size. The extruded rounds are then heated and subjected to another extrusion operation, which forms a shell with a very heavy wall. The surface of the extruded shells is finished to size on specially designed turning lathes.

Scrap

In manufacturing copper and copper-base-alloy products, approximately 50 percent scrap is generated when billets, slabs, or cakes are cast and processed into finished products. This is considered a reasonable overall average when all products fabricated are considered.

The scrap generated for each product will range between 30 and 60 percent—depending on the product being manufactured, type of equipment used, and the method employed. In addition, there is a zinc loss of approximately 1 percent when casting alloys. There is also a metal loss of approximately 3 percent during manufacture of copper and alloys, beginning with receipt of the raw materials and ending with the finished products; this is a nonrecoverable loss.

The scrap generated by fabricating copper and nonferrous alloy products is in the following form and originates from:

Melting furnaces—skimmings, spills, and drosses.

Casting—gates, physical defects, rejects due to off mixture.

Processing tube—butts and slugs from extrusion operations, pieces cut from the ends of extruded and pierced tubes, points, saw cuttings, and rejects due to offgage surface defects, etc.

Processing rod and shapes—butts from the extruder, rod ends and points, saw cuttings, rejects due to wrong size or dimensions, etc.

Processing strip—sheets—plates—milling or scalping scrap from overhauling slabs or cakes after breakdown; points and tails cut from the ends of the coils or sheets before entering the rolls; trimming scrap from the slitters or shears; rejects due to offgage, wrong temper, grain structure, or other defects.

All this scrap is classified as plant or production scrap and is usually consumed in the plant of generation without any treatment except the skimmings, spills, and drosses.

By its very nature, scrap is bulky and difficult to handle; the customary practice is to bale the light scrap and to cut the heavy scrap to suitable size, so it can be handled more easily when in storage and when charging.

The secondary manufacturer generates 30 to 60 percent scrap as clippings, trimmings, stampings, borings, and turnings when processing copper and copper-base products into semi-finished and finished articles. The actual percentage of scrap generated varies with the article being manufactured. Scrap also originates from surplus, obsolete, damaged, or idle inventory.

This type of scrap is classified as processed or new scrap that can be utilized by copper and copper-base alloy fabricators when casting billets and slabs without any treatment except borings and turnings that are put over a magnetic separator to remove any ferrous scrap, such as iron fines, fuzz, or filings. Also available at times are certain types and grades of usable old scrap. All grades and types of old copper and copper-base alloy scrap that cannot be utilized by the fabricators, owing to composition or corroded condition, or that has been soldered, enameled, or plated is classified as old scrap. Old or new tube scrap usually is not accepted by the fabricator unless special arrangements are made. Tinned scrap is accepted only if the tin content can be determined. Typical types of old scrap that are acceptable are fired cartridge cases, copper roofing, discarded trolley wire, transmission lines, bus bars, and other utility and industrial scrap—when properly graded.

Some fabricators have installed refinery furnaces to melt down old scrap not usable due to its composition or condition, to reclaim the copper and zinc to obtain their metal requirements, and to reduce their metal costs.

It is not always possible for a fabricator to obtain scrap from the various secondary manufacturers, because they do not always keep the various grades separated and, in most cases, they do not have enough storage space to accumulate a sizable amount for shipment back to the fabricator.

Therefore, large amounts of this new scrap are lost to the fabricators as they have no means of collecting small individual lots of scrap generated by the secondary manufacturers and other users of copper and alloy products, such as plumbers, sheet-metal concerns, and others, who obtain their materials from distributors or jobbers. The result is that this new scrap is sold to and collected by scrap dealers and is used for other purposes than manufacturing billets, slabs, and cakes.

Apparently there is available for use by the fabricators of copper and copper-base alloy products, enough new scrap (50 percent by the fabricators and sufficient amounts generated by secondary manufacturers and others, plus

TABLE 17.—*Average percentage of scrap generated when casting copper and copper-base alloys into billets, slabs, and cakes to be fabricated into copper-alloy products*

Forms	Source of scrap	Percent
Billets:		
Extrusion, rod and shapes	Gates (1st cut)	3–5
All alloys	Physical defects (2d cut)	2–4
Electric furnaces	Off mixtures	½–2
Water-cooled molds	General average, all scrap	5
Air-cooled molds	do	8
Rolled rods	Gates (1st cut)	6–8
All alloys	Physical defects (2d cut)	3–4
Electric furnaces	Off mixtures	½–2
Air-cooled molds	General average, all scrap	10
Rolled rods	Gates (1st cut)	8–12
All alloys	Physical defects (2d cut)	4–6
Reverberatory furnaces	Off mixtures	½–2
Air-cooled molds	General average, all scrap	12
Extrusion, tube	Gates (1st cut)	3–5
All alloys	Physical defects (2d cut)	1–2
Electric furnaces	Off mixtures	½–2
Water-cooled molds	General average, all scrap	6
Air-cooled molds	do	9
Piercing, tubes	Gates (1st cut)	4–6
Copper	Physical defects (2d cut)	2–4
Electric furnaces	Off mixtures	½–2
Water-cooled molds	General average, all scrap	8
Air-cooled molds	do	10
Piercing, tubes	Gates (1st cut)	4–6
All alloys	Physical defects (2d cut)	2–3
Electric furnaces	Off mixtures	½–2
Water-cooled molds	General average, all scrap	10
Air-cooled molds	do	12
Slabs:		
Flat for strip	Gates (1st cut)	3–5
All alloys, other than rich mixtures	Physical defects (2d cut)	1–2
Electric furnaces	Off mixtures	½–1
Water-cooled molds	General average, all scrap	7
Air-cooled molds	do	9
Flat for strip	Gates (1st cut)	3–5
All alloys, rich mixtures included	Physical defects (2d cut)	2–4
Nickel silver, electric furnaces	Off mixtures	½–2
Water-cooled molds	General average, all scrap	9
Air-cooled molds	do	12
Cakes:		
Flat for sheets and plates	Gates (1st cut)	12–18
All alloys	Physical defects (2d cut)	2–4
Air-cooled molds	Off mixtures	3–6
Electric and reverberatory furnaces	General average	16

usable old scrap), to permit the mill to use large quantities of scrap in place of new metal.

Specifications.—The following specifications are used by some fabricators to cover scrap purchases:

All brass and copper scrap must be free from excess grease, oil, and other impurities. Plated, enameled, or soldered materials cannot be accepted. All scrap must be of uniform mixture with various alloys strictly segregated. Heavy scrap, rod ends, turnings, etc., must be packed separately. Under normal conditions tube scrap is not acceptable.

In addition, the following requirements must also be met:

1. Copper scrap shall be 99.9 percent pure and consist of skeleton scrap from new sheets or strip stock.
2. Brass scrap shall consist of skeleton, trimmings, clippings, and punchings scrap from new sheet or strip. Punchings may not be smaller than ¼ inch in diameter and may not comprise more than 10 percent of the total shipment.
3. Turnings and borings from free-cutting brass rod shall consist solely of free-cutting turnings—free from iron, steel, aluminum, manganese, and all other alloys. They shall be free of grindings and babbits and shall contain not more than 0.30 percent tin, nor more than 0.15 percent combined iron, and not more than 3 percent oil and moisture.
4. Brass forging-rod flashings shall contain not more than 10 percent punchings. The punchings may not be smaller than ¼ inch in diameter.
5. Brass forging-rod turnings shall consist solely of rod turnings free from aluminum, manganese, and all other alloys. They shall be free of grindings and babbits and shall contain not more than 0.3 percent tin, not more than 0.15 percent combined iron, and not more than 3 percent oil and moisture.
6. Commercial bronze and low brass shall meet the same requirements as for sheet brass and must contain no tin.

Scrap should be shipped loose, not in compressed form. Receiving weights are to govern.

TABLE 18.—*Average percentages of scrap generated in fabricating copper and alloy products from the cast billet or slab to finished size*

Form	Percent
Strip 20 inches wide and narrower, all gages, all alloys	30–45
Sheet wider than 20 inches, all gages, all alloys	30–50
Copper sheets wider than 20 inches	30–45
Copper strip 20 inches wide and narrower, all gages	25–40
Alloy tubes, all sizes and gages	30–55
Plates, all mixtures, all sizes and shapes	40–60
Copper tubes, all sizes and gages	25–40
Rods, all alloys, all sizes	25–35
Shapes, all alloys, all sizes	30–50

Sources.—Details of the sources of fabricating-plant scrap in average practice are given in tables 17 and 18. The actual percentages of scrap generated depend on the equipment and practices of each plant.

All of the scrap in the preceding tables is considered production or plant scrap and is utilized by the plant when melting new charges. In addition, approximately 2 to 4 percent dross and skimmings is generated in melting. About one-third of the weight of dross and skimmings is zinc oxide and ash from charcoal, and almost all of the remainder is small particles of metal. The metal content of the skimmings averages between 30 and 40 percent; about half or three-fourths is usually reclaimed by passing it through a ballmill and shakers and overscreens. The remainder of the material is shipped to the refineries, where the copper content is recovered and usually returned to the original shipper.

Limits of Use.—Fabricators prefer to utilize as much clean selected scrap as possible to conserve new metal, which is more expensive than scrap. Certain technical limitations apply to the maximum copper and alloy-scrap ratios to new metal that can be utilized, but it is generally possible to use 90 or 100 percent scrap if it is available in usable form and composition.

It is customarily assumed that at least 1 cent per pound can be saved in metal cost when scrap is used in place of virgin metal. However, casting shops are reluctant to use the maximum amount of scrap permissable, because it requires more manual effort to charge the furnace. Also the melting time may be longer if the greater percentage of the scrap is fine or loose, resulting in fewer pounds produced per furnace and man-hour; however, with proper control, production and quality are not affected.

The practical limits of scrap utilization for the fabricators of various copper and brass products are given in table 19.

TABLE 19.—*Practical maximum limits of scrap utilization in copper and brass fabrication*

Forms	Type of scrap	Percent
Billets:		
Rod and shapes, containing 2.25 percent lead or more	Borings	50–90
	Reclaims	10–15
	Copper or brass	5–10
Rod and shapes, containing 1 to 2 percent lead	Borings	20–40
	Reclaims	5–10
	Copper or brass	80–90
Rod, containing less than 1 percent lead	Borings	10–20
	Reclaims	5
	Copper or brass	70–80
Rod, nonleaded	Brass	30–50
	Copper	30–50
Tube-piercing, all alloys	Brass	30–50
	Copper	30–60
Tube-piercing, copper	Copper	90
Tube-extrusion, copper	Copper	90
Tube-extrusion, all alloys	Brass	30–50
	Copper	30–70
Slabs, cakes:		
Rolling brass strip and sheets, 75 percent copper and under	Brass	25–75
	Copper	20–30
Rolling brass strip and sheets, 76 percent copper and over	Brass	20–50
	Copper	25–60
Hot rolled, strip and sheets, all mixtures	Brass	25–50
	Copper	25–50
Rolling lead brass strip and sheets	Brass	25–75
	Copper	20–40
Rolling nickel-silver strip and sheets	Brass	20–30
	Copper	50–80
	Nickel	10–15
Muntz metal strip, sheets, and plates	Brass	40–50
	Copper	50–60

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CHAPTER 6.—SUPPLY AND DISTRIBUTION

WORLD PRODUCTION

North America

United States.—The United States is the largest world producer and consumer of copper, producing nearly one-fourth of the world copper output and consuming about one-third of it. From the beginning of the 20th century to 1927, the United States furnished more than half the world copper supply. For many years the United States produced much more copper than it consumed and exported the surplus. Huge demands for copper at the beginning of World War I resulted in record domestic production tonnages. The records achieved in 1916–18 were not surpassed until 1929, when production reached a temporary peak of about 1 million tons as a result of the high level of industrial activity. The highest prices since 1920 also were reached in 1929 and early 1930 stimulating development of copper mines throughout the world, particularly in Africa and Canada. In 1930 the British Empire became self-sufficient and had an exportable surplus.

The worldwide depression that began in 1930 was quickly reflected in a severe decline in copper consumption and a nearly comparable curtailment in production. By the middle of 1933 the copper industry was operating at about 30 percent of the 1929 rate. Between 1929 and 1936 the relation of the leading copper-producing countries to world production changed appreciably (table 20). The United States lost its position as the foremost copper-producing country in the world in 1934 when Chile outranked it—the only time since 1883 that the United States has not been in first place. Domestic mines, smelters, and refineries were adversely affected by the depression; idle smelter and refinery capacity increased sharply, and many mines were forced to reduce operations or to close. In June 1932 a 4-cent-per-pound excise tax was imposed on copper to discourage importations of foreign materials.

The depth of the depression was reached at the end of 1932; the copper industry began to show improvement. Domestic mine and smelter production was higher in 1934 than in 1933, although still having the lowest levels in more than 30 years. The copper industry in the United States continued to recover for the next four years but did not increase as much as abroad. Consumption of copper outside the United States in 1935 and 1936 exceeded all previous records—partly as a result of increased demand in Europe.

In the early months of 1938 demand for copper in the United States was at an extremely low level as a result of a business recession. Curtailment of output about midyear succeeded in bringing new supply below consumption requirements, and stocks were reduced from May through October. Consumption continued at record rates abroad, and selling conditions during the year frequently were more favorable in London than in New York. Exports of domestic copper were higher than in any other year since 1928.

Great Britain and France declared war on Germany in September 1939, and the domestic copper industry began an expansion program that resulted in record rates. At the beginning of 1940 U.S. producers watched the European market dwindle and wondered where they were going to dispose of their metal, but by the end of the year producers were straining to meet demand and were even reconciled to an influx of foreign copper to ease their load. The inability to meet all requirements continued and was accentuated in 1940 and 1941. Copper was consumed at a tremendous rate in the United States for its own military requirements and for the needs of its allies. Efforts of various Government agencies were directed toward increasing supplies by obtaining greater imports and by confining exports to essential needs of the Allies; civilian uses were curtailed and the Premium Price Plan was inaugurated in February 1942.

By 1943 the copper supply appeared virtually in balance, and copper was placed lower on the list of critical materials. Despite labor shortages in 1944 and 1945 the supply of copper was adequate for war requirements and essential

TABLE 20.—*Percent of total world production by leading countries*

	1929	1935	1936
Belgian Congo	7. 0	7. 0	6. 0
Canada	4. 0	11. 0	10. 0
Chile	16. 0	17. 0	14. 0
Rhodesia	. 3	10. 0	8. 0
United States	48. 0	23. 0	31. 0

civilian needs. Due largely to cutbacks in military requirements in 1945, the downward trend in production begun in 1943 continued in 1945.

Fears that with the termination of hostilities war stocks would flood the domestic mining industry and result in a stagnant copper industry, such as that after World War I, did not materialize. Demand in 1946 for reconversion needs exceeded expectations, and supply from domestic sources was short of requirements. In addition, labor strikes occurred at mines, smelters, refineries, and fabricating plants. Peak peacetime domestic consumption continued into 1948. Prices had advanced sharply after removal of controls on November 10, 1946, and the annual average for 1948 established a 30-year peak. In the early months of 1949 the supply of copper exceeded demand. Prices dropped from 23.2 cents at the beginning of the year to 15.7 cents by the end of June, and production curtailments were begun in May.

The copper industry experienced increased activity in early 1950, and the upward movement was accelerated following outbreak of hostilities in Korea in June 1950. Strikes in 1951 adversely affected operations in all major producing States. Efforts of Government and industry were directed again to assuring adequate supplies. The Defense Production Act of 1950 was extended; copper raw materials were placed under allocation control; a ceiling price of 24.5 cents per pound, delivered, was established; and over-the-ceiling contracts were awarded to high-cost mines. The inadequate supply situation changed in 1953 to one in which more than enough copper was available domestically, and a sizable world surplus developed. Throughout 1953 the Chilean Government maintained a price 6 cents a pound more than the price of U.S. producers. Imports from Chile fell sharply, and large stocks of unsold Chilean copper accumulated in that country and in the United States. In August the Chilean Government requested the United States Government to purchase the accumulated stocks—reported to be 180,000 tons—for the strategic stockpile, and in March 1954 the two Governments reached agreement for the purchase of 100,000 tons at market price.

Although four new large operations reached the production stage in 1954, mine production declined 10 percent. Interruptions to output due to labor strikes from August to October and to the voluntary curtailments by mining companies in the early months of the year, when it appeared that supply would exceed demand, more than offset gains in the new productive capacity. In contrast, output in 1955 rose 20 percent despite serious work stoppages at several important mines, and supplies were inadequate to meet increased demand. Copper shortages caused the price of domestic copper to move upward sharply during the year to the highest point in 90 years. Foreign prices, however, rose even more sharply and additional foreign metal was not attracted to U.S. markets. To help relieve the situation the Government permitted postponement of stockpile deliveries, authorized sale of Defense Production Act (DPA) inventories, placed restrictions on copper exports, and extended the suspension of the excise tax.

The situation was reversed in 1956 when more than enough copper was available for all requirements. United States and World production established new highs, and copper prices rose. The oversupply continued into 1957 and was not relieved by efforts of major producers in the United States and abroad to curtail outputs or by the drop in copper prices from 46 cents in July 1956 to 27 cents in September 1957. An upward trend in consumption which had begun in the second half of 1958 continued through June 1959. In August 1959, operations at most of the principal domestic copper mines, smelters, and refineries were halted by the longest strike in history. As a result mine output fell 16 percent and smelter and refinery production from domestic ores dropped 20 percent. Because of high consumption and reduced supply, stocks of refined copper at the end of 1959 were the lowest since before 1900. The last strikes were settled by late March 1960, and the need for copper stimulated production; mine output was the largest since 1957; in 1962 a new record was set. Salient copper statistics from 1906 through 1962 are shown in table 21.

Production of copper by States from the beginning of operations through 1962 is shown in table 22; data given reflect smelter output from 1845 to 1905 and mine production thereafter. Tables 23 and 24 give world mine and smelter production for 1926–60, and figure 35 shows production, consumption, and price of copper in the U.S. for 1910–62.

Primary Copper.—Copper production is measured at three stages of processing—mining, smelting, and refining. These separate determinations are desirable because each has a particular advantage over the others for certain purposes. Because they show different aspects of production, the three sets of figures do not agree exactly.

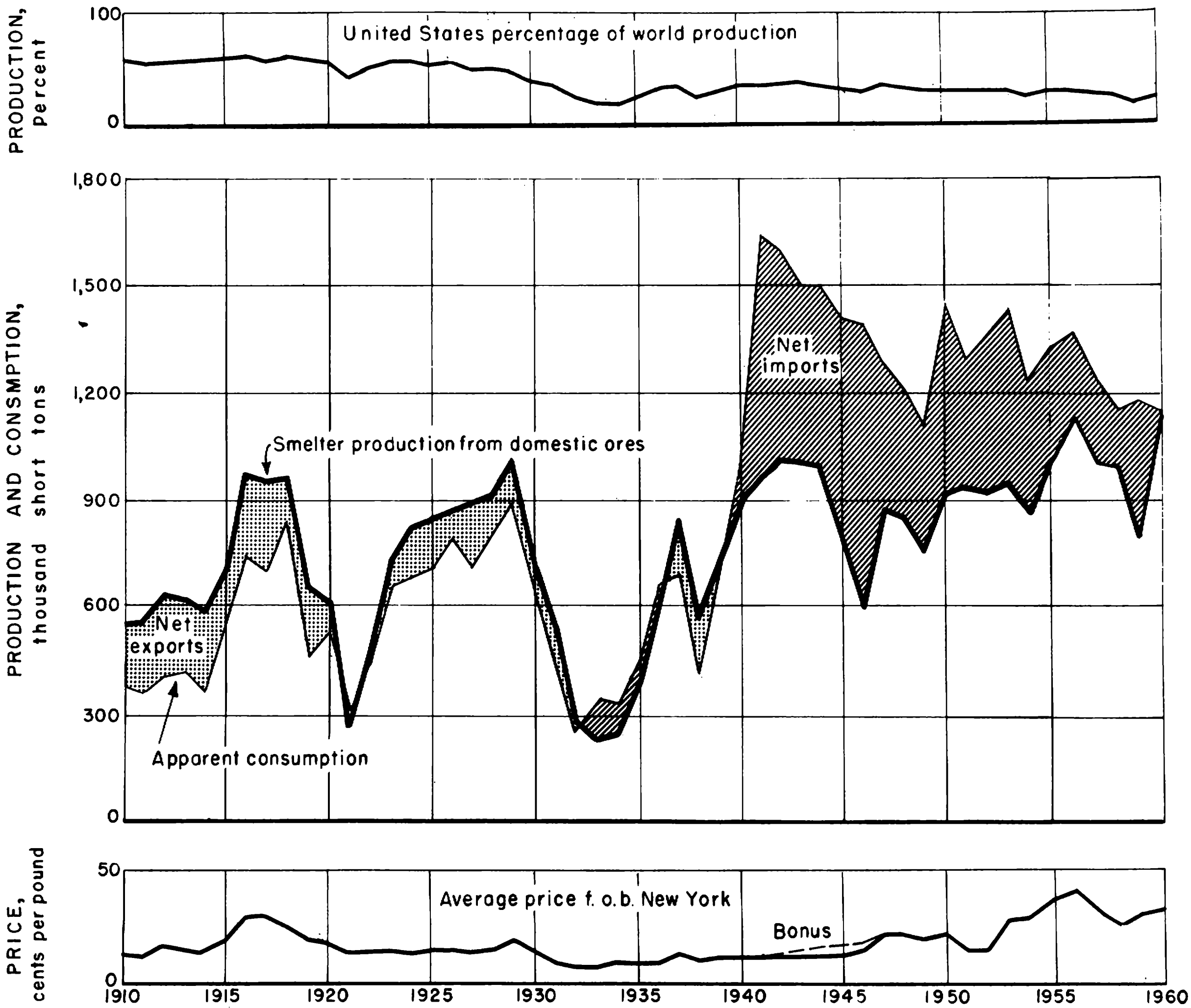

FIGURE 35.—U.S. Production, Consumption, and Price of Copper, 1910–60.

TABLE 21.—*Salient copper statistics*

	1906	1907	1908	1909	1910
Mine production....short tons..	458,486	423,576	478,420	563,261	544,119
Average yield of copper....percent..	2.50	2.11	2.08	1.98	1.88
Smelter production from domestic ores....short tons..	458,903	434,498	471,285	546,476	540,080
Refinery production, primary, from:					
Domestic materials....short tons..	448,691	413,311	459,556	532,782	535,947
Foreign materials....do....	90,835	102,947	109,425	162,728	175,072
Total....do....	539,526	516,258	568,981	695,510	711,019
Imports, refined [1]....do....	(2)	(2)	(2)	(2)	(2)
Exports, refined [1]....do....	[3] 227,376	[3] 254,465	[3] 330,938	[3] 341,423	[3] 354,158
Apparent consumption of new copper [4]....do....	343,100	243,900	240,000	344,300	366,200
Production from scrap as metal and in alloys:					
Old scrap....short tons..	(5)	(5)	(5)	(5)	64,500
New scrap....do....	(5)	(5)	(5)	(5)	30,000
Price at New York [6]....cents per pound..	19.77	20.86	13.39	13.11	12.88
World smelter production....short tons..	797,800	794,700	820,100	912,300	946,100

	1911	1912	1913	1914	1915
Mine production....short tons..	557,382	624,547	617,785	574,216	744,036
Average yield of copper....percent..	1.83	1.71	1.67	1.60	1.66
Smelter production from domestic ores....short tons..	548,616	621,634	612,242	575,069	694,005
Refinery production, primary, from:					
Domestic materials....short tons..	550,635	601,838	618,412	605,212	693,853
Foreign materials....do....	166,302	182,214	189,122	161,679	123,249
Total....do....	716,937	784,052	807,534	766,891	817,102
Imports, refined [1]....do....	(2)	(2)	(2)	(2)	(2)
Exports, refined [1]....do....	[3] 393,277	[3] 387,500	408,956	374,451	293,782
Apparent consumption of new copper [4]....do....	340,900	388,000	406,100	350,800	568,300
Production from scrap as metal and in alloys:					
Old scrap....short tons..	76,000	107,000	91,500	87,900	121,200
New scrap....do....	31,000	30,500	45,000	40,000	75,000
Price at New York [6]....cents per pound..	12.55	16.48	15.52	13.31	17.47
World smelter production....short tons..	980,800	1,102,500	1,090,600	1,027,100	1,165,500

	1916	1917	1918	1919	1920
Mine production....short tons..	1,002,938	947,717	955,011	606,167	612,275
Average yield of copper....percent..	1.70	1.60	1.51	1.65	1.63
Smelter production from domestic ores....short tons..	963,925	943,060	954,267	643,210	604,531
Refinery production, primary, from:					
Domestic materials....short tons..	944,376	936,773	941,437	716,743	591,212
Foreign materials....do....	185,318	274,124	255,712	168,341	171,871
Total....do....	1,129,694	1,210,897	1,197,149	885,084	763,083
Imports, refined [1]....do....	4,206	3,376	19,044	17,569	54,372
Exports, refined [1]....do....	358,308	515,390	345,014	219,080	275,613
Apparent consumption of new copper....do....	739,400	697,400	830,800	457,200	526.900
Production from scrap as metal and in alloys:					
Old scrap....short tons..	175,000	194,900	176,700	152,600	169,000
New scrap....do....	175,000	188,500	176,000	134,600	143,500
Price at New York [6]....cents per pound..	28.46	29.19	24.68	18.90	17.50
World smelter production....short tons..	1,518,600	1,575,300	1,574,300	1,095,700	1,057.200

	1921	1922	1923	1924	1925
Mine production....short tons..	233,095	482,292	738,870	803,083	839,059
Average yield of copper....percent..	1.70	1.74	1.58	1.59	1.54
Smelter production from domestic ores....short tons..	252,793	475,143	717,500	817,125	837,435
Refinery production, primary, from:					
Domestic materials....short tons..	304.707	452,335	732,083	837.107	841,448
Foreign materials....do....	170,682	175,423	257,835	292,931	260,839
Total....do....	475,389	627,758	989,918	1,130,038	1,102,287
Imports, refined [1]....do....	34,625	51,572	80,356	72,955	49,887
Exports, refined [1]....do....	298,059	326,333	364,690	504,812	484,033
Apparent consumption of new copper [4]....do....	305,500	448,300	650,200	677,400	700,500
Production from scrap as metal and in alloys:					
Old Scrap....short tons..	132,000	202,800	270,900	266,200	291,000
New scrap....do....	85,300	133,100	140,000	122,100	129,200
Price at New York [6]....cents per pound..	12.65	13.56	14.61	13.16	14.16
World smelter production....short tons..	614,600	952,400	1,341,500	1,493,600	1,546,500

See footnotes at end of table.

TABLE 21.—*Salient copper statistics*—Continued

	1926	1927	1928	1929	1930
Mine production____short tons__	862,838	824,980	904,898	997,455	705,074
Average yield of copper____percent__	1.46	1.41	1.41	1.41	1.43
Smelter production from domestic ores____short tons__	869,811	842,020	912,950	1,001,432	697,195
Refinery production, primary, from:					
Domestic materials____short tons__	865,649	859,476	895,899	991,366	695,612
Foreign materials____do____	295,594	303,406	347,905	378,690	382,918
Total____do____	1,161,243	1,162,882	1,243,804	1,370,056	1,078,530
Imports, refined [1]____do____	85,283	51,640	42,365	67,007	43,105
Exports, refined [1]____do____	428,062	461,233	474,737	411,227	297,057
Apparent consumption of new copper [4]____do____	785,100	711,500	804,300	889,300	632,500
Production from scrap as metal and in alloys:					
Old scrap____short tons__	337,300	339,400	365,500	404,400	342,200
New scrap____do____	142,500	150,800	170,900	222,200	125,000
Price at New York [6]____cents per pound__	13.93	13.05	14.68	18.23	13.11
World smelter production____short tons__	1,608,300	1,673,300	1,880,500	2,098,800	1,760,000

	1931	1932	1933	1934	1935
Mine production____short tons__	528,875	238,111	190,643	237,401	380,491
Average yield of copper____percent__	1.50	1.83	2.11	1.92	1.89
Smelter production from domestic ores____short tons__	521,356	272,005	225,000	244,227	381,294
Refinery production, primary, from:					
Domestic materials____short tons__	537,303	222,539	240,669	233,029	338,321
Foreign materials____do____	213,418	117,895	130,120	212,331	250,484
Total____do____	750,721	340,434	370,789	445,360	588,805
Imports, refined [1]____do____	87,225	83,897	5,432	27,417	18,071
Exports, refined [1]____do____	202,698	110,977	124,582	262,366	260,735
Apparent consumption of new copper [4]____do____	451,000	259,600	339,400	322,600	441,400
Production from scrap as metal and in alloys:					
Old scrap____short tons__	261,300	181,000	260,300	310,900	361,700
New scrap____do____	85,700	67,200	77,800	66,500	87,200
Price at New York [6]____cents per pound__	8.24	5.67	7.15	8.53	8.76
World smelter production____short tons__	1,536,000	1,027,000	1,143,000	1,448,000	1,681,000

	1936	1937	1938	1939	1940
Mine production____short tons__	614,516	841,998	557,763	728,320	878,086
Average yield of copper____percent__	1.54	1.29	1.34	1.25	1.20
Smelter production from domestic ores____short tons__	611,410	834,661	562,328	712,675	909,084
Refinery production, primary, from:					
Domestic materials____short tons__	645,462	822,253	552,574	704,873	927,239
Foreign materials____do____	177,027	244,561	239,842	304,642	386,317
Total____do____	822,489	1,066,814	792,416	1,009,515	1,313,556
Imports, refined [1]____do____	4,782	7,487	1,802	16,264	68,337
Exports, refined [1]____do____	220,390	295,064	370,545	372,777	356,431
Apparent consumption of new copper [4]____do____	656,200	694,600	407,000	714,900	1,008,800
Production from scrap as metal and in alloys:					
Old scrap____short tons__	382,700	408,900	267,300	286,900	333,890
New scrap____do____	101,900	123,200	92,500	212,800	198,156
Price at New York [6]____cents per pound__	9.58	13.27	10.10	11.07	11.40
World smelter production____short tons__	1,895,000	2,585,000	2,254,000	2,396,000	2,734,000

	1941	1942	1943	1944	1945
Mine production____short tons__	958,149	1,080,061	1,090,818	972,549	772,894
Average yield of copper____percent__	1.15	1.09	1.04	0.99	0.93
Smelter production from domestic ores____short tons__	966,072	1,087,991	1,092,939	1,003,379	782,726
Refinery production, primary, from:					
Domestic materials____short tons__	975,408	1,064,792	1,082,079	973,852	775,738
Foreign materials____do____	419,901	349,769	297,184	247,335	332,861
Total____do____	1,395,309	1,414,561	1,379,263	1,221,187	1,108,599
Imports, refined [1]____do____	346,994	401,436	402,762	492,395	531,367
Exports, refined [1]____do____	103,602	131,406	175,859	68,373	48,563
Apparent consumption of new copper [4]____do____	1,641,600	1,608,000	1,502,000	1,504,000	1,415,000
Production from scrap as metal and in alloys:					
Old scrap____short tons__	412,699	427,122	427,521	456,710	497,095
New scrap____do____	313,697	500,633	658,526	494,232	509,421
Price at New York [6]____cents per pound__	11.87	11.87	11.87	11.87	11.87
World smelter production____short tons__	2,905,000	3,076,000	3,038,000	2,850,000	2,436,000

See footnotes at end of table.

TABLE 21.—*Salient copper statistics*—Continued

	1946	1947	1948	1949	1950
Mine production.......short tons..	608,737	847,563	834,813	752,750	909,343
Average yield of copper.......percent..	0.91	0.90	0.92	0.91	0.89
Smelter production from domestic ores.......short tons..	599,656	862,872	842,477	757,931	911,352
Refinery production, primary, from:					
Domestic materials.......short tons..	578,429	909,213	860,022	695,015	920,748
Foreign materials.......do....	300,233	250,757	247,424	232,912	319,086
Total.......do....	878,662	1,159,970	1,107,446	927,927	1,239,834
Imports, refined [1].......do....	154,371	149,478	249,124	275,811	317,363
Exports, refined [1].......do....	52,629	147,642	142,598	137,827	144,561
Apparent consumption of new copper [4].......do....	1,391,000	1,286,000	1,214,000	1,072,000	1,447,000
Production from scrap as metal and in alloys:					
Old scrap.......short tons..	406,453	503,376	505,464	383,548	485,211
New scrap.......do....	397,093	458,365	467,324	329,595	492,028
Price at New York [6].......cents per pound..	13.92	21.15	22.20	19.36	21.46
World smelter production.......short tons..	2,067,000	2,490,000	2,580,000	2,600,000	2,915,000

	1951	1952	1953	1954	1955
Mine production.......short tons..	928,330	925,359	926,448	835,472	998,570
Average yield of copper.......percent..	0.90	0.85	0.85	0.83	0.83
Smelter production from domestic ores.......short tons..	930,774	927,365	943,391	834,381	1,007,311
Refinery production, primary, from:					
Domestic materials.......short tons..	951,559	923,192	932,232	841,717	997,499
Foreign materials.......do....	255,429	254,504	360,885	370,202	344,960
Total.......do....	1,206,988	1,177,698	1,293,117	1,211,919	1,342,459
Imports, refined [1].......do....	238,972	346,960	274,111	215,086	202,312
Exports, refined [1].......do....	133,305	174,135	109,580	215,951	199,819
Apparent consumption of new copper [4].......do....	1,304,000	1,360,000	1,435,000	1,235,000	1,336,000
Production from scrap as metal and in alloys:					
Old scrap.......short tons..	458,124	414,635	429,388	407,066	514,585
New scrap.......do....	474,158	488,562	529,076	432,841	474,419
Price at New York [6].......cents per pound..	24.37	24.37	28.92	29.82	37.39
World smelter production.......short tons..	3,085,000	3,105,000	3,275,000	3,275,000	3,630,000

	1956	1957	1958	1959	1960	1961	1962
Mine production.......short tons..	1,104,156	1,086,859	979,329	824,846	1,080,169	1,165,155	1,228,421
Average yield of copper.......percent..	0.78	0.77	0.79	0.74	0.73	0.75	0.75
Smelter production from domestic ores.......short tons..	1,117,580	1,081,055	992,918	799,329	1,142,848	1,162,480	1,282,126
Refinery production, primary, from:							
Domestic materials.......short tons..	1,080,207	1,050,496	1,001,645	796,452	1,121,286	1,181,015	1,214,146
Foreign materials.......do....	362,426	403,680	350,875	301,795	397,641	369,124	397,584
Total.......do....	1,442,633	1,454,176	1,352,520	1,098,247	1,518,927	1,550,139	1,611,730
Imports, refined [1].......do....	191,745	162,309	128,464	214,058	142,709	66,855	98,820
Exports, refined [1].......do....	223,103	346,025	384,868	158,938	433,762	428,718	336,525
Apparent consumption of new copper [4].......do....	1,367,000	1,239,000	1,157,000	1,183,000	1,148,000	1,237,000	1,352,000
Production from scrap as metal and in alloys:							
Old scrap.......short tons..	468,489	444,492	411,367	471,007	429,365	411,110	415,674
New scrap.......do....	462,175	397,395	386,021	459,563	442,023	437,829	506,154
Price at New York [6].......cents per pound..	41.88	29.99	26.13	30.82	32.16	30.14	30.82
World smelter production.......short tons..	3,990,000	4,040,000	3,950,000	4,190,000	4,990,000	5,090,000	5,300,000

[1] Imports and exports may include refined copper produced from scrap. Categories not wholly comparable from year to year.
[2] Data not separately recorded.
[3] Includes plates and old.
[4] Adjusted for changes in stocks.
[5] Data not available.
[6] American Metal Market price for electrolytic copper in New York, f.o.b. refinery through August 1927, New York refinery equivalent thereafter.

Geographic distribution of output is shown more precisely by mine-production statistics than by those of smelter and refinery production. Likewise, the character of the ores produced, their contents of copper and other valuable metals, and the treatment other than smelting that they may have undergone can be learned accurately only from mine data. However, mine statistics show only the estimated recoverable metal content of the ores.

The actual quantity of crude copper recovered from copper ores and from other ores having a low content of copper is shown by the smelter statistics. Lead, zinc, silver, and gold ores, and pyrite roasted in the manufacture of sulfuric acid often carry some copper recovered at smelters. However, the mines are not paid for the copper contained and do not report it, causing a difference between the figures of mine and of smelter production. The lag in time between the production and the smelting of an ore also causes production data to differ. For example, ore mined in December of any year may not be represented in the figures of smelter production until the following year. Still another cause of difference between these two sets of figures is that the quantity of metal contained in ore, matte, and other material held in stock or in process at smelters is rarely the same at the beginning and the end of a year.

The precise quantity of copper made available for consumption in a given period, as well as that of the precious metals recovered from crude copper, is shown only by refinery statistics, but these do not reveal the distribution of output by source.

Differences between smelter and refinery statistics occur for much the same reasons. Some time must elapse after the copper is smelted before it is refined; and the quantity of copper in stocks of untreated or unfinished material at the beginning of the year differs from that at the end, at smelters as well as at the refineries.

Two or three months usually elapse between the time ore is mined and the time the copper derived from the ore becomes available for consumption. Hence, the refinery statistics for a calendar year represent approximately the ore mined between October of the past year and October of the current year. In periods when the course of production is little disturbed by pronounced fluctuations of activity, the three sets of statistics on production from domestic ores do not differ greatly. Any decided rise or fall in production between October of one year and March of the year following, however, tends to accentuate the differences among the three sets of figures.

So that smelter and refinery figures may be compared as nearly as possible, smelter data must have added to them some refined copper that does not require smelting. Thus furnace-refined Lake copper and copper leached from ores and recovered from solution by electrolysis are included in smelter statistics.

Mine Production.—Statistics on mine production in the United States have been compiled since 1906 (table 22). Total production from the earliest record through 1962 has been almost 50 million tons; most has come from the Western States. Arizona was the supplier of 38 percent of the total, followed by Utah with 18 percent; Montana, 16 percent; Nevada, 6 percent; and New Mexico, 5 percent. Of the remaining copper-producing States, Michigan furnished 11 percent of the remaining output. There are a number of active copper-producing mines in the United States, most of them small, and more than 95 percent of the output has been supplied regularly by 25 mines.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*

	1845	1846	1847	1848	1849	1850
Alabama						
Alaska						
Arizona						
California						
Colorado[2]						
Georgia						
Idaho						
Maine						
Maryland						
Massachusetts						
Michigan	13	29	239	516	753	641
Missouri						
Montana						
Nevada						
New Hampshire						
New Mexico						
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah						
Vermont						
Virginia						
Washington						
Wisconsin						
Wyoming						
Other[3]	99	140	97	44	31	87
Total	112	169	336	560	784	728

See footnotes at end of table.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1851	1852	1853	1854	1855	1856
Alabama						
Alaska						
Arizona						
California						
Colorado[2]						
Georgia						
Idaho						
Maine						
Maryland						
Massachusetts						
Michigan	872	887	1, 453	2, 037	2, 904	4, 106
Missouri						
Montana						
Nevada						
New Hampshire						
New Mexico						
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah						
Vermont						
Virginia						
Washington						
Wisconsin						
Wyoming						
Other[3]	136	345	787	483	456	374
Total	1, 008	1, 232	2, 240	2, 520	3, 360	4, 480

	1857	1858	1859	1860	1861	1862
Alabama						
Alaska						
Arizona						40
California						1, 300
Colorado[2]						
Georgia						
Idaho						
Maine						
Maryland						
Massachusetts						
Michigan	4, 766	4, 579	4, 463	6, 035	7, 519	6, 793
Missouri						
Montana						
Nevada						
New Hampshire						
New Mexico					[4] 500	
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah						
Vermont						
Virginia						
Washington						
Wisconsin						
Wyoming						
Other[3]	610	1, 581	2, 593	2, 029	381	2, 447
Total	5, 376	6, 160	7, 056	8, 064	8, 400	10, 580

See footnotes at end of table.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1863	1864	1865	1866	1867	1868
Alabama						
Alaska						
Arizona						
California	1, 100	2, 400	1, 800	1, 300	700	650
Colorado[2]				56		25
Georgia						
Idaho						
Maine						
Maryland						
Massachusetts						
Michigan	6, 493	6, 245	7, 179	6, 875	8, 763	10, 468
Missouri						
Montana						2
Nevada						
New Hampshire						
New Mexico						
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah						
Vermont						
Virginia						
Washington						
Wisconsin						
Wyoming						
Other[3]	1, 927	315	541	1, 737	1, 245	1, 847
Total	9, 520	8, 960	9, 520	9, 968	11, 200	12, 992

	1869	1870	1871	1872	1873	1874
Alabama						
Alaska						
Arizona				420		225
California	288	28	300	175	225	160
Colorado[2]	51	91	92	102	190	238
Georgia						
Idaho	4					
Maine						
Maryland						
Massachusetts						
Michigan	13, 312	12, 311	13, 374	12, 276	15, 045	17, 166
Missouri						
Montana	4				50	
Nevada					72	185
New Hampshire						
New Mexico		6			16	25
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah		50	195	300	438	187
Vermont						
Virginia						
Washington						
Wisconsin						
Wyoming						
Other[3]	341	1, 626	599	727	1, 324	1, 414
Total	14, 000	14, 112	14, 560	14, 000	17, 360	19, 600

See footnotes at end of table.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1875	1876	1877	1878	1879	1880
Alabama						
Alaska						
Arizona	250	250	1, 500	1, 500	1, 592	1, 000
California			250	200	256	500
Colorado [2]	140	167	247	268	352	430
Georgia						
Idaho						
Maine						
Maryland						
Massachusetts						
Michigan	18, 020	19, 185	19, 513	19, 845	21, 425	24, 868
Missouri						
Montana	50	260	200	175	250	606
Nevada					67	
New Hampshire						
New Mexico	150	154			2	
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah	358	473	321	382	129	43
Vermont						
Virginia						
Washington						
Wisconsin						
Wyoming						
Other [3]	1, 192	791	1, 489	1, 710	1, 687	2, 793
Total	20, 160	21, 280	23, 520	24, 080	25, 760	30, 240

	1881	1882	1883	1884	1885	1886
Alabama						
Alaska						
Arizona	4, 000	8, 992	11, 937	13, 367	11, 353	7, 828
California	250	413	800	438	235	215
Colorado [2]	442	747	576	1, 007	573	500
Georgia						
Idaho				23	20	
Maine						
Maryland						
Massachusetts						
Michigan	26, 787	28, 492	29, 851	34, 677	36, 074	40, 459
Missouri						
Montana	725	4, 529	12, 332	21, 546	33, 899	28, 806
Nevada		175	144	50	5	25
New Hampshire						
New Mexico	250	435	411	30	40	279
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah	193	303	171	133	63	250
Vermont						
Virginia						
Washington						
Wisconsin						
Wyoming		50	481			
Other [3]	3, 193	1, 187	1, 060	1, 202	676	519
Total	35, 840	45, 323	57, 763	72, 473	82, 938	78, 881

See footnotes at end of table.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1887	1888	1889	1890	1891	1892
Alabama						
Alaska						
Arizona	8, 860	15, 899	15, 793	17, 398	19, 937	19, 218
California	800	785	76	12	1, 699	1, 490
Colorado[2]	1, 006	811	585	1, 793	3, 168	3, 797
Georgia						
Idaho		25	78	44	73	113
Maine						
Maryland						
Massachusetts						
Michigan	38, 014	43, 236	44, 088	50, 705	57, 111	61, 599
Missouri						
Montana	39, 350	48, 949	49, 111	56, 491	56, 032	81, 603
Nevada		25	13			
New Hampshire						
New Mexico	142	816	1, 843	425	617	594
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah	1, 250	1, 065	33	503	781	1, 105
Vermont						
Virginia						
Washington						
Wisconsin						
Wyoming		116	50			
Other[3]	1, 317	1, 454	1, 718	2, 511	2, 643	2, 980
Total	90, 739	113, 181	113, 388	129, 882	142, 061	172, 499

	1893	1894	1895	1896	1897	1898
Alabama						
Alaska						
Arizona	21, 951	22, 257	23, 977	36, 468	40, 765	55, 579
California	120	60	109	345	5, 994	8, 463
Colorado[2]	3, 848	3, 241	3, 040	3, 011	5, 936	8, 137
Georgia						
Idaho	18		713		92	633
Maine						
Maryland						
Massachusetts						
Michigan	56, 302	57, 155	64, 665	71, 762	72, 641	79, 246
Missouri						
Montana	77, 605	91, 536	95, 086	110, 959	116, 364	103, 717
Nevada	10					219
New Hampshire						
New Mexico	140	16	72	1, 351	351	796
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah	568	574	1, 092	1, 751	1, 960	1, 875
Vermont						
Virginia						
Washington	20					
Wisconsin						
Wyoming						117
Other[3]	4, 095	2, 255	1, 553	4, 384	2, 936	4, 474
Total	164, 677	177, 094	190, 307	230, 031	247, 039	263, 256

See footnotes at end of table.

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TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1899	1900	1901	1902	1903	1904
Alabama						
Alaska					670	1, 022
Arizona	66, 528	59, 159	65, 389	59, 972	73, 824	95, 802
California	13, 111	14, 256	16, 834	12, 519	8, 888	14, 265
Colorado [2]	5, 822	3, 913	4, 901	4, 211	2, 079	4, 753
Georgia						
Idaho	55	145	240	114	390	1, 079
Maine						
Maryland						
Massachusetts						
Michigan	73, 700	72, 731	78, 145	85, 305	96, 200	104, 155
Missouri						
Montana	112, 572	135, 377	115, 312	144, 675	136, 365	149, 207
Nevada	278	204	297	82	75	
New Hampshire						
New Mexico	1, 968	2, 085	4, 815	3, 307	3, 650	2, 684
North Carolina						
Oregon						
Pennsylvania						
South Carolina						
South Dakota						
Tennessee						
Texas						
Utah	4, 792	9, 177	10, 058	11, 970	19, 151	23, 531
Vermont						
Virginia						
Washington				105	40	332
Wisconsin						
Wyoming	1, 552	2, 102	1, 349	445	512	1, 783
Other [3]	3, 955	3, 910	3, 696	7, 049	7, 178	7, 656
Total	284, 333	303, 059	301, 036	329, 754	349, 022	406, 269

	1905	1906	1907	1908	1909	1910
Alabama			42		(5)	
Alaska	2, 450	2, 936	3, 154	2, 293	2, 062	2, 121
Arizona	113, 427	133, 416	127, 440	142, 929	151, 950	148, 746
California	8, 349	14, 363	14, 264	19, 388	28, 644	24, 350
Colorado [2]	4, 702	2, 860	3, 862	4, 999	5, 461	4, 180
Georgia		13	(5)			
Idaho	3, 661	4, 779	5, 445	5, 021	4, 558	3, 519
Maine						
Maryland			(5)		(5)	
Massachusetts		5		(6)		
Michigan	115, 144	112, 286	108, 884	111, 643	117, 068	111, 342
Missouri		27	(5)	(5)	[7] 600	[7] 47
Montana	157, 375	145, 351	110, 054	125, 834	156, 029	142, 404
Nevada	207	813	891	7, 799	28, 988	32, 180
New Hampshire				[8] 94	(5)	6
New Mexico	2, 667	3, 514	5, 495	3, 056	2, 697	2, 307
North Carolina		352	291	(5)	112	70
Oregon	423	208	277	146	118	7
Pennsylvania					(5)	464
South Carolina				(5)	(5)	
South Dakota					(5)	
Tennessee		8, 990	9, 447	9, 730	9, 603	8, 419
Texas		26			(5)	2
Utah	27, 042	28, 297	32, 129	43, 424	54, 474	63, 798
Vermont		120	325			
Virginia			30	12	112	3
Washington	112	118	149	156	128	43
Wisconsin						
Wyoming	1, 265	12	1, 129	1, 226	246	111
Other [3]	7, 568		268	670	411	
Total	444, 392	458, 486	423, 576	478, 420	563, 261	544, 119

See footnotes at end of table.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1911	1912	1913	1914	1915	1916
Alabama						
Alaska	13, 634	14, 615	10, 830	10, 725	43, 255	59, 927
Arizona	153, 071	182, 519	203, 962	196, 509	229, 986	360, 917
California	18, 158	16, 726	17, 288	15, 254	20, 376	27, 949
Colorado [2]	4, 012	3, 554	3, 864	3, 320	3, 556	4, 312
Georgia						402
Idaho	2, 576	3, 746	4, 796	3, 223	3, 489	4, 239
Maine						
Maryland	(5)	(5)	(5)	(5)	(5)	(5)
Massachusetts						
Michigan	109, 920	109, 069	67, 927	82, 172	132, 642	136, 846
Missouri	320	220	288	22	201	193
Montana	136, 424	154, 869	143, 914	116, 615	133, 615	176, 464
Nevada	33, 689	43, 239	45, 347	30, 493	34, 318	52, 558
New Hampshire						
New Mexico	2, 029	17, 016	28, 154	29, 654	38, 394	46, 374
North Carolina		38		10	9	5
Oregon	47	130	22	20	226	1, 791
Pennsylvania	(5)	(5)	(5)	(5)	(5)	(5)
South Carolina						
South Dakota			1			
Tennessee	9, 425	9, 242	9, 695	9, 369	9, 023	7, 340
Texas			17	12	21	50
Utah	73, 480	68, 654	80, 723	76, 017	93, 836	120, 138
Vermont			7		40	137
Virginia	45	56	28	69	(5)	(5)
Washington	159	543	477	389	510	1, 322
Wisconsin				5		
Wyoming	59	14	193	9	224	1, 305
Other [3]	[9] 334	297	252	329	315	669
Total	557, 382	624, 547	617, 785	574, 216	744, 036	1, 002, 938

	1917	1918	1919	1920	1921	1922
Alabama						
Alaska	44, 397	34, 612	23, 610	35, 218	28, 506	38, 984
Arizona	356, 083	382, 428	269, 051	279, 128	92, 517	200, 022
California	24, 077	23, 837	10, 866	6, 313	5, 872	11, 270
Colorado [2]	4, 061	3, 139	1, 780	2, 022	2, 077	1, 687
Georgia	465	199	4	3		3
Idaho	3, 914	3, 267	1, 561	1, 269	844	1, 641
Maine	15	383	188			
Maryland	(5)					
Massachusetts						
Michigan	127, 855	113, 397	89, 413	77, 347	43, 185	60, 856
Missouri	183	289	809	756	69	399
Montana	137, 231	161, 587	84, 991	88, 530	24, 049	82, 877
Nevada	61, 397	58, 158	26, 166	25, 280	5, 481	11, 566
New Hampshire						
New Mexico	52, 784	49, 132	25, 575	27, 200	7, 134	15, 969
North Carolina	62		2			
Oregon	1, 237	1, 226	1, 107	1, 178	87	523
Pennsylvania	(5)	390		202	156	615
South Carolina			1			
South Dakota	5	32				
Tennessee	8, 017	7, 400	7, 812	8, 364	7, 542	7, 120
Texas	12	5	1	7		2
Utah	123, 337	113, 585	62, 031	58, 466	15, 445	48, 597
Vermont	77	558	291			
Virginia	(5)					
Washington	1, 100	961	838	992	126	159
Wisconsin						
Wyoming	1, 014	426	70		5	2
Other [3]	394					
Total	947, 717	955, 011	606, 167	612, 275	233, 095	482, 292

See footnotes at end of table.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1923	1924	1925	1926	1927	1928
Alabama	--------	--------	--------	--------	--------	--------
Alaska	42, 960	37, 037	36, 928	33, 889	27, 671	20, 711
Arizona	309, 464	338, 876	356, 678	361, 648	341, 095	366, 138
California	14, 159	26, 054	23, 432	16, 733	13, 567	12, 575
Colorado [2]	2, 124	1, 357	1, 180	1, 702	2, 835	4, 297
Georgia	--------	--------	--------	--------	--------	--------
Idaho	1, 990	1, 370	1, 649	668	1, 087	1, 036
Maine	--------	--------	--------	--------	--------	--------
Maryland	--------	--------	--------	--------	--------	--------
Massachusetts	--------	--------	--------	--------	--------	--------
Michigan	69, 152	67, 831	77, 579	87, 690	88, 769	89, 221
Missouri	101	91	6	538	225	33
Montana	112, 063	124, 576	134, 455	127, 686	111, 746	124, 131
Nevada	33, 602	36, 903	39, 650	50, 914	60, 130	79, 438
New Hampshire	--------	--------	--------	--------	--------	--------
New Mexico	30, 678	37, 346	38, 214	40, 821	37, 126	44, 927
North Carolina	32	--------	--------	734	2, 722	4, 104
Oregon	642	384	53	148	244	179
Pennsylvania	852	557	518	509	868	2, 489
South Carolina	--------	--------	--------	--------	--------	--------
South Dakota	--------	--------	--------	--------	--------	--------
Tennessee	9, 361	9, 168	9, 894	9, 303	7, 470	8, 187
Texas	2	--------	--------	6	11	224
Utah	111, 197	121, 069	118, 243	128, 737	128, 467	146, 618
Vermont	--------	--------	--------	236	104	--------
Virginia	--------	--------	--------	--------	--------	--------
Washington	436	464	580	676	843	589
Wisconsin	--------	--------	--------	--------	--------	--------
Wyoming	55	--------	--------	--------	--------	1
Other [3]	--------	--------	--------	--------	--------	--------
Total	738, 870	803, 083	839, 059	862, 638	824, 980	904, 898

	1929	1930	1931	1932	1933	1934
Alabama	--------	--------	--------	--------	--------	6
Alaska	20, 255	16, 326	11, 307	4, 369	15	57
Arizona	415, 314	288, 096	200, 672	91, 246	57, 021	89, 041
California	16, 609	13, 643	6, 466	709	495	285
Colorado [2]	4, 453	5, 257	4, 083	3, 699	4, 834	5, 647
Georgia	--------	--------	--------	--------	--------	--------
Idaho	2, 566	1, 555	572	572	781	766
Maine	--------	--------	--------	--------	--------	--------
Maryland	--------	--------	--------	--------	--------	--------
Massachusetts	--------	--------	--------	--------	--------	--------
Michigan	93, 201	84, 691	59, 030	27, 198	23, 427	24, 108
Missouri	1	88	--------	--------	--------	23
Montana	148, 863	98, 094	92, 278	42, 424	32, 738	31, 632
Nevada	70, 069	54, 602	36, 317	15, 744	14, 245	20, 805
New Hampshire	--------	--------	--------	--------	--------	--------
New Mexico	48, 859	32, 575	30, 752	14, 209	13, 473	11, 815
North Carolina	(5)	6, 695	(5)	(5)	(5)	(5)
Oregon	328	88	1	16	6	19
Pennsylvania	1, 727	1, 430	(5)	(5)	(5)	(5)
South Carolina	--------	--------	--------	--------	--------	(6)
South Dakota	--------	--------	--------	--------	--------	--------
Tennessee	(5)	10, 584	(5)	(5)	(5)	(5)
Texas	171	71	--------	4	1	15
Utah	159, 141	90, 263	75, 618	32, 482	36, 791	43, 012
Vermont	(5)	407	--------	--------	--------	--------
Virginia	--------	--------	--------	--------	--------	(6)
Washington	700	603	101	3	3	7
Wisconsin	--------	--------	--------	--------	--------	--------
Wyoming	2	6	5	(6)	--------	2
Other [3]	15, 296	--------	11, 673	5, 436	6, 813	10, 161
Total	997, 555	705, 074	528, 875	238, 111	190, 643	237, 401

See footnotes at end of table.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1935	1936	1937	1938	1939	1940
Alabama	5	7	4	-	-	-
Alaska	7, 750	18, 850	17, 336	14, 549	128	55
Arizona	139, 015	211, 275	288, 478	210, 797	262, 112	281, 169
California	977	4, 381	5, 251	806	4, 180	6, 438
Colorado [2]	7, 327	8, 865	10, 934	14, 171	13, 215	12, 152
Georgia	-	-	-	-	-	13
Idaho	1, 048	1, 477	2, 232	2, 139	2, 516	3, 349
Maine	-	-	-	-	-	-
Maryland	-	-	-	-	-	-
Massachusetts	-	-	-	-	-	-
Michigan	32, 054	47, 984	47, 464	46, 743	43, 985	45, 198
Missouri	34	191	269	-	-	685
Montana	77, 479	109, 544	144, 528	77, 213	97, 827	126, 391
Nevada	37, 133	70, 696	74, 603	46, 169	66, 597	78, 454
New Hampshire	-	-	-	-	-	-
New Mexico	2, 253	3, 166	32, 053	20, 439	46, 142	69, 848
North Carolina	(5)	(5)	(5)	(5)	(5)	(5)
Oregon	199	287	410	38	48	88
Pennsylvania	(5)	(5)	(5)	(5)	(5)	(5)
South Carolina	(6)	-	1	(6)	-	(6)
South Dakota	-	-	-	-	-	6
Tennessee	(5)	(5)	(5)	(5)	(5)	(5)
Texas	14	27	160	16	34	30
Utah	64, 758	126, 217	205, 994	108, 126	171, 890	231, 864
Vermont	-	-	-	-	-	-
Virginia	(6)	-	(6)	(5)	-	-
Washington	43	102	64	6, 017	8, 998	9, 612
Wisconsin	-	-	-	-	-	-
Wyoming	1	-	-	-	-	2
Other [3]	10, 401	11, 447	12, 217	10, 540	10, 648	12, 732
	380, 491	614, 516	841, 998	557, 763	728, 320	878, 086
	1941	**1942**	**1943**	**1944**	**1945**	**1946**
Alabama	-	-	-	-	-	-
Alaska	72	22	27	2	5	2
Arizona	326, 317	393, 387	403, 181	358, 303	287, 203	289, 223
California	3, 943	1, 058	8, 762	12, 721	6, 473	4, 240
Colorado [2]	6, 748	1, 102	1, 028	1, 048	1, 485	1, 754
Georgia	-	-	-	-	-	-
Idaho	3, 621	3, 430	2, 324	1, 688	1, 548	1, 038
Maine	-	-	-	-	-	-
Maryland	-	-	-	-	-	-
Massachusetts	-	-	-	-	-	-
Michigan	46, 440	45, 679	46, 764	42, 421	30, 401	21, 663
Missouri	1, 400	1, 300	1, 340	3, 302	3, 399	1, 857
Montana	128, 036	141, 194	134, 525	118, 190	88, 506	58, 481
Nevada	78, 911	83, 663	71, 068	61, 232	52, 595	48, 616
New Hampshire	-	-	-	-	-	-
New Mexico	73, 478	80, 100	76, 163	69, 730	56, 571	50, 191
North Carolina	(5)	(5)	1, 112	282	-	-
Oregon	83	103	6	3	1	7
Pennsylvania	(5)	(5)	5, 175	4, 942	3, 565	2, 839
South Carolina	(6)	(6)	(6)	-	-	-
South Dakota	-	1	-	1	-	-
Tennessee	(5)	(5)	7, 568	7, 636	6, 959	6, 985
Texas	6	99	81	115	55	3
Utah	266, 838	306, 691	323, 989	282, 575	226, 376	114, 284
Vermont	-	-	290	1, 898	1, 861	3, 026
Virginia	-	28	100	291	70	-
Washington	8, 686	8, 030	7, 315	6, 169	5, 821	4, 527
Wisconsin	-	-	-	-	-	-
Wyoming	4	-	-	-	-	1
Other [3]	13, 566	14, 174	-	-	-	-
Total	958, 149	1, 080, 061	1, 090, 818	972, 549	772, 894	608, 737

See footnotes at end of table.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1947	1948	1949	1950	1951	1952
Alabama						
Alaska	12	16	4	6	1	
Arizona	366, 218	375, 121	359, 010	403, 301	415, 870	395, 719
California	2, 407	481	649	646	921	800
Colorado [2]	2, 150	2, 298	2, 403	3, 141	3, 212	3, 606
Georgia						
Idaho	1, 640	1, 624	1, 438	2, 107	2, 160	3, 213
Maine						
Maryland						
Massachusetts						
Michigan	24, 184	27, 777	19, 506	25, 608	24, 979	21, 699
Missouri	1, 760	2, 370	3, 670	2, 982	2, 422	2, 576
Montana	57, 900	58, 252	56, 611	54, 478	57, 406	61, 948
Nevada	49, 603	45, 242	38, 058	52, 569	56, 474	57, 537
New Hampshire						
New Mexico	60, 205	74, 687	55, 388	66, 300	73, 558	76, 112
North Carolina						
Oregon	14	2	20	19	11	1
Pennsylvania	3, 613	5, 347	3, 974	4, 142	5, 297	3, 485
South Carolina						
South Dakota						
Tennessee	6, 825	6, 693	6, 489	6, 851	7, 069	7, 620
Texas	6	23	24	2	1	18
Utah	266, 533	227, 007	197, 245	278, 630	271, 086	282, 894
Vermont	2, 248	2, 208	2, 986	3, 504	3, 774	3, 774
Virginia	5					
Washington	2, 240	5, 665	5, 275	5, 057	4, 089	4, 357
Wisconsin						
Wyoming						
Other [3]						
Total	847, 563	834, 813	752, 750	909, 343	928, 330	925, 359

	1953	1954	1955	1956	1957	1958
Alabama						
Alaska		4	1	(6)	(6)	5
Arizona	393, 525	377, 927	454, 105	505, 908	515, 854	485, 839
California	382	362	613	859	945	749
Colorado [4]	2, 941	4, 523	4, 323	4, 228	5, 115	4, 193
Georgia						
Idaho	3, 136	4, 828	5, 618	6, 656	7, 912	9, 846
Maine						
Maryland						
Massachusetts						
Michigan	24, 097	23, 593	50, 066	61, 526	58, 400	58, 005
Missouri	2, 374	1, 925	1, 722	1, 890	1, 604	1, 429
Montana	77, 617	59, 349	81, 542	96, 426	91, 512	90, 683
Nevada	61, 850	70, 217	78, 925	80, 824	77, 750	66, 137
New Hampshire						
New Mexico	72, 477	60, 558	66, 417	74, 345	67, 472	55, 540
North Carolina		(6)	(6)	(10)	(10)	(10)
Oregon	9	5	4	7	23	10
Pennsylvania	3, 027	3, 270	4, 110	[11] 4, 102	[11] 7, 516	[11] 8, 073
South Carolina						
South Dakota						
Tennessee	7, 829	9, 087	9, 911	10, 449	9, 790	9, 109
Texas			1			
Utah	269, 496	211, 835	232, 949	250, 604	237, 857	189, 184
Vermont	3, 947	4, 352	4, 305	3, 403	3, 405	475
Virginia						
Washington	3, 740	3, 636	3, 958	2, 926	1, 700	52
Wisconsin						
Wyoming	1	1		3	4	(6)
Other [3]						
Total	926, 448	835, 472	998, 570	1, 104, 156	1, 086, 859	979, 329

See footnotes at end of table.

TABLE 22.—*Mine production*[1] *by State of recoverable copper in the United States, short tons*—Con.

	1959	1960	1961	1962	Total from earliest record through 1962
Alabama					64
Alaska	36	41	92		686, 084
Arizona	430, 297	538, 605	587, 053	644, 242	18, 426, 686
California	663	1, 087	1, 382	1, 162	639, 932
Colorado [2]	2, 940	3, 247	4, 141	4, 534	307, 706
Georgia					1, 117
Idaho	8, 713	4, 208	4, 328	3, 861	179, 075
Maine					(12)
Maryland					(12)
Massachusetts					(12)
Michigan	55, 300	56, 385	70, 245	74, 099	5, 494, 959
Missouri	1, 065	1, 087	1, 479	2, 752	[13] 52, 785
Montana	65, 911	91, 972	104, 000	94, 021	7, 777, 981
Nevada	57, 375	77, 485	78, 022	82, 602	2, 813, 338
New Hampshire					(12)
New Mexico	39, 688	67, 288	79, 606	82, 683	2, 422, 523
North Carolina	(10)	(10)	(10)	(10)	61, 561
Oregon		6	(10)	(10)	12, 492
Pennsylvania	[11] 6, 604	[11] 7, 907	8, 934	6, 108	(12)
South Carolina					10
South Dakota		1			107
Tennessee	11, 490	12, 723	12, 272	14, 298	533, 378
Texas					1, 384
Utah	144, 715	218, 049	213, 534	218, 018	8, 610, 077
Vermont					(12)
Virginia					(12)
Washington	49	78	66	41	121, 855
Wisconsin					(12)
Wyoming			1		16, 336
Other [3]					
Total	824, 846	1, 080, 169	1, 165, 155	1, 228, 421	[14] 48, 404, 846

[1] Smelter production from 1845 through 1905, thereafter mine production.
[2] For several of the early years production credited to Colorado included recovery from some ores of uncertain origin smelted in Colorado plants.
[3] Includes States shown as (5). Also includes lead desilverizers and unapportioned.
[4] Comprises period 1858-61, inclusive.
[5] Included with "Other." Bureau of Mines not at liberty to publish separately.
[6] Less than 1 ton.
[7] Includes unapportioned.
[8] 1908 volume of Mineral Resources credits this figure to Massachusetts and New Hampshire; 1909 volume credits it to New Hampshire alone.
[9] Includes 1 ton produced in Philippine Islands.
[10] Included with Pennsylvania to avoid disclosing operations of individual companies.
[11] Includes North Carolina to avoid disclosing operations of individual companies.
[12] Not available.
[13] Small quantity for Wisconsin included with Missouri.
[14] Largely smelter production for States east of Mississippi River, except Michigan; includes 245,396 tons for States indicated by (5).

TABLE 23.—*World copper mine production, short tons*

	1926	1927	1928	1929	1930
North America:					
United States	862, 638	824, 980	904, 898	997, 555	705, 074
Canada	66, 547	70, 074	101, 510	125, 091	152, 792
Cuba	[1] 9, 028	[1] 14, 807	18, 239	16, 515	17, 299
Mexico	62, 112	66, 001	74, 216	95, 409	80, 293
South America:					
Bolivia [2]	8, 962	9, 622	9, 354	7, 923	4, 395
Chile	268, 476	267, 420	316, 143	353, 434	242, 864
Peru	46, 860	61, 033	62, 233	62, 853	55, 323
Other [3]	3, 134	1, 102	----------	----------	106
Europe:					
Austria	2, 500	2, 571	3, 346	2, 294	2, 443
Finland	1, 092	922	3, 759	5, 032	5, 496
Germany:					
East / West	30, 520	30, 061	28, 895	31, 948	29, 732
Norway	6, 842	13, 632	17, 393	20, 823	19, 089
Poland	----------	----------	----------	----------	----------
Spain [4]	54, 600	55, 900	59, 700	70, 200	64, 400
Sweden	782	863	682	1, 243	890
U.S.S.R. [5]	11, 722	14, 988	20, 939	928, 000	37, 600
Yugoslavia [6]	10, 660	14, 179	16, 629	22, 790	26, 966
Other [7]	6, 158	6, 256	5, 369	6, 456	7, 124
Asia:					
China	[2] 3, 369	[2] 1, 160	[2] 4, 845	[2] 3, 824	[2] 1, 326
Cyprus [2]	3, 369	4, 712	5, 401	6, 504	5, 732
India [8]	6, 504	5, 622	6, 603	7, 937	13, 007
Japan	[9] 74, 257	[9] 73, 382	[9] 75, 214	[9] 83, 190	[9] 87, 119
Philippines	----------	----------	----------	----------	----------
Taiwan [10]	1, 893	1, 526	1, 653	6, 923	3, 373
Turkey [6]	----------	----------	----------	----------	----------
Other [11]	858	1, 107	669	603	649
Africa:					
Northern Rhodesia	[9] 793	[9] 3, 658	[9] 6, 643	[9] 6, 121	9, 513
Republic of the Congo	88, 889	98, 278	122, 919	149, 406	150, 359
Republic of South Africa	[9] 9, 722	[9] 10, 278	[9] 9, 754	[9] 10, 261	9, 510
Southern Rhodesia	[10] 8	----------	[10] 121	[9] 399	[9] 1, 470
South-West Africa	9, 811	11, 795	12, 456	13, 889	16, 645
Other [12]	1, 012	852	672	315	662
Oceania:					
Australia	9, 769	11, 170	10, 602	14, 350	14, 542
Total [13]	1, 665, 000	1, 680, 000	1, 900, 000	2, 150, 000	1, 765, 000

See footnotes at end of table.

TABLE 23.—*World copper mine production, short tons*—Continued

	1931	1932	1933	1934	1935
North America:					
United States	528, 875	238, 111	190, 643	237, 405	380, 491
Canada	147, 759	126, 212	153, 476	186, 633	212, 756
Cuba	14, 889	6, 533	9, 873	6, 826	7, 672
Mexico	59, 758	38, 816	43, 899	48, 797	43, 401
South America:					
Bolivia [2]	2, 259	2, 223	2, 038	1, 950	2, 176
Chile	246, 381	113, 729	180, 112	282, 963	294, 408
Peru	49, 332	25, 232	27, 419	30, 573	32, 687
Other [3]	822	----	----	----	----
Europe:					
Austria	1, 447	188	147	91	61
Finland	7, 050	7, 329	12, 524	9, 300	13, 213
Germany:					
East } West }	32, 879	33, 886	32, 445	28, 627	30, 225
Norway	9, 599	18, 678	21, 913	23, 283	21, 724
Poland	----	----	----	----	----
Spain [4]	59, 500	38, 600	38, 600	36, 400	33, 100
Sweden	1, 801	4, 750	7, 574	5, 621	7, 042
U.S.S.R.[5]	34, 300	33, 817	36, 035	48, 591	69, 718
Yugoslavia [6]	26, 842	33, 245	44, 443	48, 932	42, 990
Other [7]	4, 448	1, 981	1, 987	1, 862	2, 846
Asia:					
China	326	485	532	519	424
Cyprus [2]	4, 299	3, 638	4, 740	4, 519	13, 700
India [8]	12, 897	12, 566	12, 015	12, 897	12, 432
Japan	[9] 83, 608	[9] 79, 231	[9] 76, 096	[9] 73, 857	[9] 78, 169
Philippines	----	----	----	----	4
Taiwan [10]	4, 538	4, 860	4, 400	4, 400	4, 353
Turkey [6]	----	----	----	----	----
Other [11]	769	765	875	1, 581	2, 392
Africa:					
Northern Rhodesia	36, 291	97, 708	144, 954	176, 511	188, 898
Republic of the Congo	132, 277	59, 525	73, 409	121, 348	118 699
Republic of South Africa	11, 250	10, 365	9, 241	8, 666	11, 793
Southern Rhodesia	[9] 593	[9] 7	----	----	----
South-West Africa	9, 259	2, 646	----	----	----
Other [12]	88	185	3, 326	276	22
Oceania:					
Australia	15, 156	16, 417	16, 142	13, 454	19, 029
Total [13]	1, 540, 000	1, 010, 000	1, 150, 000	1, 415, 000	1, 645, 000

See footnotes at end of table.

TABLE 23.—*World copper mine production, short tons*—Continued

	1936	1937	1938	1939	1940
North America:					
United States	614, 516	841, 998	557, 763	728, 320	878, 086
Canada	216, 394	274, 342	294, 503	315, 810	338, 185
Cuba	12, 305	14, 541	15, 907	10, 983	11, 574
Mexico	32, 753	50, 791	46, 133	48, 932	41, 449
South America:					
Bolivia [2]	3, 581	4, 077	3, 180	4, 471	7, 341
Chile	282, 422	455, 265	387, 442	373, 874	388, 024
Peru	36, 764	39, 355	41, 369	39, 260	48, 463
Other [3]	------	------	------	18	1, 612
Europe:					
Austria	13	13	------	22	22
Finland	12, 556	13, 263	13, 735	14, 940	16, 926
Germany:					
East West	29, 629	29, 905	33, 000	33, 000	33, 000
Norway	24, 920	22, 866	23, 840	22, 441	17, 118
Poland	------	------	------	------	------
Spain [4]	28, 700	30, 900	32, 000	19, 200	14, 300
Sweden	8, 932	7, 908	10, 239	10, 593	10, 461
U.S.S.R.[5]	91, 491	103, 893	126, 272	143, 904	[14] 173, 000
Yugoslavia [6]	43, 431	43, 442	46, 289	45, 920	47, 345
Other [7]	2, 555	4, 782	3, 051	3, 510	7, 044
Asia:					
China	357	443	493	[9] 1, 081	[9] 1, 549
Cyprus [2]	18, 313	30, 271	32, 827	23, 226	6, 658
India [8]	9, 968	7, 952	6, 724	8, 400	8, 736
Japan	[9] 85, 950	71, 655	72, 752	73, 414	81, 494
Philippines	1, 121	3, 680	4, 889	8, 263	10, 206
Taiwan [10]	6, 520	7, 622	7, 933	7, 673	6, 876
Turkey [6]	------	441	2, 743	7, 425	9, 650
Other [11]	4, 009	9, 835	5, 394	6, 238	6, 063
Africa:					
Northern Rhodesia	191, 216	275, 396	280, 983	237, 068	293, 881
Republic of the Congo	105, 455	165, 995	136, 624	135, 197	164, 056
Republic of South Africa	9, 996	12, 554	12, 462	12, 123	15, 802
Southern Rhodesia	88	------	6	17	488
South-West Africa	------	1, 736	5, 322	3, 891	1, 637
Other [12]	------	------	24	42	24
Oceania:					
Australia	20, 788	21, 422	21, 779	23, 027	22, 087
Total [13]	1, 895, 000	2, 545, 000	2, 225, 000	2, 360, 000	2, 665, 000

See footnotes at end of table.

TABLE 23.—*World copper mine production, short tons*—Continued

	1941	1942	1943	1944	1945
North America:					
United States	958, 149	1, 080, 062	1, 090, 818	972, 549	772, 894
Canada	328, 988	308, 075	293, 842	279, 067	242, 628
Cuba	10, 845	9, 828	7, 060	7, 258	9, 995
Mexico	53, 700	56, 103	54, 866	45, 528	67, 990
South America:					
Bolivia [2]	8, 018	7, 028	6, 626	6, 801	6, 721
Chile	513, 089	533, 907	548, 003	549, 524	518, 285
Peru	40, 589	38, 947	36, 825	35, 710	35, 181
Other [3]	3, 537	1, 749	4, 870	4, 101	3, 625
Europe:					
Austria	816	1, 082	1, 505	1, 627	376
Finland	18, 328	17, 749	18, 037	17, 462	16, 510
Germany:					
East, West	26, 500	25, 400	23, 800	25, 900	[14] 6, 600
Norway	19, 828	17, 054	17, 910	15, 942	5, 735
Poland	-----	-----	-----	-----	-----
Spain [4]	10, 300	11, 800	12, 200	12, 200	9, 100
Sweden	14, 760	19, 903	19, 656	17, 770	16, 453
U.S.S.R. [5]	[14] 176, 000	[14] 149, 000	[14] 143, 000	[14] 149, 000	[14] 154, 000
Yugoslavia [6]	25, 353	35, 274	29, 762	25, 022	13, 800
Other [7]	3, 232	3, 075	3, 104	2, 438	1, 209
Asia:					
China	[9] 1, 623	[9] 1, 210	[9] 1, 359	[9] 1, 135	[9] 687
Cyprus [2]	-----	-----	5, 707	1, 567	-----
India [8]	7, 616	7, 392	7, 616	7, 392	6, 867
Japan	84, 925	78, 824	89, 300	87, 620	32, 038
Philippines	10, 900	9, 900	9, 800	2, 400	2, 301
Taiwan [10]	6, 196	5, 585	6, 636	4, 393	276
Turkey [6]	11, 584	9, 103	10, 725	12, 181	10, 867
Other [11]	4, 817	4, 542	2, 328	3, 064	1, 379
Africa:					
Northern Rhodesia	255, 644	276, 199	284, 848	248, 775	219, 731
Republic of the Congo	178, 758	182, 915	172, 897	182, 415	176, 602
Republic of South Africa	22, 860	27, 098	25, 057	25, 209	26, 473
Southern Rhodesia	559	293	557	110	173
South-West Africa	-----	1, 764	5, 512	-----	-----
Other [12]	125	552	503	827	188
Oceania:					
Australia	23, 362	22, 850	27, 245	31, 422	27, 463
Total [13]	2, 820, 000	2, 945, 000	2, 960, 000	2, 780, 000	2, 390, 000

See footnotes at end of table.

TABLE 23.—*World copper mine production, short tons*—Continued

	1946	1947	1948	1949	1950
North America:					
United States	608,737	847,563	834,813	752,750	909,343
Canada	188,881	230,107	245,278	263,457	264,209
Cuba	12,481	15,134	18,000	19,180	22,500
Mexico	67,300	69,988	65,120	63,103	68,011
South America:					
Bolivia [2]	6,754	6,880	7,293	5,593	5,185
Chile	397,976	470,432	490,602	409,209	400,071
Peru	27,108	24,793	19,917	30,819	33,124
Other [3]	2,975	183	522	776	580
Europe:					
Austria	138	285	1,082	1,429	1,802
Finland	14,936	16,985	20,265	20,658	17,196
Germany:					
East	20,200	[15] 7,700	[15] 11,000	[15] 11,000	[15] 9,100
West		263	401	952	1,520
Norway	13,502	16,212	16,658	16,397	17,219
Poland					440
Spain [4]	13,400	7,114	6,066	7,388	6,802
Sweden	16,934	14,489	16,353	17,938	17,747
U.S.S.R. [5]	[14] 165,000	[14] 182,000	[14] 198,000	[14] 220,000	[14] 240,000
Yugoslavia [6]	23,953	35,660	40,642	37,902	44,181
Other [7]	2,123	1,116	1,674	2,207	2,718
Asia:					
China	[9] 1,044	[9] 1,179	[9] 520	[9] 2,066	[14] [9] 4,400
Cyprus [2]	78	13,978	17,345	26,385	25,685
India [8]	6,680	6,021	6,962	6,950	7,700
Japan	18,307	23,664	28,387	36,244	43,463
Philippines		2,758	3,693	7,724	11,446
Taiwan [10]	496	882	606	298	220
Turkey [6]	11,078	11,111	12,102	12,437	12,897
Other [11]	585	708	147	101	75
Africa:					
Northern Rhodesia	211,143	217,473	249,642	285,591	327,923
Republic of the Congo	158,606	166,272	171,388	155,866	193,918
Republic of South Africa	29,767	32,331	32,463	33,570	37,459
Southern Rhodesia	160	192	144	88	129
South-West Africa		3,417	9,128	10,656	12,122
Other [12]	163	85	1,005	1,215	1,560
Oceania:					
Australia	19,886	14,698	13,853	15,077	16,693
Total [13]	2,040,000	2,440,000	2,540,000	2,480,000	2,760,000

See footnotes at end of table.

TABLE 23.—*World copper mine production, short tons*—Continued

	1951	1952	1953	1954	1955
North America:					
United States	928, 330	925, 359	926, 448	835, 472	998, 570
Canada	269, 971	258, 038	253, 252	302, 732	325, 994
Cuba	21, 700	19, 700	17, 800	17, 500	20, 800
Mexico	74, 242	64, 444	66, 302	60, 413	60, 269
South America:					
Bolivia [2]	5, 342	5, 184	4, 920	4, 037	3, 855
Chile	419, 630	450, 440	400, 287	400, 861	477, 873
Peru	35, 576	33, 563	39, 023	42, 356	47, 844
Other [3]	2	------	------	------	------
Europe:					
Austria	2, 026	2, 913	3, 279	3, 381	2, 841
Finland	20, 280	24, 250	21, 000	23, 150	23, 700
Germany:					
East	[15] 9, 400	[15] 12, 100	[15] 17, 400	[15] 22, 800	[15] 23, 100
West	1, 840	2, 593	2, 262	2, 600	1, 335
Norway	15, 436	15, 027	14, 362	14, 980	15, 419
Poland	2, 500	3, 700	4, 700	5, 300	6, 100
Spain [4]	8, 333	9, 895	9, 406	7, 951	6, 726
Sweden	15, 925	17, 500	14, 924	14, 565	17, 275
U.S.S.R.[5]	[14] 280, 000	[14] 325, 000	[14] 334, 000	[14] 352, 000	[14] 385, 000
Yugoslavia [6]	35, 286	36, 177	34, 381	33, 394	32, 098
Other [7]	3, 665	3, 801	5, 295	7, 964	8, 931
Asia:					
China	[14 9] 6, 600	[14 9] 6, 600	[14 9] 8, 800	[14 9] 8, 800	[14 9] 11, 000
Cyprus [2]	25, 145	29, 564	23, 937	30, 059	26, 179
India [8]	8, 144	7, 183	5, 500	8, 300	8, 500
Japan	47, 135	59, 031	64, 907	73, 056	80, 466
Philippines	14, 013	14, 596	14, 016	15, 817	19, 247
Taiwan [10]	419	689	287	906	1, 451
Turkey [6]	14, 436	25, 717	25, 901	27, 042	26, 740
Other [11]	117	612	1, 580	661	1, 929
Africa:					
Northern Rhodesia	352, 048	363, 190	410, 808	438, 708	395, 308
Republic of the Congo	211, 598	226, 799	236, 057	243, 424	259, 161
Republic of South Africa	37, 182	38, 704	39, 843	46, 638	49, 239
Southern Rhodesia	105	120	197	331	1, 187
South-West Africa	13, 907	15, 645	13, 357	15, 668	23, 563
Other [12]	1, 540	2, 486	3, 358	5, 289	3, 557
Oceania:					
Australia	18, 600	22, 498	40, 875	45, 760	50, 956
Total [13]	2, 900, 000	3, 020, 000	3, 050, 000	3, 110, 000	3, 420, 000

See footnotes at end of table.

TABLE 23.—*World copper mine production, short tons*—Continued

	1956	1957	1958	1959	1960	1961	1962
North America:							
United States	1, 104, 156	1, 086, 859	979, 329	824, 846	1, 080, 169	1, 165, 155	1, 228, 421
Canada	354, 860	359, 109	345, 114	395, 269	439, 262	439, 088	465, 446
Cuba	18, 200	18, 000	14, 343	9, 942	[2] 13, 058	[4] 5, 500	[4] 5, 300
Mexico	60, 748	66, 800	71, 609	63, 134	66, 502	54, 359	51, 945
South America:							
Bolivia [2]	4, 896	4, 320	3, 168	2, 461	2, 503	2, 294	2, 645
Chile	539, 844	535, 306	514, 925	602, 108	591, 330	607, 233	646, 069
Peru	50, 966	63, 023	59, 105	54, 914	200, 313	218, 315	182, 877
Other [3]	893	1, 417	1, 353	1, 648	1, 611	1, 611	1, 574
Europe:							
Austria	2, 579	2, 574	2, 695	2, 726	2, 188	2, 105	2, 168
Finland	23, 150	28, 700	31, 800	32, 400	31, 000	37, 500	38, 700
Germany:							
East	[15] 23, 100	[15] 24, 250	[14] 19, 300	[14] 20, 800	[14] 20, 900	[14] 27, 500	[14] 30, 700
West	1, 076	1, 202	1, 484	1, 963	1, 960	1, 816	1, 904
Norway	16, 488	16, 787	17, 501	15, 828	16, 966	15, 379	16, 100
Poland	8, 000	8, 300	[14] 8, 800	[14] 9, 900	[14] 11, 600	[14] 12, 900	[14] 14, 300
Spain [4]	7, 525	11, 077	7, 466	12, 137	8, 786	10, 922	9, 920
Sweden	18, 436	19, 924	20, 453	19, 079	18, 396	18, 629	21, 050
U.S.S.R. [5]	[14] 430,000	[14] 450,000	[14] 470,000	[14] 480, 000	([14])	[14] 600, 000	[14] 700, 000
Yugoslavia [6]	35, 088	36, 883	38, 840	38, 141	36, 681	41, 786	57, 008
Other [7]	7, 707	9, 082	21, 449	23, 260	25, 782	26, 979	27, 359
Asia:							
China	[14] [9] 13,000	[14] [9] 16,500	[14] 35, 000	[14] 55, 000	[14] 80, 000	[14] 110, 000	[14] 110, 000
Cyprus [2]	39, 497	43, 676	36, 614	39, 978	39, 096	31, 585	27, 735
India [8]	8, 800	9, 000	9, 150	8, 900	9, 750	9, 750	10, 910
Japan	86, 497	90, 066	89, 837	93, 970	98, 307	106, 273	113, 681
Philippines	29, 722	44, 513	51, 842	54, 587	48, 513	57, 182	60, 327
Taiwan [10]	2, 011	2, 251	1, 702	1, 793	2, 315	2, 460	2, 323
Turkey [6]	30, 544	28, 871	27, 744	30, 551	30, 110	31, 793	31, 115
Other [11]	1, 135	853	1, 020	4, 239	5, 414	5, 774	6, 339
Africa:							
Northern Rhodesia	445, 466	480, 313	441, 073	598, 835	635, 326	633, 139	619, 856
Republic of the Congo	275, 538	267, 028	261, 867	310, 955	333, 175	325, 400	325, 442
Republic of South Africa	51, 252	50, 959	54, 615	54, 066	50, 846	57, 952	51, 115
Southern Rhodesia	1, 931	3, 226	8, 430	12, 016	15, 128	15, 243	15, 146
South-West Africa	28, 980	29, 910	30, 975	34, 436	22, 555	27, 770	24, 971
Other [12]	5, 492	6, 084	16, 438	17, 919	21, 316	18, 637	22, 944
Oceania:							
Australia	59, 406	64, 034	84, 801	106, 344	122, 567	107, 173	118, 138
Total [13]	3, 790, 000	3, 890, 000	3, 780, 000	[16] 4,030,000	[16] 4,640,000	[16] 4,840,000	[16] 5,050,000

[1] United States imports.
[2] Exports.
[3] "Other" South America includes Argentina, Brazil, Ecuador, and Venezuela.
[4] 1926–37, inclusive, estimated by Metallgesellschaft; beginning 1938 figures from American Bureau of Metal Statistics, excluding copper content of iron pyrites which may or may not have been recovered.
[5] Smelter production; output from U.S.S.R. in Asia included with U.S.S.R. in Europe.
[6] Smelter production through 1954.
[7] Other Europe includes Albania, Bulgaria, Czechoslovakia, France, Greece, Hungary, Italy, Portugal, Rumania, United Kingdom, and Ireland (from 1958).
[8] Includes Burma through 1936.
[9] Smelter production.
[10] Includes copper content of cement copper.
[11] Other Asia includes Burma (from 1937), Indonesia, Republic of Korea, Saudi Arabia, and Israel (from 1958).
[12] "Other" Africa includes Algeria, Angola, French Equatorial Africa, Morocco, (Southern Zone), Tanganyika, Congo, Republic of (from 1961), and Uganda (from 1958).
[13] Data do not add to exact totals shown because of rounding where estimated figures are included in the detail.
[14] Estimate.
[15] Estimated by Metallgesellschaft.
[16] Includes Nicaragua (from 1959) and Haiti (from 1960).

TABLE 24.—*World smelter production of copper, short tons*

	1926	1927	1928	1929	1930
North America:					
United States [1]	945, 840	930, 184	1, 004, 694	1, 100, 975	804, 258
Canada	33, 289	35, 215	62, 412	80, 095	111, 944
Mexico	40, 153	43, 263	51, 660	65, 033	59, 552
South America:					
Chile	207, 934	248, 795	302, 318	333, 460	228, 794
Peru [2]	45, 897	51, 122	57, 642	59, 483	53, 020
Europe:					
Austria	3, 531	3, 646	3, 774	4, 293	4, 493
Finland	402	390	413	259	-
Germany:					
East, West	50, 900	55, 800	53, 500	59, 100	65, 300
Norway	212	14	869	2, 646	5, 676
Poland	-	-	-	-	-
Spain [3]	19, 954	22, 313	18, 563	18, 775	16, 369
Sweden	4, 182	5, 959	3, 743	5, 234	6, 088
U.S.S.R.	11, 722	14, 988	20, 939	28, 000	37, 600
Yugoslavia	10, 660	14, 179	16, 629	22, 790	26, 966
Other [4]	34, 017	39, 368	37, 783	38, 700	39, 792
Asia:					
China	[5] 2, 280	[5] 1, 160	[5] 4, 845	[5] 3, 824	[5] 1, 326
India	-	-	-	1, 831	3, 331
Japan	74, 257	73, 382	75, 214	83, 190	87, 119
Turkey	-	-	-	-	-
Other [6]	858	1, 107	669	603	649
Africa:					
Northern Rhodesia	793	3, 685	6, 643	6, 121	7, 022
Republic of the Congo	88, 889	98, 278	122, 919	149, 406	150, 359
Republic of South Africa	9, 722	10, 278	9, 754	10, 261	8, 254
Uganda	-	-	-	-	-
Other [7]	8	-	121	399	1, 470
Oceania:					
Australia	12, 486	10, 712	13, 281	12, 179	16, 688
World total [8]	1, 600, 000	1, 665, 000	1, 870, 000	2, 085, 000	1, 735, 000

See footnotes at end of table.

TABLE 24.—*World smelter production of copper, short tons*—Continued

	1931	1932	1933	1934	1935
North America:					
United States [1]	592, 133	307, 541	250, 470	276, 928	417, 363
Canada	121, 902	105, 502	130, 193	167, 350	193, 419
Mexico	48, 213	37, 400	43, 651	51, 919	45, 415
South America:					
Chile	237, 290	107, 244	172, 800	272, 264	286, 523
Peru [2]	50, 024	24, 836	27, 204	30, 901	33, 496
Europe:					
Austria	3, 566	2, 190	1, 102	658	1, 474
Finland					
Germany:					
East West	61, 200	56, 100	54, 900	58, 400	61, 700
Norway	4, 797	5, 970	7, 379	8, 806	9, 301
Poland					
Spain [3]	19, 567	9, 921	11, 076	8, 227	11, 282
Sweden	3, 146	3, 459	7, 317	8, 658	9, 289
U.S.S.R.	34, 300	33, 817	36, 035	48, 591	69, 718
Yugoslavia	26, 842	33, 245	44, 443	48, 932	42, 990
Other [4]	55, 894	46, 977	53, 707	82, 142	107, 184
Asia:					
China	[5] 173	18	40		391
India	4, 557	4, 976	5, 400	7, 055	7, 700
Japan	83, 608	79, 231	76, 096	73, 857	78, 169
Turkey					
Other [6]	769	765	865	1, 581	2, 392
Africa:					
Northern Rhodesia	9, 998	76, 034	116, 709	154, 445	160, 721
Republic of the Congo	132, 277	59, 525	73, 409	121, 348	118, 699
Republic of South Africa	11, 271	10, 347	9, 235	9, 180	10, 546
Uganda					
Other [7]	593	7			
Oceania:					
Australia	14, 489	14, 904	12, 586	8, 927	12, 508
World total [8]	1, 517, 000	1, 020, 000	1, 135, 000	1, 440, 000	1, 680, 000

See footnotes at end of table.

TABLE 24.—*World smelter production of copper, short tons*—Continued

	1936	1937	1938	1939	1940
North America:					
United States [1]	653, 279	904, 261	629, 173	769, 774	1, 016, 693
Canada	191, 154	231, 512	237, 804	252, 834	282, 517
Mexico	35, 961	50, 436	44, 744	43, 040	34, 449
South America:					
Chile	269, 734	437, 004	372, 038	357, 800	371, 325
Peru [2]	35, 874	39, 065	39, 398	37, 605	37, 124
Europe:					
Austria	1, 984	2, 286	2, 446	1, 262	2, 355
Finland	7, 315	11, 624	13, 034	14, 601	11, 973
Germany:					
East, West	67, 900	72, 200	[9] 77, 000	[9] 74, 000	[9] 54, 100
Norway	9, 221	9, 151	11, 626	11, 528	7, 419
Poland	------	------	------	------	------
Spain [3]	9, 459	10, 075	10, 774	8, 047	7, 055
Sweden	10, 524	10, 023	11, 759	12, 209	13, 744
U.S.S.R.	91, 491	103, 893	126, 272	143, 904	[9] 173, 000
Yugoslavia	43, 431	43, 442	46, 289	45, 920	47, 345
Other [4]	77, 910	114, 267	102, 862	81, 981	39, 774
Asia:					
China	324	410	396	1, 081	1, 549
India	8, 064	7, 650	5, 970	7, 319	7, 448
Japan	85, 950	96, 562	81, 137	80, 538	98, 941
Turkey	------	440	2, 743	7, 425	9, 650
Other [6]	4, 009	5, 646	6, 424	11, 616	3, 534
Africa:					
Northern Rhodesia	159, 413	233, 153	238, 595	237, 068	293, 881
Republic of the Congo	105, 455	165, 995	136, 624	135, 197	164, 056
Republic of South Africa	9, 996	14, 663	14, 846	15, 530	18, 766
Uganda	------	------	------	------	------
Other [7]	------	------	------	------	------
Oceania:					
Australia	14, 911	19, 488	19, 149	20, 011	20, 318
World total [8]	1, 895, 000	2, 585, 000	2, 231, 000	2, 370, 000	2, 715, 000

See footnotes at end of table.

733-740 O—65——13

TABLE 24.—*World smelter production of copper, short tons*—Continued

	1941	1942	1943	1944	1945
North America:					
United States [1]	1, 119, 233	1, 225, 179	1, 216, 868	1, 126, 989	864, 407
Canada	280, 528	269, 010	256, 553	246, 973	218, 730
Mexico	45, 100	49, 305	47, 414	36, 348	58, 739
South America:					
Chile	500, 001	525, 737	538, 498	540, 028	509, 355
Peru [2]	31, 183	32, 488	35, 544	33, 264	31, 507
Europe:					
Austria	2, 775	3, 043	4, 791	5, 071	1, 270
Finland	9, 682	14, 620	17, 124	7, 447	15, 086
Germany:					
East, West	[9] 48, 900	[9] 42, 200	[9] 34, 500	[9] 26, 500	[9] 20, 000
Norway	5, 530	5, 067	2, 220	1, 033	1, 865
Poland	-----	-----	-----	-----	-----
Spain [3]	8, 124	7, 742	9, 634	9, 193	4, 922
Sweden	13, 094	16, 697	17, 569	16, 603	20, 116
U.S.S.R.	[9] 176, 000	[9] 149, 000	[9] 143, 000	[9] 149, 000	[9] 154, 000
Yugoslavia	25, 353	35, 274	29, 762	25, 022	[9] 13, 800
Other [4]	20, 928	19, 857	19, 644	5, 028	468
Asia:					
China	1, 623	1, 210	1, 359	1, 135	687
India	6, 742	6, 579	6, 832	6, 418	6, 720
Japan	95, 898	103, 329	121, 297	72, 858	28, 453
Turkey	11, 584	9, 103	10, 725	12, 181	10, 867
Other [6]	4, 195	4, 773	5, 020	6, 665	2, 178
Africa:					
Northern Rhodesia	255, 644	276, 199	281, 119	247, 355	217, 367
Republic of the Congo	178, 758	182, 915	172, 897	182, 415	176, 602
Republic of South Africa	22, 004	26, 320	24, 416	24, 688	26, 086
Uganda	-----	-----	-----	-----	-----
Other [7]	-----	-----	-----	-----	-----
Oceania:					
Australia	24, 268	27, 562	22, 912	22, 285	22, 958
World total [8]	2, 885, 000	3, 035, 000	3, 021, 000	2, 805, 000	2, 405, 000

See footnotes at end of table.

TABLE 24.—*World smelter production of copper, short tons*—Continued

	1946	1947	1948	1949	1950
North America:					
United States [1]	652, 824	944, 693	925, 450	859, 633	1, 008, 529
Canada	166, 928	198, 414	221, 275	226, 083	238, 203
Mexico	57, 729	62, 539	53, 750	54, 409	53, 437
South America:					
Chile	395, 291	450, 183	468, 383	386, 621	380, 802
Peru [2]	24, 316	19, 648	13, 034	23, 280	25, 603
Europe:					
Austria		417	2, 362	4, 146	5, 918
Finland	23, 096	23, 244	22, 787	20, 088	14, 961
Germany:					
East	[9] [10] 42, 780 (East and West)	[9] 17, 600	[9] 17, 600	[9] 18, 200	[9] 18, 200
West		[10] 35, 292	[10] 68, 612	[10] 160, 426	[10] 223, 218
Norway	8, 321	8, 730	9, 849	10, 258	9, 959
Poland			[10] 1, 500	[10] 8, 900	[10] 13, 000
Spain [3]	8, 981	6, 582	5, 588	6, 785	5, 451
Sweden	15, 952	15, 717	18, 938	15, 828	18, 417
U.S.S.R.	[9] 165, 000	[9] 182, 000	[9] 198, 000	[9] 220, 000	[9] 240, 000
Yugoslavia	23, 953	35, 600	40, 642	37, 902	44, 181
Other [4]	1, 240	466	489	33	130
Asia:					
China	1, 044	1, 179	520	2, 066	[9] 4, 400
India	7, 068	6, 643	6, 566	7, 157	7, 408
Japan	22, 818	31, 760	32, 104	42, 487	40, 979
Turkey	11, 078	11, 111	12, 102	12, 437	12, 897
Other [6]	3, 676	4, 242	3, 405	3, 057	2, 620
Africa:					
Northern Rhodesia	204, 596	215, 905	239, 250	290, 449	308, 632
Republic of the Congo	158, 606	166, 272	171, 388	155, 866	193, 918
Republic of South Africa	29, 457	31, 996	31, 959	32, 757	36, 753
Uganda					
Other [7]				882	1, 702
Oceania:					
Australia	25, 378	21, 846	12, 756	11, 010	17, 270
World total [8]	2, 050, 000	2, 490, 000	2, 580, 000	2, 610, 000	2, 930, 000

See footnotes at end of table.

TABLE 24.—*World smelter production of copper, short tons*—Continued

	1951	1952	1953	1954	1955
North America:					
United States [1]	1, 036, 637	1, 024, 427	1, 047, 810	945, 899	1, 106, 526
Canada	245, 466	196, 320	236, 966	253, 365	288, 997
Mexico	65, 302	56, 402	57, 633	48, 527	49, 730
South America:					
Chile	396, 944	421, 937	371, 745	372, 818	447, 292
Peru [2]	26, 804	22, 640	25, 802	29, 178	34, 862
Europe:					
Austria	7, 110	7, 097	10, 278	10, 357	11, 363
Finland	19, 677	20, 191	21, 814	23, 551	24, 583
Germany:					
East	[9] 19, 800	[9] 22, 000	[9] 27, 500	[9] 28, 000	[9] 30, 000
West	[10] 225, 750	[10] 206, 747	[10] 233, 334	[10] 258, 271	[10] 286, 306
Norway	9, 542	11, 033	13, 342	14, 210	15, 142
Poland	[10] 13, 500	[10] 13, 800	[10] 17, 000	9, 000	17, 300
Spain [3]	5, 506	5, 070	6, 590	6, 374	6, 477
Sweden	16, 540	14, 840	19, 215	18, 422	19, 159
U.S.S.R.	[9] 280, 000	[9] 325, 000	[9] 334, 000	[9] 352, 000	[9] 385, 000
Yugoslavia	35, 286	36, 177	34, 381	33, 394	31, 151
Other [4]	1, 086	1, 957	2, 585	3, 193	5, 158
Asia:					
China	[9] 6, 600	[9] 6, 600	[9] 8, 800	[9] 8, 800	[9] 11, 000
India	7, 933	6, 808	5, 510	8, 020	8, 155
Japan	48, 334	54, 353	70, 080	75, 914	89, 353
Turkey	19, 320	25, 717	26, 188	27, 793	26, 234
Other [6]	3, 228	2, 269	874	1, 119	1, 657
Africa:					
Northern Rhodesia	346, 239	349, 837	406, 087	424, 045	384, 357
Republic of the Congo	211, 598	226, 791	236, 057	243, 424	259, 161
Republic of South Africa	36, 290	37, 702	38, 575	45, 152	47, 482
Uganda	—	—	—	—	—
Other [7]	1, 351	1, 228	1, 301	1, 909	861
Oceania:					
Australia	17, 070	22, 409	38, 258	42, 613	41, 932
World total [8]	3, 100, 000	3, 120, 000	3, 290, 000	3, 290, 000	3, 630, 000

See footnotes at end of table.

TABLE 24.—*World smelter production of copper, short tons*—Continued

	1956	1957	1958	1959	1960	1961	1962
North America:							
United States [1]	1, 231, 352	1, 178, 145	1, 069, 052	841, 795	1, 233, 629	1, 207, 354	1, 322, 614
Canada	328, 458	323, 540	329, 239	365, 366	417, 029	406, 359	382, 502
Mexico	52, 089	62, 061	67, 109	61, 105	64, 861	52, 498	50, 177
South America:							
Chile	506, 256	496, 736	484, 678	570, 593	556, 464	578, 068	614, 947
Peru [2]	35, 005	46, 137	42, 403	38, 024	181, 650	420, 699	164, 927
Europe:							
Austria	11, 088	8, 806	10, 525	11, 601	12, 964	13, 044	14, 186
Finland	24, 767	28, 469	33, 873	35, 941	34, 140	37, 800	37, 400
Germany:							
East	[9] 27, 500	[9] 27, 500	[9] 27, 500	[9] 33, 000	[9] 35, 000	[9] 35, 000	[9] 38, 000
West	[10] 279, 463	[10] 279, 313	[10] 295, 694	[10] 310, 729	[10] 340, 695	[10] 335, 476	[10] 339, 778
Norway	17, 013	17, 447	19, 365	21, 218	23, 825	24, 218	21, 051
Poland	22, 396	21, 966	19, 146	19, 127	23, 961	24, 504	26, 608
Spain [3]	6, 940	6, 600	5, 556	7, 660	9, 041	20, 029	20, 580
Sweden	18, 673	21, 472	22, 268	27, 922	23, 927	22, 822	25, 098
U.S.S.R.	[9] 430, 000	[9] 450, 000	[9] 470, 000	[9] 480, 000	[9] 550, 000	[9] 600, 000	[9] 700, 000
Yugoslavia	32, 390	37, 186	37, 117	38, 858	39, 384	34, 027	50, 421
Other [4]	6, 133	6, 743	7, 965	8, 717	10, 285	12, 940	13, 840
Asia:							
China	[9] 13, 000	[9] 16, 500	[9] 35, 000	[9] 55, 000	[9] 80, 000	[11] 110, 000	[11] 110, 000
India	8, 543	8, 790	8, 782	8, 459	9, 822	9, 189	10, 781
Japan	101, 946	120, 013	131, 651	169, 318	232, 659	232, 659	233, 828
Turkey	27, 297	26, 897	24, 835	27, 599	28, 674	22, 040	28, 412
Other [6]	2, 659	2, 757	2, 718	2, 811	3, 075	3, 956	5, 182
Africa:							
Northern Rhodesia	429, 503	466, 157	420, 164	595, 093	625, 958	627, 137	602, 999
Republic of the Congo	275, 538	267, 028	261, 867	310, 955	333, 175	325, 400	325, 442
Republic of South Africa	48, 681	48, 229	53, 406	53, 842	50, 846	57, 652	50, 905
Uganda	168	8, 361	12, 131	13, 377	16, 257	14, 742	17, 173
Other [7]	1, 537	1, 855	1, 608	1, 782	1, 744	13, 852	15, 800
Oceania:							
Australia	54, 914	56, 440	72, 360	76, 712	79, 561	69, 997	72, 576
World total [8]	3, 990, 000	4, 040, 000	3, 970, 000	4, 190, 000	4, 990, 000	5, 090, 000	5, 300, 000

[1] Smelter output from domestic and foreign ores, exclusive of scrap.
[2] Includes U.S. imports from Ecuador for 1943–46.
[3] Excluding electrolytic copper.
[4] "Other" Europe includes Albania, Belgium, Bulgaria, Czechoslovakia, France, Italy, Rumania, and United Kingdom. Beginning 1944, Belgium figures excluded from world table to aviod duplication with production from Belgian Congo. Beginning 1941, United Kingdom refined copper derived from imported blister; figures omitted from world table.
[5] Exports.
[6] "Other" Asia includes North Korea, Republic of Korea, and Taiwan.
[7] "Other" Africa includes Angola, Morocco (Northern Zone), Southern Rhodesia, and South-West Africa (1962).
[8] Data do not add to exact totals shown because of rounding where estimated figures are included in detail.
[9] Estimate.
[10] Includes scrap.
[11] Data represent estimated mine production.

Except for 1909, Arizona has led all other States since 1907 in output of copper. Production comes from many properties and areas. Output averaged 221,000 tons annually in the first 15 years of recorded mine production; it fell sharply in 1921 as a result of the post-World War-I depression and more than doubled in the following year. In only one other period (1932–35) has production dropped to the 1921 rate. Peak production was attained in 1962.

From 1936 to 1950, seven producing areas accounted for most of the Arizona output but the order of importance changed considerably.

The leading districts in that period were as follows:

Rank, *1936–40:*	*District*
1	Globe-Miami.
2	Warren (Bisbee).
3	Ajo.
4	Yavapai County (mostly United Verde Jerome).
5	Mineral Creek (Ray).
6	Pioneer (Superior).
7	Copper Mountain (Morenci).

Rank, *1941–45:*	*District*
1	Globe-Miami.
2	Copper Mountain (Morenci).
3	Ajo.
4	Warren (Bisbee).
5	Yavapai County (mostly United Verde Jerome).
6	Mineral Creek (Ray).
7	Pioneer (Superior).

Rank, *1946–50:*	*District*
1	Copper Mountain (Morenci).
2	Globe-Miami.
3	Ajo.
4	Mineral Creek (Ray).
5	Yavapai County (mostly United Verde Jerome).
6	Pioneer (Superior).
7	Warren (Bisbee).

In 1951–55 Yavapai County was removed from the list of important producers; six districts produced 94 percent of Arizona output, ranked as follows: Copper Mountain (Morenci), Globe-Miami, Ajo, Mineral Creek (Ray), Warren (Bisbee), and Pioneer (Superior). Four new large operations were brought into production in this period—the Bisbee East (Lavender Pit), Warren (Bisbee); Copper Cities, Globe-Miami; Silver Bell, Silver Bell; and San Manuel, Old Hat. Production from the Bisbee East property was the chief cause for the Warren (Bisbee) area to rise from seventh to fifth place.

The Pima mine (Pima district) began production in 1957, and the Esperanza mine (Pima district) completed its first full year of operation in 1960. From 1956–60, inclusive, nine districts produced 96 percent of the Arizona output. Principal producers, in order of quantity produced, were as follows: Copper Mountain (Morenci), Globe-Miami, Ajo, Warren (Bisbee), Old Hat, Mineral Creek (Ray), Pima, Silver Bell, and Pioneer (Superior).

Total output of Arizona through 1962 was more than double that of Utah, the second ranking copper State.

Utah ranks second in total production of copper in the United States and has been in second place among principal copper-producing States since 1936. Output comes predominantly from one mine—Utah Copper—the largest copper producer in the United States. Record production was made in 1943.

In total United States production Montana ranks third, having an output 7 percent less than that of Utah. Montana was the leading copper-producing State in 1906 and 1909, but thereafter, except for 1921, fluctuated between second and third positions until 1947. New Mexico ranked ahead of Montana almost without interruption after World War II, but with the start of the Greater Butte project in 1953 Montana outranked New Mexico. Virtually all of the State output has come from the Butte mines in Silver Bow county. Peak production was reached in 1916.

For many years after copper production was begun in 1845, Michigan was the foremost source of copper; historically, it ranks fourth. All of the output has come from the Upper Peninsula in Houghton, Keweenaw, and Ontonagon Counties. Production rose sharply in 1955 to the largest since 1931, following the first full year operation of the White Pine mine. The record for the State was reached in 1916.

Among the Western States, Nevada has ranked fourth in output but in total United States production it ranks fifth. Mines in White Pine County supplied most of the Nevada output for many years. Record production was attained in 1942. In 1953 the Yerington mine, Lyon County, was brought into production, and from 1954–62 Lyon County furnished more than one-third of the Nevada output.

The sixth leading copper-producing State in the United States is New Mexico having an output 15 percent less than Nevada but substantially higher than any of the remaining Western States. Peak production was recorded in 1962. Grant County has produced most of the copper reported for New Mexico.

Of the other Western States, Alaska produced notable quantities of copper through 1929. A record output of nearly 60,000 tons was made in 1916. Most of the copper has come from the Ketchikan, Prince William Sound, and Copper River regions.

California ranks next to Alaska, having a total output 7 percent less than the production of Alaska. Next in importance are Colorado, Idaho, and Washington. Considerably smaller quantities have been reported from Wyoming and Oregon.

The remaining important copper production has come from Missouri, North Carolina, Pennsylvania, Tennessee, and Vermont, with Tennessee supplying by far the largest tonnage. Copper mining ceased in Vermont in 1958.

Table 25 shows the quantity and estimated recoverable copper content of ore produced by copper mines in the United States. Classification of some of the complex western ores is difficult and more or less arbitrary. Copper ores include not only those that contain 2.5 percent or more recoverable copper but also those that contain less than this percentage if they are valuable chiefly for copper, notably the porphyry ores. Mines report considerable copper from ores mined primarily for other products including siliceous gold and silver ores, lead and zinc ores, and pyritic ores.

Smelter Production.—The longtime record of copper production covers smelter output from

TABLE 25.—*Copper ore [1] sold or treated, method of treatment, and recoverable metals*

	1926	1927	1928	1929	1930	1931
Concentrating ore……thousand tons	52,084	49,179	54,215	59,728	41,327	30,057
Percent yield	1.24	1.23	1.24	1.22	1.23	1.33
Copper produced……tons	647,472	606,466	673,098	729,975	508,365	398,528
Copper produced, percent of total copper production	78	76	77	76	75	78
Smelting ore……thousand tons	3,768	3,407	3,766	4,235	2,984	1,520
Percent yield	4.75	4.67	4.44	4.60	4.57	5.38
Copper produced……tons	179,001	159,017	167,118	194,971	136,218	81,778
Copper produced, percent of total copper production	21	20	19	20	20	16
Leaching ore……thousand tons	1,330	4,139	4,116	4,338	3,174	2,441
Percent yield	0.81	0.82	0.84	0.95	1.04	1.19
Copper produced……tons	10,729	34,100	34,452	41,098	33,010	29,108
Copper produced, percent of total copper production	1	4	4	4	5	6
Total ore……thousand tons	57,182	56,725	62,097	68,422	47,382	34,051
Total yield in percent	1.46	1.41	1.41	1.41	1.43	1.50
Total copper produced [2]……tons	837,202	799,583	874,668	967,525	678,657	509,567
Recoverable gold produced……troy ounces	364,091	366,784	413,388	457,017	332,368	214,744
Recoverable silver produced……do	16,764,289	14,492,690	14,675,074	17,942,873	13,611,804	9,573,651
Value per ton in gold and silver	$0.31	$0.28	$0.28	$0.28	$0.26	$0.21
Copper produced from precipitates……tons	4,434	5,169	10,323	7,145	12,779	11,332

	1932	1933	1934	1935	1936	1937
Concentrating ore……thousand tons	10,965	7,476	10,682	17,065	35,988	58,738
Percent yield	1.51	1.63	1.53	1.57	1.28	1.15
Copper produced……tons	165,791	121,947	163,286	268,289	461,833	672,847
Copper produced, percent of total copper production	74	69	73	75	80	85
Smelting ore……thousand tons	759	872	977	1,612	2,375	2,763
Percent yield	6.98	6.30	6.21	5.42	4.74	4.30
Copper produced……tons	52,986	54,957	60,660	87,387	112,471	118,890
Copper produced, percent of total copper production	24	31	27	24	20	15
Leaching ore……thousand tons	568	----	----	331	----	----
Percent yield	1.03	----	----	1.13	----	----
Copper produced……tons	5,531	----	----	3,758	----	----
Copper produced, percent of total copper production	2	----	----	1	----	----
Total ore……thousand tons	12,320	8,388	11,724	19,112	38,371	[3] 61,513
Total yield in percent	1.83	2.11	1.92	1.89	1.50	1.29
Total copper produced [2]……tons	224,968	177,102	224,800	360,273	574,304	[3] 791,737
Recoverable gold produced……troy ounces	98,914	105,838	145,930	226,760	380,023	495,812
Recoverable silver produced……do	5,180,776	5,836,105	7,748,876	12,692,582	17,121,761	20,095,650
Value per ton in gold and silver	$0.28	$0.57	$0.86	$0.93	$0.69	$0.53
Copper produced from precipitates……tons	7,461	7,056	4,023	8,615	8,447	19,568

	1938	1939	1940	1941	1942	1943
Concentrating ore……thousand tons	34,374	50,710	63,900	72,532	85,865	92,247
Percent yield	1.17	1.09	1.10	1.06	1.02	0.97
Copper produced……tons	401,351	554,635	702,048	772,393	875,602	897,496
Copper produced, percent of total copper production	79	80	85	85	87	88
Smelting ore……thousand tons	2,028	2,396	2,179	2,135	2,221	2,151
Percent yield	4.49	4.61	4.33	4.29	4.00	3.64
Copper produced……tons	91,072	108,477	94,334	91,492	88,810	78,254
Copper produced, percent of total copper production	18	16	11	10	9	8
Leaching ore……thousand tons	1,380	2,114	3,199	3,786	4,200	3,722
Percent yield	1.14	1.20	1.10	1.11	1.04	1.08
Copper produced……tons	15,799	25,350	35,295	42,064	43,779	40,027
Copper produced, percent of total copper production	3	4	4	5	4	4
Total ore……thousand tons	[3] 37,795	55,239	69,278	78,453	92,286	98,120
Total yield in percent	1.34	1.25	1.20	1.15	1.09	1.04
Total copper produced [2]……tons	[3] 508,219	688,462	831,716	905,949	1,008,191	1,015,777
Recoverable gold produced……troy ounces	340,777	470,917	537,358	559,062	583,463	536,406
Recoverable silver produced……do	15,632,807	18,395,319	20,787,406	18,775,951	14,941,913	13,942,200
Value per ton in gold and silver	$0.58	$0.52	$0.48	$0.42	$0.34	$0.29
Copper produced from precipitates……tons	22,964	25,262	30,422	35,032	55,706	53,196

See footnotes at end of table.

TABLE 25.—*Copper ore [1] sold or treated, method of treatment, and recoverable metals*—Continued

	1944	1945	1946	1947	1948	1949
Concentrating ore ... thousand tons	86,393	73,959	58,520	83,283	80,098	72,019
Percent yield	0.94	0.90	0.88	0.87	0.89	0.89
Copper produced ... tons	814,195	663,769	515,141	727,299	710,047	643,671
Copper produced, percent of total copper production	90	92	91	92	91	93
Smelting ore ... thousand tons	1,540	1,037	743	910	878	646
Percent yield	3.84	3.52	3.12	3.66	3.78	3.46
Copper produced ... tons	59,041	36,462	23,198	33,292	33,219	22,332
Copper produced, percent of total copper production	7	5	4	4	4	3
Leaching ore ... thousand tons	3,131	2,477	2,969	3,672	3,753	3,368
Percent yield	0.92	0.73	0.96	0.92	0.93	0.85
Copper produced ... tons	28,896	18,076	28,531	33,959	34,918	28,514
Copper produced, percent of total copper production	3	3	5	4	5	4
Total ore ... thousand tons	91,064	77,473	62,232	87,865	84,729	76,033
Total yield in percent	0.99	0.93	0.91	0.90	0.92	0.91
Total copper produced [2] ... tons	902,132	718,307	566,870	794,550	778,184	694,517
Recoverable gold produced ... troy ounces	451,518	396,952	284,372	513,198	489,869	435,700
Recoverable silver produced ... do	11,829,306	9,233,160	5,679,932	8,316,044	7,997,147	7,042,954
Value per ton in gold and silver	$0.27	$0.26	$0.23	$0.29	$0.29	$0.28
Copper produced from precipitates ... tons	47,553	38,561	28,222	37,734	39,541	36,026

	1950	1951	1952	1953	1954	1955
Concentrating ore ... thousand tons	90,206	91,021	95,307	96,316	85,979	103,526
Percent yield	0.88	0.87	0.82	0.82	0.80	0.81
Copper produced ... tons	791,943	795,265	785,826	792,941	684,817	838,609
Copper produced, percent of total copper production	94	93	93	93	88	89
Smelting ore ... thousand tons	624	777	904	893	896	877
Percent yield	3.37	3.63	3.27	3.47	4.02	3.81
Copper produced ... tons	21,024	28,176	29,552	30,982	36,000	33,461
Copper produced, percent of total copper production	2	3	3	3	5	4
Leaching ore ... thousand tons	3,756	3,696	3,736	3,856	6,779	8,147
Percent yield	0.88	0.85	0.87	0.84	0.78	0.78
Copper produced ... tons	32,922	31,387	32,517	32,296	53,005	63,750
Copper produced, percent of total copper production	4	4	4	4	7	7
Total ore ... thousand tons	94,586	95,494	99,947	101,065	93,654	112,550
Total yield in percent	0.89	0.90	0.85	0.85	0.83	0.83
Total copper produced [2] ... tons	845,889	854,828	847,895	856,219	773,822	935,820
Recoverable gold produced ... troy ounces	583,205	564,471	572,882	671,712	502,091	581,421
Recoverable silver produced ... do	8,389,913	8,362,150	8,197,888	9,163,964	8,073,017	11,527,224
Value per ton in gold and silver	$0.30	$0.29	$0.27	$0.30	$0.27	$0.28
Copper produced from precipitates ... tons	39,951	46,668	53,483	49,499	41,969	43,045

	1956	1957	1958	1959	1960	1961	1962
Concentrating ore ... thousand tons	122,871	[4] 124,877	[4] 110,202	[4] 99,121	[4] 129,953	[4] 137,883	[4] 144,509
Percent yield	0.75	0.75	0.77	0.72	0.72	0.74	0.72
Copper produced ... tons	926,703	922,519	822,771	688,146	911,411	997,865	1,054,084
Copper produced, percent of total copper production	90	92	91	90	93	93	94
Smelting ore ... thousand tons	906	827	631	468	670	734	599
Percent yield	4.11	4.32	4.78	3.98	3.26	3.39	3.25
Copper produced ... tons	37,248	35,745	30,199	18,598	21,838	24,875	19,456
Copper produced, percent of total copper production	4	3	3	2	2	2	2
Leaching ore ... thousand tons	7,999	[4] 8,124	[4] 8,225	[4] 9,120	[4] 9,335	[4] 9,649	[4] 9,137
Percent yield	0.76	0.55	0.69	0.66	0.56	0.52	0.50
Copper produced ... tons	60,777	44,755	56,762	60,190	51,945	49,872	46,123
Copper produced percent of total copper production	6	5	6	8	5	5	4
Total ore ... thousand tons	131,776	129,716	114,824	103,716	134,994	142,722	150,217
Total yield in percent	0.78	0.77	0.79	0.74	0.73	0.75	0.75
Total copper produced [2] ... tons	1,024,728	1,003,019	909,732	766,934	985,194	1,072,612	1,119,663
Recoverable gold produced ... troy ounces	579,617	562,234	464,051	367,455	539,249	532,215	483,243
Recoverable silver produced ... do	11,512,013	11,097,267	9,182,070	6,838,927	9,469,133	10,385,661	10,944,522
Value per ton in gold and silver	$0.23	$0.23	$0.21	$0.18	$0.20	$0.20	$0.19
Copper produced from precipitates ... tons	57,194	58,074	49,649	39,628	72,370	69,240	83,452

[1] Includes old tailings 1929–52 for United States; thereafter only tailings from Michigan included. In 1929–40, data include small quantities of other than copper ore but more closely identified with copper than other raw materials and copper recovered therefrom.

[2] Excludes copper recovered from precipitates; includes copper recovered from magnetite-pyrite-chalcopyrite ores 1931–52, inclusive.

[3] Excludes Alaska; Bureau of Mines not at liberty to publish.

[4] Includes ore leached followed by concentration.

domestic ores. From 1880, when Arizona and Montana became important copper producers, the industry has grown rapidly. Only seven times from 1880 until 1915 did production decrease from that of the preceding year—1886, 1893, 1901, 1907, 1910, 1913, and 1914. The average of 826,000 tons a year attained in 1914–18 was not reached again until 1925–29, when production averaged 893,000 tons. During 1916, the peak year of the 1913–18 period, 34 smelters treated domestic materials, compared with 23 plants in 1929. In 1930 output fell 30 percent below 1929. The decline in smelter production continued through 1933, when output was the lowest since 1895.

Following the economic depression in 1930

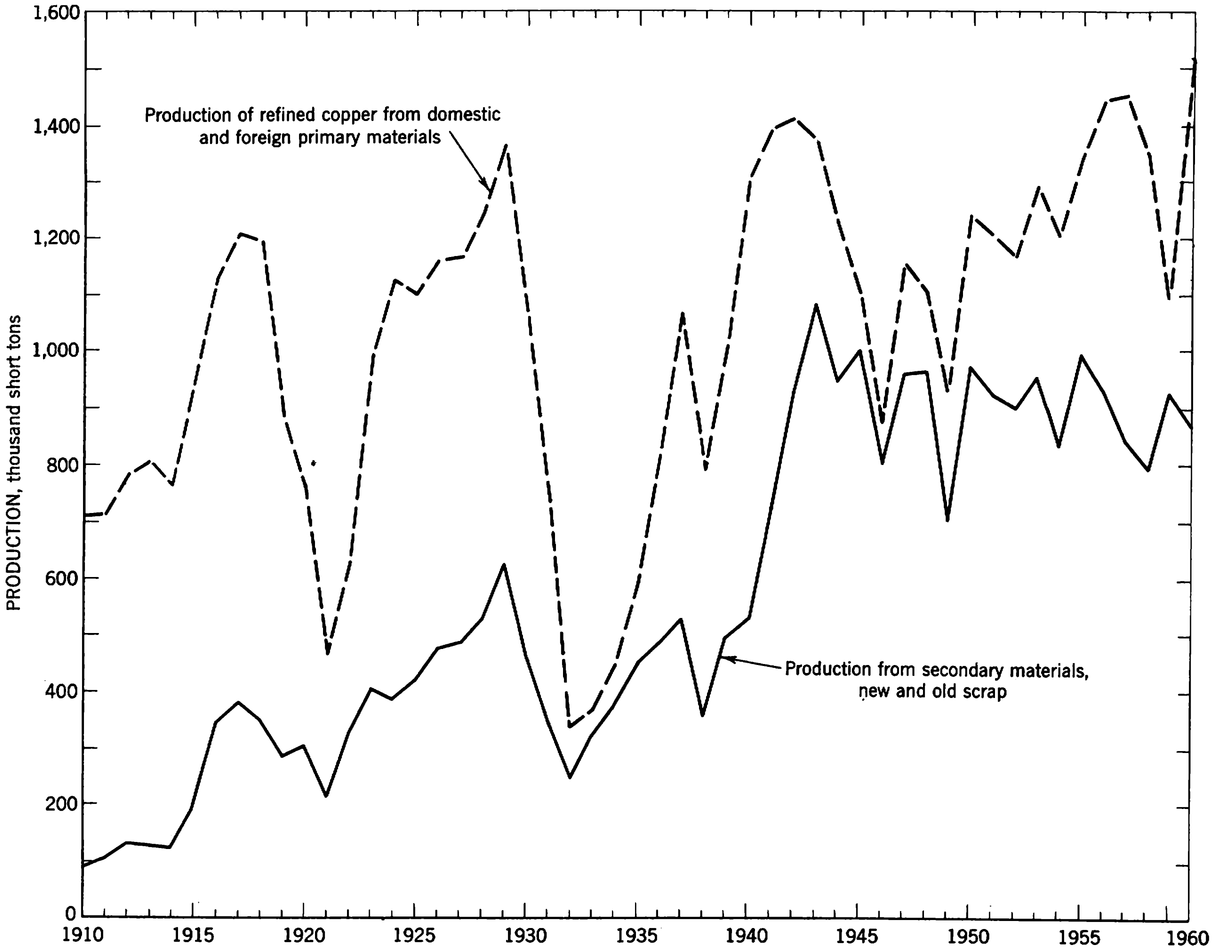

FIGURE 36.—U.S. Production of Refined Copper From Primary and Secondary Source Materials.

many companies were forced to close, and those that remained in operation utilized only a small portion of their productive capacity—16 smelters operated in 1933. Although operations began to return to normal in late 1933, it was not until 1937 that production showed a marked improvement. The trend toward recovery was halted temporarily by the 1938 recession, and the decline carried over into the first half of 1939. By the end of 1939, however, domestic and foreign demand for copper had increased greatly owing to preparation for war.

Output continued to rise from 1940 to 1942, and in 1943 it reached 1.1 million tons, the World War II peak. By 1945 the demand for copper had declined considerably, and smelter production fell 22 percent from 1944, 28 percent from the 1943 peak. Labor shortages, strikes, and reduced war needs were factors in the even lower output for 1946. The upward trend begun in 1950 as a result of the Korean conflict was interrupted by reduced supplies because of strikes and by voluntary curtailments due to short periods of more than adequate supplies.

Three new smelters were brought into operation during the 1950's, all in Arizona; Ajo in 1950, San Manuel in 1955, and Hayden in 1958.

Table 26 shows smelter production from domestic ores for 1845–1960, and table 27 gives smelter output from domestic and foreign ores and from secondary materials.

Refinery Production.—Refinery output is composed of electrolytic copper from domestic and foreign primary materials; Lake copper from the Lake Superior, Mich., region; fire-refined copper produced from blister containing insufficient precious metals to pay for electrolytic refining; and copper produced from secondary sources (fig. 36). Except for 1944–46 and 1959, 90 percent or more of the copper produced in the United States has been by the electrolytic process (table 28). Refinery production is cast into five principal forms—billets, cakes, cathodes, ingots and ingot bars, and wirebars (table 29).

TABLE 26.—*Smelter production of copper from domestic ores in the United States*

Year	Short tons	Value, thousands	Year	Short tons	Value, thousands	Year	Short tons	Value, thousands	Year	Short tons	Value, thousands
1845	112	$45	1875	20,160	$9,152	1905	444,392	$138,650	1935	381,294	$63,295
1846	169	57	1876	21,280	8,937	1906	458,903	177,136	1936	611,410	112,499
1847	336	124	1877	23,520	8,937	1907	434,498	173,799	1937	834,661	201,988
1848	560	218	1878	24,080	7,994	1908	471,285	124,419	1938	562,328	110,216
1849	784	349	1879	25,760	9,582	1909	546,476	142,084	1939	712,675	148,236
1850	728	320	1880	30,240	12,943	1910	540,080	137,180	1940	909,084	205,453
1851	1,008	334	1881	35,840	13,046	1911	548,616	137,154	1941	966,072	227,993
1852	1,232	542	1882	45,323	17,313	1912	621,634	205,139	1942	1,087,991	[1] 256,766
1853	2,240	985	1883	57,763	19,062	1913	612,242	189,795	1943	1,092,939	[1] 257,934
1854	2,520	1,108	1884	72,473	18,843	1914	575,069	152,968	1944	1,003,379	[1] 236,797
1855	3,360	1,814	1885	82,938	17,915	1915	694,005	242,902	1945	782,726	[1] 184,723
1856	4,480	2,419	1886	78,881	17,512	1916	963,925	474,288	1946	599,656	[1] 172,701
1857	5,376	2,688	1887	90,739	25,044	1917	943,060	514,911	1947	862,872	[1] 360,680
1858	6,160	2,833	1888	113,181	38,029	1918	954,267	471,408	1948	842,477	365,635
1859	7,056	3,104	1889	113,388	30,615	1919	643,210	239,274	1949	757,931	298,625
1860	8,064	3,709	1890	129,882	40,523	1920	604,531	222,467	1950	911,352	379,122
1861	8,400	3,696	1891	142,061	36,368	1921	252,793	65,221	1951	930,774	450,495
1862	10,580	4,655	1892	172,499	40,020	1922	475,143	128,289	1952	927,365	448,845
1863	9,520	6,473	1893	164,677	35,570	1923	717,500	210,945	1953	943,391	541,506
1864	8,960	8,422	1894	177,094	33,648	1924	817,125	214,087	1954	834,381	492,285
1865	9,520	7,473	1895	190,307	40,726	1925	837,435	237,832	1955	1,007,311	751,454
1866	9,968	6,828	1896	230,031	49,687	1926	869,811	243,547	1956	1,117,580	949,943
1867	11,200	5,682	1897	247,039	59,289	1927	842,020	220,609	1957	1,081,055	650,795
1868	12,992	5,976	1898	263,256	65,288	1928	912,950	262,930	1958	992,918	522,275
1869	14,000	6,790	1899	284,333	97,242	1929	1,001,432	352,504	1959	799,329	490,788
1870	14,112	5,977	1900	303,059	100,615	1930	697,195	181,271	1960	1,142,848	733,708
1871	14,560	7,023	1901	301,036	100,546	1931	521,356	94,887	1961	1,162,480	697,488
1872	14,000	9,956	1902	329,754	80,460	1932	272,005	34,273	1962	1,282,126	789,790
1873	17,360	9,721	1903	349,022	95,632	1933	225,000	28,800			
1874	19,600	8,624	1904	406,269	104,005	1934	244,227	39,076			

[1] Exclusive of bonus payments of the Office of Metals Reserve under Premium Price Plan, which covered the period February 1, 1942, to June 30, 1947, inclusive.

TABLE 27.—*Copper produced by primary smelters*

	1945	1946	1947	1948
Domestic	782,726	599,656	862,872	842,477
Foreign	81,681	53,168	81,821	82,973
Secondary	63,109	30,738	103,559	89,779
Total	927,516	683,562	1,048,252	1,015,229
	1949	1950	1951	1952
Domestic	757,931	911,352	930,774	927,365
Foreign	101,702	97,177	105,863	97,062
Secondary	71,089	62,827	43,297	43,477
Total	930,722	1,071,356	1,079,934	1,067,904
	1953	1954	1955	1956
Domestic	943,391	834,381	1,007,311	1,117,580
Foreign	104,419	111,518	99,215	113,772
Secondary	72,532	83,747	53,554	81,374
Total	1,120,342	1,029,646	1,160,080	1,312,726
	1957	1958	1959	1960
Domestic	1,081,055	992,918	799,329	1,142,848
Foreign	97,090	76,134	42,466	90,781
Secondary	75,931	61,848	54,895	74,472
Total	1,254,076	1,130,900	896,690	1,308,101
	1961	1962		
Domestic	1,162,480	1,282,126		
Foreign	44,874	40,488		
Secondary	78,377	86,903		
Total	1,285,731	1,409,517		

TABLE 28.—*Primary and secondary copper produced by primary refineries in the United States, short tons*

	1926	1927	1928	1929	1930	1931
Primary:						
From domestic ores, etc.: [1]						
Electrolytic	776,521	760,038	803,560	892,877	614,208	473,533
Lake	86,186	97,568	89,552	92,651	71,493	52,611
Casting	2,942	1,870	2,787	5,838	9,911	11,159
Total	865,649	859,476	895,899	991,366	695,612	537,303
From foreign ores, etc.: [1]						
Electrolytic	294,466	302,874	346,893	378,278	382,594	213,153
Casting and best select	1,128	532	1,012	412	323	265
Total refinery production of primary copper	1,161,243	1,162,882	1,243,804	1,370,056	1,078,529	750,721
Secondary:						
Electrolytic [2]	81,531	84,383	95,662	165,929	139,712	78,050
Casting	31,028	20,551	20,661	1,150	553	14
Total secondary	112,559	104,934	116,323	167,079	140,265	78,064
Grand total	1,273,802	1,267,816	1,360,127	1,537,135	1,218,794	828,785

	1932	1933	1934	1935	1936	1937
Primary:						
From domestic ores, etc.: [1]						
Electrolytic	186,746	210,659	207,010	301,413	599,066	774,429
Lake	26,908	29,749	25,841	36,802	45,553	42,003
Casting	8,885	261	178	106	843	5,820
Total	222,539	240,669	233,029	338,321	645,462	822,252
From foreign ores, etc.: [1]						
Electrolytic	117,620	130,024	212,262	250,440	176,909	243,142
Casting and best select	275	96	69	44	118	1,419
Total refinery production of primary copper	340,434	370,789	445,360	588,805	822,489	1,066,813
Secondary:						
Electrolytic [2]	60,199	85,439	121,595	148,014	132,719	156,416
Casting	28	80	360	464	196	190
Total seconadry	60,227	85,519	121,955	148,478	132,915	156,606
Grand total	400,661	456,308	567,315	737,283	955,404	1,223,419

	1938	1939	1940	1941	1942	1943
Primary:						
From domestic ores, etc.: [1]						
Electrolytic	516,488	662,409	883,610	929,711	963,177	938,727
Lake	36,011	42,464	43,629	45,697	46,523	44,867
Casting	75	------------	------------	------------	55,092	98,485
Total	552,574	704,873	927,239	975,408	1,064,792	1,082,079
From foreign ores, etc.: [1]						
Electrolytic	239,818	304,642	386,317	419,901	343,834	297,184
Casting and best select	24	------------	------------	------------	5,935	------------
Total refinery production of primary copper	792,416	1,009,515	1,313,556	1,395,309	1,414,561	1,379,263
Secondary:						
Electrolytic [2]	92,542	116,613	117,669	95,437	83,079	114,259
Casting	------------	------------	------------	4,238	2,064	8,205
Total secondary	92,542	116,613	117,669	99,675	85,143	122,464
Grand total	884,958	1,126,128	1,431,225	1,494,984	1,499,704	1,501,727

	1944	1945	1946	1947	1948	1949
Primary:						
From domestic ores, etc.: [1]						
Electrolytic	837,089	669,705	475,571	805,718	745,102	606,826
Lake	41,597	29,995	21,567	23,998	26,511	17,608
Casting	95,166	76,038	81,291	79,497	88,409	70,581
Total	973,852	775,738	578,429	909,213	860,022	695,015
From foreign ores, etc.: [1]						
Electrolytic	247,335	298,128	300,233	250,757	247,424	232,912
Casting and best select	------------	34,733	------------	------------	------------	------------
Total refinery production of primary copper	1,221,187	1,108,599	878,662	1,159,970	1,107,446	927,927
Secondary:						
Electrolytic [2]	78,402	84,044	97,615	249,560	222,602	196,850
Casting	7,996	12,618	7,957	19,525	22,774	15,542
Total secondary	86,398	96,662	105,572	269,085	245,376	212,392
Grand total	1,307,585	1,205,261	984,234	1,429,055	1,352,822	1,140,319

See footnotes at end of table.

TABLE 28.—*Primary and secondary copper produced by primary refineries in the United States, short tons*—Continued

	1950	1951	1952	1953	1954	1955
Primary:						
From domestic ores, etc.: [1]						
Electrolytic	821,803	835,419	819,539	826,086	777,507	883,674
Lake	29,555	25,309	21,681	23,671	22,510	35,387
Casting	69,390	90,831	81,972	82,475	41,700	78,438
Total	920,748	951,559	923,192	932,232	841,717	997,499
From foreign ores, etc.: [1]						
Electrolytic	319,086	255,429	254,504	353,727	353,667	320,822
Casting and best select	—	—	—	7,158	16,535	24,138
Total refinery production of primary copper	1,239,834	1,206,988	1,177,696	1,293,117	1,211,919	1,342,459
Secondary:						
Electrolytic [2]	173,063	127,347	113,827	166,802	156,764	196,386
Casting	16,683	7,676	8,549	22,783	23,179	10,169
Total secondary	189,746	135,023	122,376	189,585	179,943	206,555
Grand total	1,429,580	1,342,011	1,300,072	1,482,702	1,391,862	1,549,014

	1956	1957	1958	1959	1960	1961	1962
Primary:							
From domestic ores, etc.: [1]							
Electrolytic	948,732	945,394	892,758	699,890	1,009,983	1,037,489	1,098,032
Lake	57,053	58,814	59,111	54,543	56,232	70,061	67,072
Casting	74,422	46,288	49,776	42,019	55,071	73,465	49,042
Total	1,080,207	1,050,496	1,001,645	796,452	1,121,286	1,181,015	1,214,146
From foreign ores, etc.: [1]							
Electrolytic	351,768	372,791	340,470	256,002	389,178	355,009	379,236
Casting and best select	10,658	30,889	10,405	45,793	8,463	14,115	18,348
Total refinery production of primary copper	1,442,633	1,454,176	1,352,520	1,098,247	1,518,927	1,550,139	1,611,730
Secondary:							
Electrolytic [2]	220,340	203,073	199,508	200,183	241,169	231,836	237,472
Casting	13,477	8,521	7,828	11,405	10,585	11,294	12,214
Total secondary	233,817	211,594	207,336	211,588	251,754	243,130	249,686
Grand total	1,676,450	1,665,770	1,559,856	1,309,835	1,770,681	1,793,269	1,861,416

[1] The separation of refined copper into metal of domestic and foreign origin is only approximate; accurate separation is not possible at this stage of processing.

[2] Includes copper reported from foreign scrap.

For many years 14 plants accounted for the refinery production of copper—5 electrolytic refineries on the East Coast; 3 Lake refineries on the Great Lakes; 3 electrolytic refineries (Great Falls, Mont.; Tacoma, Wash.; and El Paso, Tex.), 1 using the furnace process (Clifton, Ariz.), and 2 others in Arizona (Ajo and Inspiration) producing electrolytically refined copper from leaching operations. The Ajo plant ceased operating in 1931; the Clayton refinery, in 1933. The Hurley, N. Mex., plant began production of fire-refined copper in 1942. Of the Lake plants, Quincy Mining Co. was idle from 1933 to 1948, and the Copper Range Co. plant ceased operating in 1945 and was dismantled in 1952. In 1950, an electrolytic refinery at Garfield, Utah, was brought into operation, and in 1959 one at Baltimore, Md., began production. Fire-refined copper production was begun at White Pine, Mich., in 1955. Thus, in 1960 refinery output came from 15 plants.

Electrolytic refining capacity, exclusive of that at Inspiration, rose from 1,438,000 tons in 1926 to 1,963,000 tons in 1962, and the plants operated from a low of 23 percent of capacity in 1932 to a high of 95 percent in 1941.

Refinery production of copper paralleled mine and smelter outputs. The effects of periods of low and high industrial demand, however, are not reflected in refinery production until later. See the section on primary copper.

Secondary Production.—Copper recovered from copper scrap, copper-alloy scrap, and other copper-bearing scrap materials as metal, as copper alloys without separation of the copper, or as copper compounds is known as secondary copper.

Secondary copper is produced from new and old scrap. New scrap is defined as refuse produced during manufacture of copper articles and includes defective finished or semifinished articles that must be reworked. Typical examples are defective castings, clippings, punchings, turnings, borings, skimmings, drosses, and slag. Old scrap consists of metal articles that have been discarded after serving a useful purpose. These articles may be worn out, obsolete, or damaged and include discarded

TABLE 29.—*Copper cast in forms at primary refineries in the United States, thousands of short tons*

Year	Billets		Cakes		Cathodes		Ingots and ingot bars		Wirebars		Other		Total	
	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent
1926	--------	--------	138	11	95	8	138	11	827	66	50	4	1,248	100
1927	--------	--------	112	9	155	12	123	10	795	64	60	5	1,245	100
1928	--------	--------	181	13	177	13	109	8	826	62	47	4	1,340	100
1929	--------	--------	169	11	181	12	114	7	1,024	67	49	3	1,537	100
1930	--------	--------	133	11	88	7	88	7	856	70	54	5	1,219	100
1931	--------	--------	94	11	81	10	60	7	547	66	46	6	828	100
1932	--------	--------	49	12	59	15	45	11	209	52	38	10	400	100
1933	--------	--------	80	18	110	24	22	5	196	43	45	10	453	100
1934	--------	--------	91	16	185	33	30	5	216	38	46	8	568	100
1935	--------	--------	130	18	187	25	36	5	321	43	64	9	738	100
1936	--------	--------	171	18	165	17	56	6	492	51	72	8	956	100
1937	--------	--------	148	12	278	23	66	5	648	53	84	7	1,224	100
1938	--------	--------	108	12	261	29	44	5	412	47	60	7	885	100
1939	--------	--------	165	15	266	23	68	6	539	48	88	8	1,126	100
1940	--------	--------	146	10	453	32	88	6	622	44	122	8	1,431	100
1941	--------	--------	192	13	301	20	128	9	736	49	138	9	1,495	100
1942	--------	--------	120	8	464	31	220	15	582	39	114	7	1,500	100
1943	--------	--------	146	10	503	33	265	18	474	31	114	8	1,502	100
1944	--------	--------	104	8	358	27	229	18	493	38	124	9	1,308	100
1945	--------	--------	153	13	231	19	231	18	467	38	141	12	1,205	100
1946	112	11	142	15	115	12	102	10	502	51	11	1	984	100
1947	160	11	178	13	87	6	99	7	885	62	20	1	1,429	100
1948	187	14	134	10	76	5	148	11	783	58	25	2	1,353	100
1949	108	10	106	9	128	11	117	10	665	59	16	1	1,140	100
1950	172	12	130	9	189	13	111	8	799	56	29	2	1,430	100
1951	141	10	119	9	146	11	142	11	774	58	20	1	1,342	100
1952	137	10	108	8	138	11	139	11	767	59	11	1	1,300	100
1953	172	11	130	9	190	13	150	10	829	56	12	1	1,483	100
1954	168	12	135	10	185	13	104	7	789	57	11	1	1,392	100
1955	162	11	158	10	109	7	141	9	963	62	16	1	1,549	100
1956	190	11	141	8	125	8	155	9	1,049	63	16	1	1,676	100
1957	165	10	136	8	170	10	152	9	1,028	62	15	1	1,666	100
1958	161	10	107	7	176	11	147	10	950	61	19	1	1,560	100
1959	152	12	112	9	118	9	135	10	776	59	17	1	1,310	100
1960	159	9	134	8	158	9	124	7	1,180	66	16	1	1,771	100
1961	176	10	145	8	194	11	164	9	1,096	61	18	1	1,793	100
1962	199	10	182	10	164	9	149	8	1,150	62	17	1	1,861	100

trolley wire, fired cartridge cases, used pipe, and lithographic plates. Secondary copper is recovered as unalloyed copper and as alloyed copper, including copper in chemicals, such as copper sulfate.

Other terms used in the secondary industry are: (1) Home scrap, which is scrap processed in manufacturing operations and consumed in the same plant; (2) machine-shop scrap, which is scrap generated in a machine shop at the same location as a foundry and consumed by that foundry; (3) toll scrap, material which is treated by one company for another, and involves a conversion charge; and (4) purchased scrap, which includes all scrap (except home scrap) that has been purchased or that entails transportation costs. The statistical data presented in this report cover purchased scrap only, except that reclaimed materials from shipyard repair shops and from line operations at railroad foundries are included, although no financial transactions may have resulted.

Only old scrap is considered part of the total supply. The copper from which the articles were made was deducted from available supply when first manufactured and, therefore, is an addition to supply when returned in worn out condition for reprocessing. However, data for both new and old scrap are presented in the tables.

Secondary-copper production has increased markedly since 1910—the first year for which data are available. From an average yearly recovery of 482,000 tons in 1936–40, output rose to 940,000 in 1941–45. It dropped to 886,000 in 1946–50, rose to 925,000 in 1951–55, and dropped to 874,000 in 1956–60; the 1959 rate was exceeded in 1962. Most of the secondary copper is recovered as alloyed copper, principally brass and bronze. Recovery in this form averaged 56 percent of total secondary production in 1936–40, 87 percent in 1941–45, 72 percent in 1946–50, 77 percent in 1951–55, and 69 percent in 1956–60. Total production of secondary copper exceeded mine production in 12 of the 37 years between 1926 and 1962 and equalled it in 2 years (table 30). Although secondary copper output is closely related to economic conditions, production from all scrap usually is not curtailed as much as other phases of the industry. In the depression years, recovery from old scrap substantially exceeded output from new scrap. In most of the World War II period, however, recovery from new scrap was greater than that from old scrap.

Table 31 shows copper recovered by kind of scrap and form of recovery. In table 32 total

TABLE 30.—*Secondary copper produced in the United States,*[1] *short tons*

	1926	1927	1928	1929	1930	1931	1932
Copper recovered as unalloyed copper	200, 100	201, 000	230, 000	297, 600	244, 800	188, 300	140, 500
Copper recovered in alloys	279, 700	289, 200	306, 400	329, 000	222, 400	158, 700	107, 700
Total secondary copper	479, 800	490, 200	536, 400	626, 600	467, 200	347, 000	248, 200
Source:							
From new scrap	142, 500	150, 800	170, 900	222, 200	125, 000	85, 700	67, 300
From old scrap	337, 300	339, 400	365, 500	404, 400	342, 200	261, 300	180, 900
Percentage equivalent of domestic mine output	56	59	59	63	66	66	104

	1933	1934	1935	1936	1937	1938	1939
Copper recovered as unalloyed copper	193, 100	220, 400	270, 000	260, 000	285, 600	192, 400	151, 370
Copper recovered in alloys	145, 000	157, 000	178, 900	224, 600	246, 500	167, 400	348, 330
Total secondary copper	338, 100	377, 400	448, 900	484, 600	532, 100	359, 800	499, 700
Source:							
From new scrap	77, 800	66, 500	87, 200	101, 900	123, 200	92, 500	212, 800
From old scrap	260, 300	310, 900	361, 700	382, 700	408, 900	267, 300	286, 900
Percentage equivalent of domestic mine output	177	159	118	79	63	65	69

	1940	1941	1942	1943	1944	1945	1946
Copper recovered as unalloyed copper	170, 839	135, 869	114, 647	137, 883	102, 135	112, 856	136, 909
Copper recovered in alloys	361, 207	590, 527	813, 108	948, 164	848, 807	893, 660	666, 637
Total secondary copper	532, 046	726, 396	927, 755	1, 086, 047	950, 942	1, 006, 516	803, 546
Source:							
From new scrap	198, 156	313, 697	500, 633	658, 526	494, 232	509, 421	397, 093
From old scrap	333, 890	412, 699	427, 122	427, 521	456, 710	497, 095	406, 453
Percentage equivalent of domestic mine output	61	76	86	100	98	130	132

	1947	1948	1949	1950	1951	1952	1953
Copper recovered as unalloyed copper	303, 092	284, 026	250, 089	260, 704	186, 462	173, 904	242, 855
Copper recovered in alloys	658, 649	688, 762	463, 054	716, 535	745, 820	729, 293	715, 609
Total secondary copper	961, 741	972, 788	713, 143	977, 239	932, 282	903, 197	958, 464
Source:							
From new scrap	458, 365	467, 324	329, 595	492, 028	474, 158	488, 562	529, 076
From old scrap	503, 376	505, 464	383, 548	485, 211	458, 124	414, 635	429, 388
Percentage equivalent of domestic mine output	113	117	95	107	100	98	103

	1954	1955	1956	1957	1958	1959	1960	1961	1962
Copper recovered as unalloyed copper	212, 241	246, 928	273, 060	248, 015	255, 121	261, 588	300, 259	290, 805	301, 374
Copper recovered in alloys	627, 666	742, 076	657, 604	593, 872	542, 267	668, 982	571, 129	558, 134	620, 454
Total secondary copper	839, 907	989, 004	930, 664	841, 887	797, 388	930, 570	871, 388	848, 939	921, 828
Source:									
From new scrap	432, 841	474, 419	462, 175	397, 395	386, 021	459, 563	442, 023	437, 829	506, 154
From old scrap	407, 066	514, 585	468, 489	444, 492	411, 367	471, 007	429, 365	411, 110	415, 674
Percentage equivalent of domestic mine output	101	99	84	57	81	113	81	73	75

[1] Includes copper in chemicals for 1939–62.

TABLE 31.—*Copper recovered from scrap processed in the United States, by kind of scrap and form of recovery, short tons*

	1941	1942	1943	1944	1945	1946	1947
	Kind of scrap						
New scrap:							
Copper base	310,147	492,392	643,623	479,244	495,407	388,291	449,900
Other	3,550	8,241	14,903	14,988	14,014	8,802	8,465
Total	313,697	500,633	658,526	494,232	509,421	397,093	458,365
Old scrap:							
Copper base	409,947	424,441	425,264	454,938	495,164	401,791	495,789
Other	2,752	2,681	2,257	1,772	1,931	4,662	7,587
Total	412,699	427,122	427,521	456,710	497,095	406,453	503,376
Grand total	726,396	927,755	1,086,047	950,942	1,006,516	803,546	961,741
	Form of recovery						
As unalloyed copper:							
At primary plants	99,675	85,143	122,464	86,398	96,662	105,572	269,085
At other plants	36,194	29,504	15,419	15,737	16,194	31,337	34,007
Total	135,869	114,647	137,883	102,135	112,856	136,909	303,092
In brass and bronze	574,267	779,062	912,782	814,898	855,574	630,588	619,576
In aluminum alloys	5,749	13,894	19,396	17,054	16,768	14,434	16,962
Other	10,511	20,152	15,986	16,855	21,318	21,615	22,111
Total	590,527	813,108	948,164	848,807	893,660	666,637	658,649
Grand total	726,396	927,755	1,086,047	950,942	1,006,516	803,546	961,741

	1948	1949	1950	1951	1952	1953	1954
	Kind of scrap						
New scrap:							
Copper base	458,892	323,666	485,054	464,226	477,853	522,502	427,407
Other	8,432	5,929	6,974	9,932	10,709	6,574	5,434
Total	467,324	329,595	492,028	474,158	488,562	529,076	432,841
Old scrap:							
Copper base	500,872	381,491	481,449	454,447	411,296	425,827	404,160
Other	4,592	2,057	3,762	3,677	3,339	3,561	2,906
Total	505,464	383,548	485,211	458,124	414,635	429,388	407,066
Grand total	972,788	713,143	977,239	932,282	903,197	958,464	839,907
	Form of recovery						
As unalloyed copper:							
At primary plants	245,376	212,392	189,746	135,023	122,376	189,585	179,943
At other plants	38,650	37,697	70,958	51,439	51,528	53,270	32,298
Total	284,026	250,089	260,704	186,462	173,904	242,855	212,241
In brass and bronze	653,281	436,457	679,849	702,416	686,382	663,560	586,298
In aluminum alloys	14,678	9,951	16,621	17,230	24,606	27,232	21,386
Other	20,803	16,646	20,065	26,174	18,305	24,817	19,982
Total	688,762	463,054	716,535	745,820	729,293	715,609	627,666
Grand total	972,788	713,143	977,289	932,282	903,197	958,464	839,907

TABLE 31.—*Copper recovered from scrap processed in the United States, by kind of scrap and form of recovery, short tons*—Continued

	1955	1956	1957	1958	1959	1960	1961	1962
	Kind of scrap							
New scrap:								
Copper base	467,730	456,099	391,033	381,173	453,144	436,326	431,947	498,300
Other	6,689	6,076	6,362	4,848	6,419	5,697	5,882	7,854
Total	474,419	462,175	397,395	386,021	459,563	442,023	437,829	506,154
Old scrap:								
Copper base	510,775	464,623	440,805	408,149	467,161	426,222	406,354	410,475
Other	3,810	3,866	3,687	3,218	3,846	3,143	4,756	5,199
Total	514,585	468,489	444,492	411,367	471,007	429,365	411,110	415,674
Grand total	989,004	930,664	841,887	797,388	930,570	871,388	848,939	921,828
	Form of recovery							
As unalloyed copper:								
At primary plants	206,555	233,817	211,594	207,336	211,588	251,754	243,130	249,686
At other plants	40,373	39,243	36,421	47,785	50,000	48,505	47,675	51,688
Total	246,928	273,060	248,015	255,121	261,588	300,259	290,805	301,374
In brass and bronze	696,543	620,779	561,890	517,680	637,387	539,765	526,715	584,860
In aluminum alloys	26,934	18,784	14,800	12,445	17,899	15,605	17,921	22,470
Other	18,599	18,041	17,182	12,142	13,696	15,759	13,498	13,124
Total	742,076	657,604	593,872	542,267	668,982	571,129	558,134	620,454
Grand total	989,004	930,664	841,887	797,388	930,570	871,388	848,939	921,828

output of products is given, and table 33 shows composition of alloy production. Due to changes in classifications and reporting procedures, comparisons cannot be made for the unalloyed production for all years.

Copper Sulfate.—In addition to refined copper, some primary copper refineries produce copper sulfate either from copper shot (product of the smelters) or from copper-base scrap. Data, however, may not be shown separately and are included with output of chemical plants in tables 34 and 35.

Production rose to record levels in the World War II period as substantial quantities were required for war food supplies. In the years that followed, output was considerably above prewar rates until 1958. The sharp drop in that year was attributed to substitituon of oil as a fungicide spray at banana plantations.

Shipments by broad classifications are given in table 36. In agriculture, copper sulfate is used in wine-producing countries in a Bordeaux or Burgundy mixture to spray vines against mildew; it also is used to protect potatoes

TABLE 32.—*Production of secondary copper and copper-alloy products, short tons*

	1941	1942	1943	1944	1945	1946	1947
Unalloyed copper products:							
Refined copper by primary producers	99,675	85,143	122,464	86,398	96,662	105,572	269,085
Refined copper by secondary smelters	28,393	25,770	9,310	9,581	5,015	10,880	10,249
Copper powder	2,493	1,165	1,523	2,857	2,727	2,982	2,991
Copper castings	1,453	1,845	3,000	2,759	415	304	421
Total	132,014	113,923	136,297	101,595	104,819	119,738	282,746
Brass and bronze ingots	299,021	402,660	488,185	518,261	378,454	346,241	284,868
Brass-mill products	312,262	531,883	640,044	542,873	600,805	410,999	407,464
Brass and bronze castings	152,637	111,631	109,472	143,665	142,532	129,102	139,880
Brass powder				883	659	803	1,425
Copper in chemical products	9,804	17,455	13,019	13,357	18,666	19,192	18,838
Grand total	905,738	1,177,552	1,387,017	1,320,634	1,245,935	1,026,075	1,135,221

	1948	1949	1950	1951	1952	1953	1954
Unalloyed copper products:							
Refined copper by primary producers	245,376	212,392	189,746	135,023	122,376	189,585	179,943
Refined copper by secondary smelters	11,872	16,022	16,815	20,509	20,387	21,355	26,482
Copper powder	2,324	2,273	4,376	3,680	3,851	7,201	4,779
Copper castings	3,465	2,079	1,346	3,674	3,768	1,729	1,037
Total	263,037	232,766	212,283	162,886	150,382	219,870	212,241
Brass and bronze ingots	302,278	200,046	340,687	365,754	319,847	305,427	291,799
Brass-mill products	444,283	285,403	469,820	453,439	522,814	495,227	393,301
Brass and bronze castings	135,092	99,419	131,963	137,895	119,112	111,824	84,222
Brass powder	1,333	886	906	1,171	926	1,160	1,125
Copper in chemical products	17,612	14,840	17,413	22,905	15,388	21,550	18,055
Grand total	1,163,635	833,360	1,173,072	1,144,050	1,128,469	1,155,058	1,000,743

	1955	1956	1957	1958	1959	1960	1961	1962
Unalloyed copper products:								
Refined copper by primary producers	206,555	233,817	211,594	207,336	211,588	251,754	243,130	249,686
Refined copper by secondary smelters	29,762	27,382	25,312	38,672	38,645	39,960	38,582	40,062
Copper powder	9,138	9,337	7,348	7,768	9,796	6,866	7,993	10,162
Copper castings	1,473	2,524	3,761	1,345	1,559	1,679	1,100	1,464
Total	246,928	273,060	248,015	255,121	261,588	300,259	290,805	301,374
Brass and bronze ingots	335,908	317,000	284,247	261,322	293,194	266,012	265,016	276,550
Brass-mill products	470,780	383,057	329,956	319,125	423,789	348,074	342,383	413,156
Brass and bronze castings	105,670	102,806	102,447	74,593	86,439	77,941	66,216	57,076
Brass powder	1,715	1,027	1,225	971	1,397	1,597	1,633	1,901
Copper in chemical products	15,898	14,739	14,240	9,491	10,061	12,714	10,708	9,986
Grand total	1,176,899	1,091,689	980,130	920,623	1,076,468	1,006,597	976,761	1,060,043

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TABLE 33.—*Composition of secondary copper-alloy production, short tons*

	1941	1942	1943	1944	1945
Brass and bronze ingot production: [1]					
Aluminum	(2)	(2)	(2)	(2)	(2)
Copper	(2)	(2)	(2)	(2)	(2)
Lead	(2)	(2)	(2)	(2)	(2)
Nickel	(2)	(2)	(2)	(2)	(2)
Tin	(2)	(2)	(2)	(2)	(2)
Zinc	(2)	(2)	(2)	(2)	(2)
Total	(2)	(2)	(2)	(2)	(2)
Secondary metal content of brass-mill products:					
Aluminum	------------	72	18	79	482
Copper	225, 347	371, 561	457, 853	381, 149	423, 512
Lead	4, 166	5, 489	4, 390	4, 210	4, 938
Nickel	1, 200	379	246	275	937
Tin	236	273	282	330	837
Zinc	81, 313	154, 107	177, 255	156, 830	170, 099
Total	312, 262	[3] 531, 883	640, 044	542, 873	600, 805
Secondary metal content of brass and bronze castings:					
Aluminum	------------	------------	------------	------------	34
Copper	123, 955	95, 224	91, 548	118, 391	112, 768
Lead	9, 087	7, 235	7, 840	9, 987	12, 917
Nickel	1, 424	602	18	29	158
Tin	6, 986	5, 389	5, 838	7, 493	8, 138
Zinc	11, 185	3, 181	4, 228	7, 765	8, 517
Total	152, 637	111, 631	109, 472	143, 665	142, 532

	1946	1947	1948	1949	1950
Brass and bronze ingot production: [1]					
Aluminum	(2)	(2)	74	64	103
Copper	(2)	(2)	234, 696	158, 000	276, 646
Lead	(2)	(2)	9, 593	6, 364	11, 726
Nickel	(2)	(2)	528	439	659
Tin	(2)	(2)	8, 335	5, 693	10, 321
Zinc	(2)	(2)	36, 944	25, 665	37, 266
Total	(2)	(2)	[4] 290, 170	[4] 196, 225	[4] 336, 721
Secondary metal content of brass-mill products:					
Aluminum	69	125	102	151	125
Copper	288, 271	293, 083	318, 300	208, 991	350, 179
Lead	3, 786	3, 483	4, 137	3, 053	4, 646
Nickel	1, 749	2, 702	3, 052	2, 187	2, 904
Tin	381	276	354	221	467
Zinc	116, 743	107, 795	118, 338	70, 800	111, 499
Total	410, 999	407, 464	444, 283	285, 403	469, 820
Secondary metal content of brass and bronze castings:					
Aluminum	135	41	119	162	42
Copper	99, 959	110, 624	107, 323	78, 059	104, 709
Lead	15, 415	14, 228	13, 635	10, 381	13, 735
Nickel	112	95	39	45	74
Tin	6, 459	5, 676	5, 441	4, 045	5, 591
Zinc	7, 022	9, 216	8, 535	6, 727	7, 812
Total	129, 102	139, 880	135, 092	99, 419	131, 963

See footnotes at end of table.

TABLE 33.—*Composition of secondary copper-alloy production, short tons*—Continued

	1951	1952	1953	1954	1955
Brass and bronze ingot production:[1]					
Aluminum	121	87	75	70	66
Copper	285, 480	255, 297	241, 150	224, 664	259, 384
Lead	12, 159	13, 214	13, 905	14, 448	21, 481
Nickel	575	408	441	366	411
Tin	10, 202	10, 994	10, 076	10, 387	16, 670
Zinc	38, 655	39, 847	39, 780	41, 864	37, 896
Total	[4] 347, 192	319, 847	305, 427	291, 799	335, 908
Secondary metal content of brass-mill products:					
Aluminum	45	112	80	55	70
Copper	327, 376	381, 924	368, 684	294, 493	356, 489
Lead	5, 060	5, 680	5, 254	3, 105	4, 059
Nickel	2, 340	1, 180	1, 311	1, 576	1, 948
Tin	415	268	116	125	119
Zinc	118, 203	133, 650	119, 782	93, 947	108, 095
Total	453, 439	522, 814	495, 227	393, 301	470, 780
Secondary metal content of brass and bronze castings:					
Aluminum	47	67	80	68	165
Copper	108, 617	92, 696	83, 039	62, 879	81, 168
Lead	15, 146	14, 595	17, 505	12, 371	13, 005
Nickel	15	58	60	63	62
Tin	5, 525	5, 212	5, 221	3, 748	4, 857
Zinc	8, 545	6, 484	5, 919	5, 093	6, 413
Total	137, 895	119, 112	111, 824	84, 222	105, 670

	1956	1957	1958	1959	1960	1961	1962
Brass and bronze ingot production:[1]							
Aluminum	64	61	65	64	63	66	63
Copper	248, 828	224, 703	205, 536	231, 196	210, 659	209, 194	217, 649
Lead	20, 240	17, 425	16, 643	18, 701	16, 445	17, 228	17, 907
Nickel	526	493	418	438	463	468	212
Tin	14, 703	12, 828	12, 265	13, 931	12, 347	13, 159	13, 798
Zinc	32, 639	28, 737	26, 395	28, 864	26, 035	24, 901	26, 921
Total	317, 000	284, 247	261, 322	293, 194	266, 012	265, 016	276, 550
Secondary metal content of brass-mill products:							
Aluminum	76	95	28	12	8	39	17
Copper	290, 552	249, 597	245, 968	326, 040	265, 774	266, 088	323, 384
Lead	3, 359	3, 167	2, 620	3, 595	2, 976	2, 857	3, 609
Nickel	1, 627	1, 406	1, 205	1, 412	1, 387	1, 582	1, 596
Tin	94	94	180	132	118	112	143
Zinc	87, 349	75, 597	69, 124	92, 598	77, 811	71, 705	84, 407
Total	383, 057	329, 956	319, 125	423, 789	348, 074	342, 383	413, 156
Secondary metal content of brass and bronze castings:							
Aluminum	152	99	79	126	90	57	70
Copper	80, 540	80, 074	57, 552	66, 399	60, 322	51, 801	44, 742
Lead	11, 602	12, 227	8, 191	10, 501	8, 895	7, 511	6, 157
Nickel	51	34	30	39	24	24	18
Tin	4, 666	4, 675	3, 047	3, 755	3, 466	2, 995	2, 436
Zinc	5, 795	5, 338	5, 694	5, 619	5, 144	3, 828	3, 653
Total	102, 806	102, 447	74, 593	86, 439	77, 941	66, 216	57, 076

[1] About 95 percent from scrap and 5 percent from other than scrap.
[2] Not available.
[3] Excludes small quantity antimony.
[4] Excludes primary materials and will not agree with totals in table 32.

TABLE 34.—*Production*[1] *of copper sulfate, short tons*

	1926	1927	1928	1929	1930	1931
Gross weight	16, 682	18, 020	22, 232	20, 129	18, 488	17, 633
Copper content	4, 249	4, 590	5, 663	5, 128	4, 710	4, 492
	1932	1933	1934	1935	1936	1937
Gross weight	25, 357	24, 512	28, 053	31, 197	35, 204	47, 253
Copper content	6, 489	6, 282	7, 152	7, 944	8, 955	11, 972
	1938	1939	1940	1941	1942	
Gross weight	44, 450	43, 266	67, 016	85, 489	105, 204	
Copper content	11, 260	11, 013	17, 047	21, 668	26, 466	

[1] Copper refineries only through 1931; all plants thereafter.

TABLE 35.—*Production, shipments, and stocks of copper sulfate, short tons*

	1943	1944	1945	1946	1947	1948
Production:						
Gross weight	89, 100	102, 600	125, 500	127, 800	89, 100	96, 700
Copper content	22, 264	25, 646	31, 391	31, 956	22, 276	24, 186
Shipments, gross weight	79, 900	97, 900	114, 800	124, 700	86, 600	93, 100
Stocks end of year, gross weight [1]	14, 300	10, 300	9, 400	13, 000	10, 200	11, 800
	1949	1950	1951	1952	1953	1954
Production:						
Gross weight	79, 000	87, 300	106, 944	94, 536	72, 944	65, 308
Copper content	19, 749	21, 814	26, 736	23, 634	18, 236	16, 327
Shipments, gross weight	84, 400	91, 300	104, 260	92, 472	72, 188	66, 488
Stocks end of year, gross weight [1]	6, 400	2, 200	4, 888	6, 884	7, 072	5, 540

	1955	1956	1957	1958	1959	1960	1961	1962
Production:								
Gross weight	78, 088	66, 808	70, 680	48, 596	40, 292	58, 000	48, 584	39, 984
Copper content	19, 522	16, 702	17, 670	12, 149	10, 073	14, 500	12, 146	9, 996
Shipment, gross weight	79, 112	67, 008	70, 256	46, 580	42, 100	54, 272	46, 544	40, 332
Stocks end of year, gross weight [1]	4, 852	4, 068	3, 828	5, 168	2, 500	5, 480	6, 740	5, 572

[1] Some small quantities are purchased and used by producing companies, thus figures given do not balance exactly.

against blight, against leaf spot at banana plantations, and at tea, coffee, and rubber plantations. Among industrial applications, copper sulfate is used as a flotation reagent by mining companies, in copper-plating processes, in the dyeing and paint industries, and as a wood preservative.

Canada.—The importance of Canada as a producer of copper began about 1886. With development of copper mining in British Columbia and of nickel and copper mining in Ontario, output increased steadily (table 37).

Canada has ranked fifth among the world producers since 1951. At the beginning of World War II the British Government contracted for most of the Canadian copper output, and production reached a new high in almost every year. The contracts were terminated January 31, 1945, but because of continued demand for enormous quantities of copper in the United States, there was a steady market for Canadian output. Labor shortages and strikes in 1946 resulted in the lowest output after 1934. The demand for nickel, which is associated with

TABLE 36.—*Shipments of copper sulfate reported by producing companies,*[1] *short tons*

	1951	1952	1953	1954	1955
Agriculture	44, 000	26, 100	19, 900	17, 600	18, 200
Industrial	27, 000	24, 000	18, 000	19, 300	21, 500
Other [2]	33, 300	42, 400	34, 300	29, 600	39, 400
Total	104, 300	92, 500	72, 200	66, 500	79, 100

	1956	1957	1958	1959	1960	1961	1962
Agriculture	13, 900	15, 700	20, 800	19, 400	16, 700	17, 800	17, 800
Industrial	22, 000	20, 800	18, 100	19, 200	20, 000	20, 000	20, 300
Other [2]	31, 100	33, 800	7, 600	3, 500	17, 600	8, 700	2, 200
Total	67, 000	70, 300	46, 500	42, 100	54, 300	46, 500	40, 300

[1] Breakdown of shipments not available before 1951. [2] Chiefly for export.

copper, is also a factor in determining the rate of copper production in Canada. For many years, 50 percent or more of Canadian output has come from the Province of Ontario, where International Nickel Co., Ltd., with mines in the Sudbury District, is by far the largest copper producer in Canada. Other important producers in Ontario are Falconbridge Nickel Mines, Ltd., and Geco Mines, Ltd.

Quebec is the second largest producing Province in Canada; output in 1956–62 more than doubled that in the World War II period. Three companies, Noranda Mines, Ltd.; Waite Amulet Mines, Ltd. (subsidiary of Noranda); and Normetal Mining Corp., Ltd., in that order, accounted for virtually all of the Quebec output from 1939 to 1948. In 1949 Quemont Mining Corp., Ltd., and East Sullivan Mines, Ltd., (now Sullico Mines, Ltd.) joined the ranks of leading producers. Opemiska Copper Mines began producing in 1954, and Campbell Chibougamau Mines, Ltd., and Gaspé Copper Mines, Ltd., (subsidiary of Noranda) were brought into production in 1955.

Copper produced in Saskatchewan and Manitoba comes almost entirely from properties of the Hudson Bay Mining & Smelting Co., Ltd., and Sherritt Gordon Mines, Ltd.

Output in Newfoundland rose sharply following the start of operations at the Maritimes Mining Corp., Ltd., properties in 1958.

Granby Mining Co., Ltd., and Howe Sound Co. (Britannia Division) are the principal producers in British Columbia.

Smelting and refining developed much more slowly in Canada than did mining, and the first refined copper was produced in 1916 at Trail, British Columbia. In 1920, 5 smelters and 2 refineries were operated. In 1924 the refinery at Deschenes, Quebec, ceased operations, and in 1931 production was discontinued at Trail. Two new refineries, under construction in 1929—Montreal East, Quebec, and Copper Cliff, Ontario—began operating in 1930. Annual capacities increased from 65,000 and 120,000 tons, respectively, in 1930 to 284,400 and 168,000 tons, respectively, in 1962. Six smelters treat copper and copper-nickel ores—and are located at Falconbridge, Copper Cliff, and Coniston in Ontario; Murdochville and Noranda in Quebec; and Flin Flon, Manitoba. Annual capacity in tons of charge is 9.8 million tons.

Mexico.—For many years most Mexican copper came from Sonora and Baja California. In Sonora the largest producers were Cananea Consolidated Copper Co., at Cananea, and Moctezuma Copper Co., at Nacozari. The Compania del Boleo operated a mine and smelter near Santa Rosalía, Baja California.

Production has been at a fairly constant rate except for 1932–36. The worldwide depression in the 1930's was a factor in the decreased output in the early part of the period, and the low of 33,000 tons in 1936 was a result of labor difficulties and strikes. Output in 1941–43 exceeded all previous years to 1931, partly due to agreements between Mexico and the United States whereby the Metals Reserve Co. purchased copper, among other metals, at prices that stimulated increased production. Except for 1951, output was well below the average of 75,700 tons for 1926–30.

Mining operations ceased at Nacozari in 1949, and leaching operations, begun in 1949, stopped in 1960. The Boleo property was operated from 1886 until 1954; since then more than half of the output of Mexico has come from Cananea.

Cuba.—The principal copper-producing property in Cuba has been Minas de Matahambre, Pinar del Rio Province.

TABLE 37.—*Copper produced (mine output) in Canada, by Provinces, short tons*

	1935	1936	1937	1938	1939	1940
British Columbia	19, 239	10, 585	22, 899	32, 880	36, 265	38, 871
Manitoba	19, 006	14, 926	22, 460	32, 791	35, 229	37, 634
New Brunswick	--	--	--	--	--	--
Newfoundland	3, 257	5, 880	9, 328	8, 878	11, 759	10, 388
Northwest Territories	--	--	--	38	21	--
Nova Scotia	--	390	90	--	635	--
Ontario	126, 014	143, 957	161, 020	154, 515	164, 214	173, 966
Quebec	39, 525	33, 170	47, 327	56, 323	58, 620	67, 083
Saskatchewan	5, 715	7, 486	11, 218	9, 078	9, 067	10, 243
Total	212, 756	216, 394	274, 342	294, 503	315, 810	338, 185
	1941	**1942**	**1943**	**1944**	**1945**	**1946**
British Columbia	33, 164	25, 008	21, 111	18, 152	12, 876	8, 750
Manitoba	33, 509	23, 798	19, 008	21, 939	20, 563	19, 251
New Brunswick	--	--	--	--	--	--
Newfoundland	7, 330	6, 244	6, 247	5, 532	5, 171	4, 913
Northwest Territories	16	37	--	6	--	--
Nova Scotia	--	--	--	--	--	--
Ontario	166, 915	154, 141	138, 920	142, 654	119, 726	89, 712
Quebec	71, 892	70, 456	65, 582	54, 027	51, 342	34, 899
Saskatchewan	16, 162	28, 391	42, 974	36, 757	32, 950	31, 356
Total	328, 988	308, 075	293, 842	279, 067	242, 628	188, 881
	1947	**1948**	**1949**	**1950**	**1951**	**1952**
British Columbia	20, 900	21, 502	27, 055	21, 088	21, 932	20, 786
Manitoba	15, 316	18, 960	16, 960	20, 817	15, 839	9, 374
New Brunswick	--	--	--	--	--	--
Newfoundland	4, 245	4, 546	3, 617	3, 221	2, 899	2, 959
Northwest Territories	--	--	--	--	1	3
Nova Scotia	--	--	--	--	--	383
Ontario	113, 934	120, 383	113, 043	117, 210	128, 809	125, 343
Quebec	42, 561	48, 813	67, 822	72, 891	68, 866	68, 846
Saskatchewan	33, 151	31, 074	34, 960	28, 982	31, 625	30, 344
Total	230, 107	245, 278	263, 457	264, 209	269, 971	258, 038
	1953	**1954**	**1955**	**1956**	**1957**	**1958**
British Columbia	24, 148	25, 088	22, 127	21, 682	15, 411	6, 010
Manitoba	9, 411	12, 274	19, 380	17, 973	18, 551	12, 601
New Brunswick	--	--	35	6	5, 738	328
Newfoundland	2, 814	3, 481	3, 052	3, 108	4, 535	14, 751
Northwest Territories	--	--	--	--	165	434
Nova Scotia	788	991	1, 027	404	--	--
Ontario	130, 583	140, 776	146, 407	156, 271	171, 703	142, 035
Quebec	54, 920	83, 930	101, 021	122, 300	112, 409	131, 445
Saskatchewan	30, 588	36, 192	32, 945	33, 116	30, 597	37, 510
Total	253, 252	302, 732	325, 994	354, 860	359, 109	345, 114

TABLE 37.—*Copper produced (mine output) in Canada, by Provinces, short tons*—Continued

	1959	1960	1961	1962
British Columbia	8,121	16,559	15,845	53,709
Manitoba	12,945	12,793	12,454	10,934
New Brunswick				6,628
Newfoundland	14,989	13,863	15,752	18,342
Northwest Territories	494	520	463	304
Nova Scotia				245
Ontario	188,272	206,272	211,647	184,683
Quebec	134,912	157,470	149,007	151,390
Saskatchewan	35,536	31,785	33,479	32,126
Total	395,269	439,262	[1] 439,088	[1] 458,590

[1] Includes 441 tons and 229 tons, respectively, for Yukon Territory.

South America

For more than 150 years the west coast of South America has been an important world source of copper, and for the third quarter of the 19th century it was the greatest source. A decline began thereafter, and until the beginning of the 20th century production was of little importance. After foreign capital took an active interest in Chilean and Peruvian copper deposits, production rose rapidly. These two countries account for most of the South American output, although copper also has been produced in Argentina, Bolivia, Brazil, Ecuador, and Venezuela.

Chile.—Chile was the largest producer of copper in the world for many years. About 1870, however, its output was exceeded by that of the United States, and the decline in production extended into the 20th century. The development of three large mines by U.S. interests led to Chile becoming the second most important producer of copper in 1918. It has held second position since, except in 1919 when it was displaced by Japan; in 1934 when Chilean output surpassed that of the United States to make it first; and in 1953, 1954, 1960, and 1961 when it dropped to third, following Northern Rhodesia.

The El Teniente mine of Braden Copper Co. was the first of three mines developed, and after its acquisition by Kennecott Copper Corp. in 1915, output rose steadily. By 1927 it accounted for more than one-third of the total production of Chile. The Chuquicamata mine of Chile Exploration Co. was acquired by The Anaconda Company in 1923. More than 100,000 tons of copper was produced in that year, and except for the depression years, output has never fallen below this rate. In 1916 Andes Copper Mining Co. (subsidiary of The Anaconda Company) was formed to develop the Potrerillos property. World War I and postwar conditions delayed operations, and production began in 1927. From 1927 to 1959, when Potrerillos was replaced by the El Salvador mine, about 1.75 million tons of copper was produced.

In 1957 the La Africana mine of Santiago Mining Co., another Anaconda subsidiary, began production.

Production from U.S.-owned properties in Chile accounts for about 90 percent of the Chilean total. The remainder comes from a number of small- and medium-size copper mines. In addition to blister-copper production at the three properties, fire-refined copper is produced at Braden; electrolytic copper, at Chuquicamata. The Government-owned Paipote smelter near Copiapo began production in 1952, treating about one-third of the output from the small- and medium-size mines. The remainder is exported as ore, concentrates, etc.

Peru.—Peru is one of the early copper producers of the world; its production probably antedated the Spanish conquest. However, it was not until the advent of foreign capital that Peruvian production of copper assumed large proportions. In 1916, production totaled 47,500 tons, compared with an average of 31,800 tons in the previous 5-year period. Most of the copper output came from the Cerro de Pasco, Morococha, and Casapalca districts, where the Cerro de Pasco Corp. was, by far, the largest producer.

Production in Peru was fairly stable thereafter; in 1960 output totaled more than 200,000 tons, and the country became the sixth leading copper producer. This was achieved with the first copper production at Toquepala in early 1960. Development of this project was begun in 1955 by the Southern Peru Copper Corp., jointly owned by American Smelting and Refining Company, Cerro Corp., Newmont Mining Corp., and Phelps Dodge Corp.

Europe

Finland.—All copper output comes from pyritic ore from Outokumpu, near Joensuu in eastern Finland. The concentrate was exported for treatment until 1936 when the Government-owned smelter began operation. In 1945 another smelter was built at Harjavalta, and output rose markedly. In addition to smelter and refinery operations, Outokumpu Oy also has copper, brass, and bronze foundries; a rolling mill which produces plate and strip; and a tube mill.

Norway.—Copper is the second most important mineral in Norway, but it is produced chiefly as a byproduct of pyrite. Two exceptions are the Røros mine, where copper is the primary product, and Vestre Mofjellet, where copper is a byproduct of zinc. Most of the copper concentrates are treated at the Sulitjelma smelter, and the resulting blister is refined on a toll basis in West Germany and Sweden and is returned to Norway. The only refinery producing electrolytic copper is Falconbridge Nikkel-verk A/S Kristiansand S., a subsidiary of Falconbridge Nickel Mine, Ltd., Toronto, Canada, which refines Canadian copper-nickel matte on a toll basis.

Spain.—The copper district of southern Spain, which extends into Portugal, has been an important source of copper for many centuries, as far back as Phoenician times. Output was derived from the low-grade pyritic belt from which the Rio Tinto mine was the chief producer. Since the end of World War II, however, output has declined.

Sweden.—The Boliden Mining Co. is the largest producer of copper in Sweden; it mines copper ore and copper pyrites from the Boliden, Kristineberg, and Laver mines.

U.S.S.R.—The U.S.S.R. became the leading source of European copper in 1935 when output was more than double that in Spain and exceeded Yugoslavia by 62 percent. Most of the copper was reported to be in the Kazakhstan area (Kounradskiy near Karsakpay and Balkhash near the northern shore of Lake Balkhash) but important quantities came from the Urals, and from deposits in Uzbekistan, Bashkiria, middle Volga, west Siberia, Transcaucasia, Leningradskaya Oblast', and the Kola Peninsula. Information on recent copper production is not available.

Yugoslavia.—The Bor mine is an important source of copper in Europe. Much of the output was shipped as crude copper to the United States for refining until July 1938, when an electrolytic refinery was completed in Yugoslavia. The mine was operated by the French until June 1940, when it was taken over by the Germans. The Yugoslav partisans acquired the property in 1944. In 1958 development was begun at the Majdanpek deposits, Eastern Serbia, and the first shipment of ore was delivered to the Bor plants in July 1961.

Other Countries.—Copper also has been produced in Albania, Austria, Bulgaria, Czechoslovakia, France, Greece, Hungary, Ireland, Italy, Poland, Portugal, Rumania, and the United Kingdom. The first recorded output for many years in Ireland was in 1958 from the St. Patrick mines at Avoca.

Asia

Cyprus.—Copper is the most important mineral product of Cyprus, and the present mines are on sites worked by the Phoenicians and Romans. The Skouriotissa and Mavrovouni mines, Morphou Bay, were rediscovered in 1913, and production began in 1922 under U.S. ownership. In the months preceding World War II, production was begun at the Kalavasso mines, southeast of Troodos. Production was intermittent and negligible during the war years but by 1949 was near prewar levels. The Cyprus Mines Corp. installed an acid-leaching section at the Mavrovouni mine in 1952 and production rose markedly.

Japan.—Copper mining is one of the oldest industries in Japan, dating back about 1,200 years. During the early 1930's Japan was self sufficient in copper but in 1933 with the start of the military program imports began, increasing progressively through 1940. During World War II copper production was very active—about 500 mines produced 89,000 tons of copper in 1943. Many of these properties were marginal; most of them were shut down or abandoned after the war, and production declined sharply. An upward trend began in 1947 and continued through 1957.

Philippines.—The first recorded production of copper in the Philippines came from Lepanto Consolidated Mining Co. in 1937. Production was small and ceased completely in 1946. Operations were resumed in 1947 and except for 1953 increased each year. The open-pit copper mine and flotation plant at the Toledo mine of

Atlas Consolidated Mining & Development Corp. began operations in early 1955, and production advanced substantially. Other producing properties are the Sipalay and Bagacay of Marinduque Iron Mines Agents, Inc., and the Santo Tomas group of Philex Mining Corp.

Turkey.—The two chief copper areas in Turkey are at Maden and Damar. The Ergani mine, Maden, began producing copper in 1939. In the early 1930's some copper was produced at the Kuvarshan mine, near Damar, and the Eti Bank, which controls all three mines, began development of the Damar property in 1938. All of the output of Turkey comes from the Damar and Ergani mines.

Other Countries.—Other sources of copper in Asia are Burma, China, India, Indonesia, Republic of Korea, Saudi Arabia, and Taiwan.

Africa

Republic of the Congo.—The Republic of the Congo has been the sixth leading copper-producing country since 1946, supplying about 7 percent of the world total. All of the copper comes from properties of the Union Minière du Haut Katanga; its mines in the Western Group and the Prince Leopold mine in the Southern Group account for most of the output.

Federation of Rhodesia and Nyasaland.—Northern Rhodesia, usually the third or fourth copper producer in the world, displaced Chile in 1953, 1954, 1960, and 1961 and ranked second to the United States in copper production in those years. The opening of the Roan Antelope mine in 1925 led to extensive prospecting and to discovery of other large mines in the copper belt. Although output was small, owing to the world depression, copper smelting was begun at Roan Antelope in 1931 and at Nkana (Rhokana Corporation) in 1932.

Large-scale production began in 1933 and was derived chiefly from Roan Antelope Copper Mines, Ltd., Rhokana Corporation, Ltd., and Mufulira Copper Mines, Ltd. An electrolytic refinery at the Nkana plant of Rhokana went into operation in early 1935, and the Mufulira smelter began operating in 1937. The Nchanga Consolidated Copper Mines, Ltd., was formed in 1936 to develop the Nchanga and Chingola mines, and the first copper production was reported in 1939. For many years these four producers accounted for virtually all of the output of Northern Rhodesia. In the latter part of 1955 mining was begun at the Chibuluma mine of Chibuluma Mines, Ltd., and the first full year of operation was completed in 1957. The Kansanshi mine, Kanshanshi Copper Mining Co., Ltd., was reopened in 1956, but the mine was flooded and was closed in November 1957.

In 1946 Rhodesia Copper Refineries, Ltd., was formed by Rhokana Corp., Ltd., and Nchanga Consolidated Copper Mines, Ltd., to purchase the Nkana refinery from Rhokana and to take over and expand Rhodesian refining facilities. The electrolytic refinery of Ndola Copper Refineries, Ltd., subsidiary of Roan Antelope at Ndola, began operating in 1958.

Production in Southern Rhodesia was negligible for many years and came chiefly from the Umkondo mine of Messina (Transvaal, Republic of South Africa) Development Co., Ltd. In 1954 the company acquired the Mangula mine in the Sinoia district (formerly the Molly mine); operations were begun in 1957, and output rose sharply. Near the end of 1960 production was begun at a new copper smelter and refinery at Alaska Siding in the Lomagundi district. The plant, owned by Messina Rhodesia Smelting & Refining Co., Ltd., was erected to treat copper concentrate from the Messina Mangula and Alaska mines.

South-West Africa.—The only copper producer in South-West Africa is the Tsumeb mine of Tsumeb Corp., Ltd. Output rose rapidly following the acquisition of the property (formerly the Otavi) by Tsumeb in 1947. The company copper smelter was completed in November 1962.

Republic of South Africa.—(Officially changed from Union of South Africa May 30, 1961.) The Messina mine of Messina Development Co., Ltd., Northern Transvaal was the principal copper producer for many years. Operations in the Namaqualand area, which ceased in 1919 and were reactivated on a greatly reduced scale from 1922 to 1932, were resumed in 1940 by O'okiep Copper Co., Ltd. These two producers account for virtually all the output from South Africa.

Other countries.—Production has been reported from Algeria, Angola, French Equatorial Africa, Kenya, Morocco (southern zone), Tanganyika, and Uganda. In Uganda, the Kilembe mine, Kilembe Mines, Ltd., began operations in 1956. The company operates a concentrator, roasting plant, and smelter. Production averaged 11,000 tons annually in five years of operations.

Oceania

Australia.—The upward trend in copper production in Australia has been virtually uninterrupted since the late forties, chiefly because of expansion at Mount Isa Mines, Ltd., Queensland. Other important producers are Mount Lyell Mining & Railway Co., Ltd., Tasmania, and Morgan, Ltd., Queensland. In addition, Peko Mines, N. L., Northern Terri-

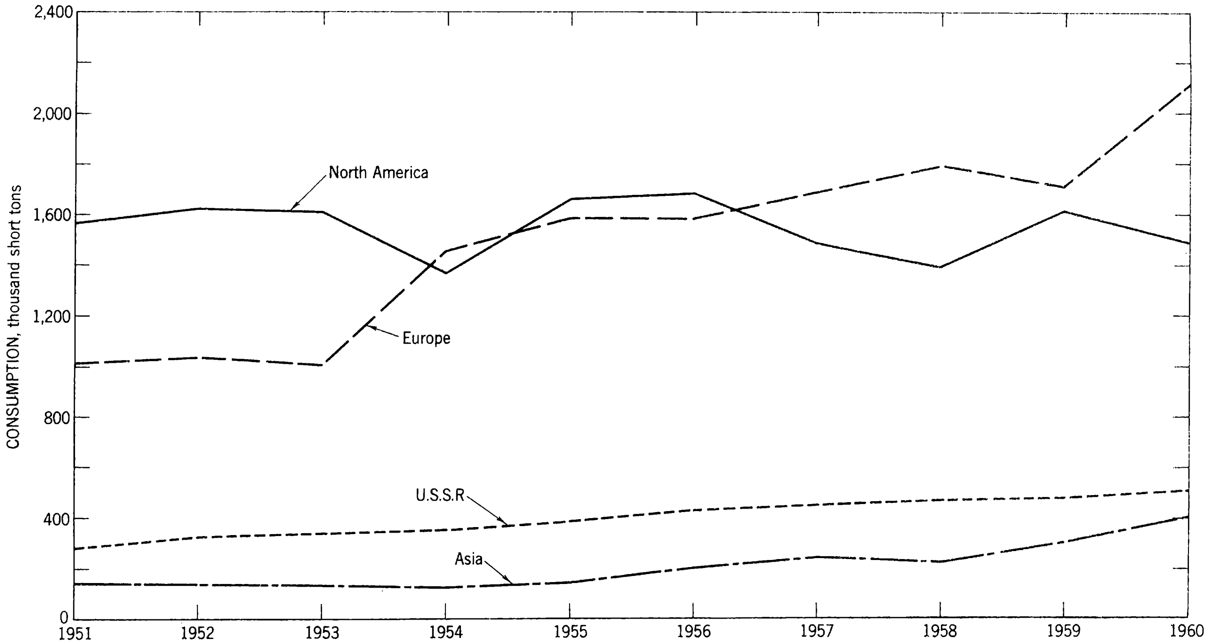

FIGURE 37.—Comsumption of Copper in North America, Europe, U.S.S.R., and Asia, 1951–60.

tory, and Ravensthorpe Copper Mines, N. L., in Western Australia, have contributed to Australian output.

A new electrolytic refinery was completed and began operating in 1959; the plant is operated by Copper Refineries Pty., Ltd., a subsidiary of Mount Isa.

WORLD CONSUMPTION

Data on copper consumption by uses throughout the world are not available. Despite the absence of a uniform method in compiling statistics by countries and the lack of complete information, such data as are available are of value because they present a picture of world trends (fig. 37).

Tables 38 and 39 have been compiled from yearbooks of the American Bureau of Metal Statistics (ABMS). U.S. data, however, are apparent consumption until 1945 when the Bureau of Mines began compiling refined-copper consumption data. These are used in the tables and world totals and, therefore, differ from those published by the ABMS.

For many years the United States consumed more copper than Continental Europe, but in 1930 this situation was reversed. In the pre-World War II period the peak of consumption in the United States was reached in 1929, whereas the peak in Europe occurred in 1938. Data for 1939 through 1945 are not available, but there is no doubt that consumption was maintained at a high rate because of preparation for war.

World consumption declined in 1949 mainly because of a 20-percent decline in U.S. consumption due to a general business recession. After the outbreak of war in Korea in mid-1950 demand increased and, except for 1953 when a surplus developed, world consumption has risen without interruption.

TABLE. 38—*Copper consumption of the world, 1926–38, thousands of short tons*

Country	1926	1927	1928	1929	1930	1931	1932
United States	785	712	804	889	633	451	260
Canada	18	17	17	21	20	17	26
Other	----------	----------	----------	----------	----------	3	2
Total	803	729	821	910	653	471	288
Austria	17	19	19	17	15	11	7
Belgium	23	26	25	25	32	30	22
Czechoslovakia	14	15	19	15	19	15	14
France	126	100	125	138	145	124	105
Germany	185	290	254	216	205	176	151
Hungary	(1)	(1)	(1)	(1)	(1)	6	6
Italy	74	67	77	55	56	59	59
Netherlands	(1)	(1)	(1)	(1)	(1)	3	3
Poland	(1)	(1)	(1)	(1)	(1)	5	5
Spain	16	14	18	14	10	12	10
Sweden	18	20	22	26	31	36	22
Switzerland	10	14	15	14	17	13	13
U.S.S.R.	26	48	50	51	68	62	48
United Kingdom	153	165	157	150	160	131	145
Other	25	31	31	35	35	13	13
Total	687	809	812	756	793	696	623
Japan	90	84	82	71	76	77	81
Other	14	9	8	8	9	8	8
Total	104	93	90	79	85	85	89
Africa	4	4	4	4	3	3	3
Australia	10	10	8	9	6	4	6
Grand total	1,608	1,645	1,735	1,758	1,540	1,259	1,009

See footnote at end of table.

TABLE 38.—*Copper consumption of the world, 1926–38, thousands of short tons*—Continued

Country	1933	1934	1935	1936	1937	1938
United States	339	323	441	656	695	407
Canada	32	43	45	50	62	53
Other	6	6	6	7	9	12
Total	377	372	492	713	766	472
Austria	8	11	16	13	21	30
Belguim	22	24	30	31	36	34
Czechoslovakia	14	20	24	32	34	35
France	119	100	116	125	132	120
Germany	187	244	230	204	252	374
Hungary	6	10	9	11	13	16
Italy	66	69	99	92	86	88
Netherlands	5	6	6	5	9	10
Poland	8	12	13	16	19	29
Spain	10	8	11	9	9	10
Sweden	33	40	45	48	56	60
Switzerland	16	16	16	13	22	21
U.S.S.R.	45	61	102	141	173	182
United Kingdom	160	243	266	285	335	286
Other	16	21	20	22	22	28
Total	715	885	1, 003	1, 047	1, 219	1, 323
Japan	91	125	149	140	202	221
Other	10	13	16	16	18	19
Total	101	138	165	156	220	240
Africa	3	4	4	4	4	6
Australia	7	9	11	14	15	19
Grand total	1, 203	1, 408	1, 675	1, 934	2, 224	2, 060

[1] Included under "Other."

United States

No data on consumption of copper by end uses are available. In some selected periods estimated end-use data have been compiled that indicate the principal uses of copper. See chapter 2 on uses.

Apparent consumption data on primary refined copper, which include deliveries to the stockpile, are available and cover a long period. The method for calculating these data is shown in table 40. At the beginning of the 20th century consumption of copper was less than 200,000 tons annually. It rose to 831,000 tons in 1918, a rate not reached again until 1929. Business and industrial expansion during 1925–29 required large quantities of copper.

The years 1933–36, and part of the next five years in the United States, were years of depression. Consumption of copper declined sharply. In 1939 business activity was accelerated because of fear of war; consumption rose rapidly, reaching a record high of 1.64 million tons in 1941.

TABLE 39.—*Copper consumption of the world, 1946–62, thousands of short tons*

Country	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
United States	1, 187	1, 463	1, 421	1, 130	1, 424	1, 417	1, 480	1, 494	1, 255	1, 502	1, 521	1, 352	1, 251	1, 463	1, 350	1, 463	1, 600
Canada	81	109	110	101	107	134	130	109	103	139	145	118	123	130	118	142	152
Mexico	8	6	4	10	11	14	10	6	10	16	15	17	22	19	22	22	24
Argentina	7	17	6	2	2	9	(1)	6	9	7	3	17	24	12	28	28	20
Brazil	15	12	13	21	19	36	22	23	41	16	22	33	31	23	33	40	40
Chile	10	12	19	29	21	51	29	26	33	38	19	9	34	45	15	13	15
Other	1	6	1	1	1	(2)	(2)	(2)	1	1	1	1	3	2	2	(2)	(2)
Total	1, 309	1, 625	1, 574	1, 294	1, 585	1, 661	1, 671	1, 664	1, 452	1, 719	1, 726	1, 547	1, 488	1, 694	1, 568	1, 708	1, 851
Austria	(1)	1	1	2	2	12	14	17	30	28	25	26	30	32	34	42	40
Belgium	48	67	60	57	64	83	67	60	77	87	81	77	80	76	96	94	74
Denmark	4	4	5	1	5	3	3	4	3	4	2	4	4	5	5	4	5
Finland	16	15	18	16	9	9	14	13	16	18	18	18	13	19	21	29	30
France	113	128	100	134	127	125	156	132	183	205	200	222	245	220	261	269	269
West Germany	20	61	78	158	200	208	192	237	344	405	386	443	480	485	593	629	543
Italy	26	73	63	49	68	70	70	78	98	98	121	133	114	124	212	218	264
Netherlands	11	11	16	18	12	17	12	18	58	48	41	32	56	35	62	47	29
Norway	2	4	3	6	6	5	7	6	7	6	6	8	8	7	9	9	9
Portugal	4	4	2	(1)	1	1	2	2	2	2	2	3	4	3	5	6	3
Spain	17	15	11	8	9	8	11	7	17	13	15	25	21	13	15	17	18
Sweden	72	73	53	54	54	52	52	36	64	59	60	57	67	83	87	79	85
Switzerland	29	25	37	18	18	28	27	13	31	28	37	41	37	30	40	57	43
United Kingdom	365	392	400	357	376	370	389	361	502	556	562	568	599	536	618	583	580
Yugoslavia	24	18	16	19	21	21	21	20	20	23	25	30	35	39	40	40	40
Other	7	25	55	16	9	(2)	(2)	(2)	4	4	2	3	1	3	4	6	8
Total	758	916	918	913	981	1, 012	1, 037	1, 004	1, 456	1, 584	1, 583	1, 690	1, 794	1, 710	2, 102	2, 129	2, 040
India	24	21	27	31	35	37	33	22	19	24	37	52	63	60	69	68	75
Japan	30	45	71	50	70	105	103	108	110	123	163	194	162	241	335	352	289
Other	5	4	1	1	1	(1)	2	3	(1)	(1)	1	(1)	1	(2)	2	(2)	1
Total	59	70	99	82	106	142	138	133	129	147	201	246	226	301	406	420	365
Africa	5	14	17	19	19	25	28	13	20	23	25	34	32	26	32	33	28
Australia	26	23	23	22	20	36	39	15	50	50	34	41	49	64	77	56	70
Total free world	2, 157	2, 648	2, 631	2, 330	2, 711	2, 876	2, 913	2, 829	3, 107	3, 523	3, 569	3, 558	3, 589	3, 795	4, 185	4, 346	4, 354
U.S.S.R	165	182	202	224	244	280	325	335	351	331	373	380	408	553	557	579	585
Soviet countries in Europe and Asia	8	9	8	20	22	27	29	36	37	99	115	131	150	171	173	178	182
Total	173	191	210	244	266	307	354	371	388	430	488	511	558	724	730	757	767
Grand total	2, 330	2, 839	2, 841	2, 574	2, 977	3, 183	3, 267	3, 200	3, 495	3, 953	4, 057	4, 069	4, 147	4, 519	4, 915	5, 103	5, 121

[1] Not reported. [2] Less than half ton.

TABLE 40.—*Primary refined-copper supply and withdrawals on domestic account, short tons*

	1926	1927	1928	1929	1930	1931	1932
Production from domestic and foreign ores, etc	1, 161, 243	1, 162, 882	1, 243, 804	1, 370, 056	1, 078, 530	750, 721	340, 434
Imports	85, 283	51, 640	42, 365	67, 007	43, 105	87, 225	83, 897
Stocks at beginning of year [1]	62, 000	73, 000	85, 500	57, 000	153, 000	307, 500	462, 300
Total available supply	1, 308, 526	1, 287, 522	1, 371, 669	1, 494, 063	1, 274, 635	1, 145, 446	886, 631
Copper exported	450, 457	490, 542	510, 400	451, 771	334, 626	232, 114	125, 029
Stocks at end of year [1]	73, 000	85, 500	57, 000	153, 000	307, 500	462, 300	502, 000
Total	523, 457	576, 042	567, 400	604, 771	642, 126	694, 414	627, 029
Apparent withdrawals on domestic account [2]	785, 100	711, 500	804, 300	889, 300	632, 500	451, 000	259, 600

	1933	1934	1935	1936	1937	1938	1939
Production from domestic and foreign ores, etc	370, 789	445, 360	588, 805	822, 489	1, 066, 814	792, 416	1, 009, 515
Imports	5, 432	27, 417	18, 071	4, 782	7, 487	1, 801	16, 264
Stocks at beginning of year [1]	502, 000	406, 500	284, 500	175, 000	110, 000	179, 000	181, 000
Total available supply	878, 221	879, 277	891, 376	1, 002, 271	1, 184, 301	973, 217	1, 206, 779
Copper exported	132, 371	272, 138	275, 006	236, 091	310, 396	385, 223	396, 406
Stocks at end of year [1]	406, 500	284, 500	175, 000	110, 000	179, 000	181, 000	95, 500
Total	538, 871	556, 638	450, 006	346, 091	489, 396	566, 223	491, 906
Apparent withdrawals on domestic account [2]	339, 400	322, 600	441, 400	656, 200	694, 900	407, 000	714, 900

	1940	1941	1942	1943	1944	1945	1946
Production from domestic and foreign ores, etc	1, 313, 556	1, 395, 309	1, 414, 561	1, 379, 263	1, 221, 187	1, 108, 599	878, 662
Imports	68, 337	346, 994	401, 436	402, 762	492, 395	531, 367	154, 371
Stocks at beginning of year [1]	95, 500	91, 500	77, 500	84, 000	68, 500	81, 000	130, 000
Total available supply	1, 477, 393	1, 833, 803	1, 893, 497	1, 866, 025	1, 782, 082	1, 720, 966	1, 163, 033
Copper exported	377, 108	114, 753	131, 406	175, 859	68, 373	48, 563	52, 629
Stocks at end of year [1]	91, 500	77, 500	84, 000	68, 500	81, 000	130, 000	96, 000
Total	468, 608	192, 253	215, 406	244, 359	149, 373	178, 563	148, 629

Apparent withdrawals on domestic account[2]	1, 008, 800	1, 641, 600	1, 608, 000	1, 502, 000	1, 504, 000	1, 415, 000	1, 391, 000

	1947	1948	1949	1950	1951	1952	1953
Production from domestic and foreign ores, etc	1, 159, 970	1, 107, 446	927, 927	1, 239, 834	1, 206, 988	1, 177, 696	1, 293, 117
Imports	149, 478	249, 124	275, 811	317, 363	238, 972	346, 960	274, 111
Stocks at beginning of year[1]	96, 000	60, 000	67, 000	61, 000	26, 000	35, 000	26, 000
Total available supply	1, 405, 448	1, 416, 570	1, 270, 738	1, 618, 197	1, 471, 960	1, 559, 656	1, 593, 228
Copper exported	147, 642	142, 598	137, 827	144, 561	133, 305	174, 135	109, 580
Stocks at end of year[1]	60, 000	67, 000	61, 000	26, 000	35, 000	26, 000	49, 000
Total	207, 642	209, 598	198, 827	170, 561	168, 305	200, 135	158, 580
Apparent withdrawals on domestic account[2]	1, 286, 000	1, 214, 000	1, 072, 000	1, 447, 000	1, 304, 000	1, 360, 000	1, 435, 000

	1954	1955	1956	1957	1958	1959	1960	1961	1962
Production from domestic and foreign ores, etc	1, 211, 919	1, 342, 459	1, 442, 633	1, 454, 176	1, 352, 520	1, 098, 247	1, 518, 927	1, 550, 139	1, 611, 730
Imports	215, 086	202, 312	191, 745	162, 309	128, 464	214, 058	142, 709	66, 855	98, 820
Stocks at beginning of year[1]	49, 000	25, 000	34, 000	78, 000	109, 000	48, 000	18, 000	99, 000	49, 000
Total available supply	1, 476, 005	1, 569, 771	1, 668, 378	1, 694, 485	1, 589, 984	1, 360, 305	1, 679, 636	1, 714, 994	1, 759, 550
Copper exported	215, 951	199, 819	223, 103	346, 025	384, 868	158, 938	433, 762	428, 718	336, 525
Stocks at end of year[1]	25, 000	34, 000	78, 000	109, 000	48, 000	18, 000	98, 000	49, 000	71, 000
Total	240, 951	233, 819	301, 103	455, 025	432, 868	176, 938	531, 762	477, 718	407, 525
Apparent withdrawals on domestic account[2]	1, 235, 000	1, 336, 000	1, 367, 000	1, 239, 000	1, 157, 000	1, 183, 000	1, 148, 000	1, 237, 000	1, 352, 000

[1] May include some copper refined from scrap.
[2] Rounded figures.

Beginning in 1945 actual consumption data became available by principal classes of consumers and types of refined copper. These data (table 41) are based on reports from consumers of quantities entering processing but make no adjustment for stock changes of material in process, nor do they distinguish between copper from new and old copper.

Brass mills and wire mills account for most of the consumption of refined copper; from 1945 to 1962 these mills consumed from 94 to 97 percent of the refined copper. In 1945 and 1946 brass mills were the principal users, but from 1947 to 1962, wire mills regularly took 50 percent or more of the total. Brass mill consumption ranged from 36 to 47 percent in the same periods. Of the types of copper consumed, wirebars accounted for more than 50 percent in most years.

Refined-copper consumption fell to a low of 1.13 million tons in 1949 as a result of a general business recession. An upward trend began in

TABLE 41.—*Refined copper consumed, by class of consumers, short tons*

Class of consumer	Billets	Cakes and slabs	Cathodes	Ingots and ingot bars	Wirebars	Other	Total
1945:							
Brass mills	108,364	158,061	239,072	219,343	57,949	1,880	784,669
Chemical plants	67	4,800	105	215	-	5,111	10,298
Foundries and miscellaneous	433	61	11,585	30,405	326	3,197	46,007
Secondary smelters	120	101	7,943	10,543	-	9	18,716
Wire mills	1	-	14	15,438	504,129	-	519,582
Total	108,985	163,023	258,719	275,944	562,404	10,197	1,379,272
1946:							
Brass mills	102,804	187,614	97,890	170,772	56,834	1,678	617,592
Chemical plants	-	-	60	4,432	-	5,661	10,153
Foundries and miscellaneous	645	180	2,263	21,954	225	2,282	27,549
Secondary smelters	250	206	17,180	12,705	-	329	30,670
Wire mills	-	-	1,803	15,238	484,004	-	501,045
Total	103,699	188,000	119,196	225,101	541,063	9,950	1,187,009
1947:							
Brass mills	173,124	222,203	68,427	117,936	67,065	4	648,759
Chemical plants	-	-	59	251	-	1,662	1,972
Foundries and miscellaneous	489	113	1,924	20,299	23	4,128	26,976
Secondary smelters	166	279	4,107	3,074	-	197	7,823
Wire mills	-	-	2,550	17,633	757,529	52	777,764
Total	173,779	222,595	77,067	159,193	824,617	6,043	1,463,294
1948:							
Brass mills	169,875	209,861	79,235	92,889	62,454	-	614,314
Chemical plants	5	-	45	655	-	2,524	3,229
Foundries and miscellaneous	355	67	1,585	23,530	216	4,634	30,387
Secondary smelters	178	242	4,847	1,411	-	127	6,805
Wire mills	-	-	13	22,390	743,403	43	765,849
Total	170,413	210,170	85,725	140,875	806,073	7,238	1,420,584
1949:							
Brass mills	123,656	163,982	72,777	72,559	45,033	119	478,126
Chemical plants	-	-	19	72	-	1,485	1,576
Foundries and miscellaneous	26	80	2,595	14,628	183	4,296	21,808
Secondary smelters	65	250	3,127	1,011	-	10	4,463
Wire mills	-	-	19	18,230	605,430	34	623,713
Total	123,747	164,312	78,537	106,500	650,646	5,944	1,129,686
1950:							
Brass mills	160,754	212,353	130,254	104,359	67,379	1	675,100
Chemical plants	-	-	17	110	-	2,995	3,122
Foundries and miscellaneous	426	70	1,783	18,198	537	5,635	26,649
Secondary smelters	-	248	4,584	1,155	192	30	6,209
Wire mills	-	6	25	17,453	695,817	53	713,354
Total	161,180	212,677	136,663	141,275	763,925	8,714	1,424,434
1951:							
Brass mills	135,058	187,041	131,531	124,614	72,415	308	650,967
Chemical plants	-	-	-	261	-	2,962	3,223
Foundries and miscellaneous	764	302	5,890	22,570	368	8,838	38,732
Secondary smelters	4	216	6,953	5,985	375	211	13,744
Wire mills	-	152	23	17,311	692,656	57	710,199
Total	135,826	187,711	144,397	170,741	765,814	12,376	1,416,865
1952:							
Brass mills	134,223	185,138	134,613	163,190	57,456	453	675,073
Chemical plants	-	-	-	279	-	3,440	3,719
Foundries and miscellaneous	624	161	5,947	23,953	130	7,720	38,535
Secondary smelters	-	326	8,819	13,203	8	562	22,918
Wire mills	-	209	11	11,977	727,257	33	739,487
Total	134,847	185,834	149,390	212,602	784,851	12,208	1,479,732

TABLE 41.—*Refined copper consumed, by class of consumers, short tons*—Continued

Class of consumer	Billets	Cakes and slabs	Cathodes	Ingots and ingot bars	Wirebars	Other	Total
1953:							
Brass mills	145,625	188,315	157,735	140,332	57,195	275	689,477
Chemical plants				300		3,549	3,849
Foundries and miscellaneous	851	227	3,902	19,493	258	7,824	32,555
Secondary smelters		114	6,588	8,269		334	15,305
Wire mills		120	4,066	16,615	732,228		753,029
Total	146,476	188,776	172,291	185,009	789,681	11,982	1,494,215
1954:							
Brass mills	155,359	170,144	83,136	82,750	54,237	19	545,645
Chemical plants				11		2,318	2,329
Foundries and miscellaneous	536	257	1,972	16,683	308	10,964	30,720
Secondary smelters		131	5,037	2,064		202	7,434
Wire mills			8,803	10,231	649,567		668,601
Total	155,895	170,532	98,948	111,739	704,112	13,503	1,254,729
1955:							
Brass mills	149,064	200,012	100,819	133,710	63,394	45	647,044
Chemical plants				564		1,180	1,744
Foundries and miscellaneous	588	321	5,466	17,083	189	10,079	33,726
Secondary smelters		469	4,768	1,213		377	6,827
Wire mills			9,050	11,797	791,816		812,663
Total	149,652	200,802	120,103	164,367	855,399	11,681	1,502,004
1956:							
Brass mills	166,426	177,583	91,887	102,451	72,716	35	611,098
Chemical plants				559		1,199	1,758
Foundries and miscellaneous	775	405	7,004	18,873	161	9,076	36,294
Secondary smelters		207	5,602	1,411		434	7,654
Wire mills			9,694	16,415	838,476		864,585
Total	167,201	178,195	114,187	139,709	911,353	10,744	1,521,389
1957:							
Brass mills	156,292	158,344	85,833	76,046	57,399	40	533,954
Chemical plants				708		772	1,480
Foundries and miscellaneous	689	205	6,023	18,369	963	8,933	35,182
Secondary smelters		212	5,197	1,839		628	7,876
Wire mills			5,641	15,406	751,815	770	773,632
Total	156,981	158,761	102,694	112,368	810,177	11,143	1,352,124
1958:							
Brass mills	150,160	116,659	91,192	74,098	47,354	47	479,510
Chemical plants				407		490	897
Foundries and miscellaneous	702	126	4,064	10,743	453	6,730	22,818
Secondary smelters		219	4,080	2,485		398	7,182
Wire mills			4,394	11,464	723,450	962	740,270
Total	150,862	117,004	103,730	99,197	771,257	8,627	1,250,677
1959:							
Brass mills	170,074	146,852	86,648	116,190	64,277	59	584,100
Chemical plants				310		484	794
Foundries and miscellaneous	511	23	6,175	15,529	222	11,389	33,849
Secondary smelters		246	5,320	2,079		466	8,111
Wire mills			6,432	11,790	817,030	925	836,177
Total	170,585	147,121	104,575	145,898	881,529	13,323	1,463,031
1960:							
Brass mills	144,725	137,667	74,993	80,247	48,776	52	486,460
Chemical plants				465		571	1,036
Foundries and miscellaneous	833	32	5,864	12,552	97	5,993	25,371
Secondary smelters		177	5,939	1,913		177	8,206
Wire mills			3,928	13,450	810,570	875	828,823
Total	145,558	137,876	90,724	108,627	859,443	7,668	1,349,896
1961:							
Brass mills	189,333	152,876	119,172	95,943	42,391	50	599,765
Chemical plants				720		549	1,269
Foundries and miscellaneous	1,225	25	8,689	13,258	96	5,200	28,493
Secondary smelters		172	6,782	2,390		160	9,504
Wire mills			604	10,356	812,065	774	823,799
Total	190,558	153,073	135,247	122,667	854,552	6,733	1,462,830
1962:							
Brass mills	198,676	184,085	113,402	97,090	42,799	97	636,149
Chemical plants				761		727	1,488
Foundries and miscellaneous	929	54	6,826	15,676	42	6,144	29,671
Secondary smelters		159	7,368	1,928		5	9,460
Wire mills				8,964	913,131	813	922,908
Total	199,605	184,298	127,596	124,419	955,972	7,786	1,599,676

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TABLE 42.—*Consumption of purchased copper-base scrap, gross weight in short tons*

	1940	1941	1942	1943	1944	1945	1946
Brass mills	(1)	314,140	547,195	609,589	511,661	596,361	401,420
Foundries, chemical plants, and miscellaneous manufacturers	333,529	170,469	136,522	133,298	168,326	159,412	158,354
Primary copper producers	[2] 374,395	[2] 519,561	[2] 625,065	[2] 790,936	[2] 727,873	[2] 714,964	[2] 609,366
Secondary smelters	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Total	707,924	1,004,170	1,308,782	1,533,823	1,407,860	1,470,737	1,169,140

	1947	1948	1949	1950	1951	1952	1953
Brass mills	391,187	425,524	275,559	446,987	448,501	516,811	499,655
Foundries, chemical plants, and miscellaneous manufacturers	171,102	169,438	131,093	161,861	173,218	151,599	171,695
Primary copper producers	[2] 911,607	500,679	415,498	385,660	241,514	220,455	327,640
Secondary smelters	(3)	393,717	273,988	446,664	458,306	400,439	386,899
Total	1,473,896	1,489,358	1,096,138	1,441,172	1,321,539	1,289,304	1,385,889

	1954	1955	1956	1957	1958	1959	1960	1961	1962
Brass mills	399,759	477,180	388,738	335,148	324,280	430,711	355,487	347,840	419,925
Foundries, chemical plants, and miscellaneous manufacturers	129,292	146,629	147,215	120,327	108,174	130,293	116,687	103,952	101,047
Primary copper producers	326,575	318,269	370,946	348,184	325,594	327,206	400,781	390,043	400,425
Secondary smelters	373,471	412,944	384,780	353,464	351,431	379,706	335,479	328,262	343,904
Total	1,229,097	1,355,022	1,291,679	1,157,123	1,109,479	1,267,916	1,208,434	1,170,097	1,265,301

[1] Not separately available. [2] Includes remelters, smelters, and refiners. [3] Included with primary copper producers.

1950, owing largely to expanded defense activities because of the Korean war, and consumption averaged 1.5 million tons for 1950–53. Use declined to 1.3 million in 1954 owing to the inadequate supply situation that developed in the latter half of the year because of labor strikes at some copper-producing properties. After the strikes ended the Office of Defense Mobilization authorized release of copper accumulated under the Defense Production Act to help relieve the situation.

Consumption rose substantially in the next two years, exceeding 1.5 million tons in each year. The economic downturn in 1957 affected important consumers of copper products, and consumption of refined copper declined 11 percent. Consumption moved upward from the second half of 1958 through mid–1959, and in 1959 exceeded 1958 by 17 percent. It dropped 8 percent in 1960, but rose to 1.6 million tons in 1962.

In addition to refined copper, consumers use substantial quantities of copper-base scrap in their manufacturing operations. Data for consumption of purchased copper scrap (table 42) also reflect periods of industrial expansion, war requirements, and economic declines.

Foreign Countries

Outside the United States, the principal copper consuming countries are the United Kingdom, Germany, France, Italy, Japan, and the U.S.S.R. Germany was second to the United States until 1935, when it was displaced by the United Kingdom; it regained this position in 1938, fell to third place in 1954, and fluctuated between second and third positions thereafter.

In Germany the copper industry was revived in 1934, as the demand for copper rose 30 percent. Domestic mines supplied about 10 percent of requirements, and large imports of raw materials were needed. Reduced consumption in 1935 and 1936 reflected the substitution of aluminum and iron alloys and restriction in the use of copper for necessities. Following the end of World War II, data are shown for West Germany. Except for 1949–52, smelter production was inadequate to meet expanding requirements, and the deficits were met by imports.

The United Kingdom has ranked second among copper-consuming countries continuously since 1946. At the beginning of World War II adequate copper from Rhodesia and Canada was available for all emergencies in the United Kingdom, and the only problems with supply revolved around ocean transportation and electrolytic refining. Consumption rose to 335,000 tons in 1937. At the beginning of 1945 the United Kingdom discontinued purchases of copper, and contracts with Rhodesian and Canadian producers were terminated in an effort to reduce large stocks on hand. At that time, Rhodesian copper was released to the United States under reverse Lend-Lease arrangements. By the end of 1945, however, the United Kingdom had to buy large quantities of copper again. New contracts were made with Rhodesian and Canadian producers, and even some Chilean copper was purchased. Consumption continued upward until 1949. The quantity used in 1953 was the smallest in more

TABLE 43.—*Consumption of copper in the United Kingdom, short tons*

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Refined copper: [1]												
Virgin	370,000	389,000	273,000	401,000	445,000	449,000	469,000	498,000	444,000	506,000	477,900	474,000
Secondary	247,000	84,000	88,000	90,000	111,000	113,000	99,000	101,000	92,000	111,000	105,000	105,900
Copper in scrap [2]		167,000	140,000	152,000	183,000	147,000	150,000	149,000	173,000	192,000	180,400	147,300
Total	617,000	640,000	501,000	643,000	739,000	709,000	718,000	748,000	709,000	809,000	763,300	727,200
Consumed in semimanufactured products:												
Refined copper	[3] 358,000	451,000	346,000	474,000	537,000	542,000	548,000	578,000	517,000	594,000	561,000	560,300
Copper in scrap	[4] 179,000	107,000	91,000	93,000	118,000	75,000	80,000	87,000	107,000	119,000	110,000	83,700
Consumed in castings, sulfate, and miscellaneous products:												
Refined copper	[3] 12,000	22,000	15,000	17,000	19,000	20,000	20,000	20,000	19,000	23,000	21,900	19,500
Copper in scrap	[4] 68,000	60,000	49,000	59,000	65,000	72,000	70,000	63,000	66,000	73,000	70,400	63,700

[1] Consumption of refined copper (virgin and secondary) is as reported by consumers. Virgin copper represents copper refined in the United Kingdom from ores and from imported blister together with copper imported as refined. Insofar as imported refined copper may have originated from secondary material this is included in the statistics as virgin. Secondary refined copper represents copper refined in the United Kingdom from scrap and other secondary material.

[2] Consumption of copper in scrap is obtained by difference between copper content of output and consumption of refined copper, and should be considered over a period, since monthly figures of scrap consumption are affected by variations in the amount of work in progress.

[3] Virgin copper only.

[4] Includes secondary refined copper.

Source: World Non-Ferrous Metal Statistics Bulletins.

TABLE 44.—*Use of copper in Japan, thousands of short tons*

	1954	1955	1956	1957	1958
Copper castings, etc.:					
Electrolytic copper	7	7	11	11	9
Scrap	11	11	20	27	27
Total	18	18	31	38	36
Copper rolling products:					
Electrolytic copper	23	31	48	47	51
Scrap	70	71	94	94	93
Total	93	102	142	141	144
Electric wire and cable:					
Electrolytic copper	74	84	127	105	120
Scrap	13	21	26	31	23
Total	87	105	153	136	143
Grand total	198	225	326	315	323

Source: Prepared from the Review of Nonferrous Metal Industry reprinted in Survey of Japanese Finance & Industry, The Industrial Bank of Japan, vol. 12, No. 3, May–June 1960, 17 pp.

than a decade; it rose 39 percent in 1954 and increased each year thereafter until 1959. Data showing consumption of refined copper and scrap are shown in table 43.

Other important consumers of copper in Europe are France and Italy. In both countries consumption has advanced steadily.

Consumption of copper in Japan averaged about 80,000 tons a year until 1934 when it rose to 37 percent more than 1933. To meet the greatly expanded demand for copper, Japan began importing foreign materials in 1934. In the years for which data are available, consumption reached a high of 221,000 tons in 1938. Following the end of World War II, consumption fell below prewar levels; then, an upward trend began in 1951. Scrap which had been collected from war-damaged areas constituted the major source of supply. Imports of raw material became large again in 1956, and consumption attained a peak of 335,000 tons in 1960. Table 44 shows use of copper for 1954–58.

WORLD TRADE

The United States is the leading country in world trade of copper. Crude materials, such as ores, concentrates, matte, and blister are imported, as well as refined copper. Fabricated copper, fabricated-copper products, manufactured goods containing copper, and refined copper are exported. The other leading producing countries—Canada, Chile, Republic of the Congo, Federation of Rhodesia and Nyasaland—export most of their output. Approximately 125,000 tons of the annual output of Canada is consumed in that country. The United Kingdom regularly imports most of its requirements.

United States

For many years before World War II, U.S. production of copper exceeded supply, and there, was a substantial surplus for export. After the beginning of the war the United States needed all the copper that entered the country to fill its large armament requirements and in 1940 again became a net importer of copper. The high level of industrial activity for most of the postwar period continued to require large importations of raw materials. Also, domestic production was adversely affected by labor strikes. The record for imports was reached in 1945 when receipts of unmanufactured copper totaled 853,000 tons. Again in June 1950 the conflict in Korea made it necessary to import large quantities of copper. About one-fourth of U.S. requirements have been met by imports. For the first time in 20 years exports exceeded imports in 1960.

After enactment of the excise tax law in 1932, copper that was imported in bond for smelting and/or refining and subsequent export was tax free; only small quantities of refined copper were received. This situation changed in 1941. It became evident that domestic metal would be inadequate to fill U.S. requirements plus sharply expanded demands of foreign countries for war products made with copper. Every effort was made to supply adequate shipping facilities to obtain all available refined copper, and this class became the principal import item. Receipt of 531,000 tons of refined copper in 1945 was a record. Imports fell sharply thereafter but an upward trend began in 1950 with conflict in Korea. A postwar high of 347,000 tons was attained in 1952 as a result of diversion of Canadian copper from a strike-bound refinery in Canada and greater receipts from Chile. The latter was due to action of the U.S. Government, which permitted passing on increased costs of foreign copper to consumers. See the section about legislation and government programs.

Virtually all copper exported is refined copper and fabrications therefrom. Refined copper was the largest export class until 1944 when insulated wire and cable became the principal class. Before World War II, exports went largely to Japan and certain European countries—Belgium, France, Germany, Italy, Sweden, and the United Kingdom. After the war began only the United Kingdom was an important customer until it was joined by the U.S.S.R. Exports fell sharply during the war years and continued far below prewar levels in many years after the war. Because the supply of copper in the United States was inadequate to fill requirements in most of this period, copper was subject to export controls. In September 1956 export restrictions were removed and shipments rose to the highest level since 1940. In 1959 a shortage developed because of strikes, and exports fell to less than half the 1958 shipments. A sharp increase was recorded in 1960 as West Germany, United Kingdom, Italy, and France took 73 percent of the total. Significant quantities went to Japan, Brazil, and Argentina.

Imports.—The longtime copper position of the United States was that of an exporting nation until World War II. U.S. smelting and refining capacity was excessive for treatment of domestic materials, and this excess capacity encouraged importation of foreign crude materials for custom treatment. Most of the imported materials were smelted and refined under bond for reexportation in refined or manufactured forms. In addition, much domestic copper was shipped for consumption abroad. In 1930, however, because of sharply reduced world consumption, the situation reversed, and the United States became a net importer. In 1932 to discourage receipts of foreign copper an excise tax was imposed, and in 1933 the United States resumed its net export position which held through 1939. After the start of World War II in Europe and the stepup of armament requirements there and elsewhere, the United States became a net importer of copper.

Four countries in the Western Hemisphere have supplied almost 80 percent of the total imports in the last 35 years. Chile ranked first with 46 percent of the total, followed by Canada, 14 percent; Mexico, 11 percent; and Peru, 8 percent. Republic of the Congo and the Federation of Rhodesia and Nyasaland each accounted for 4 percent.

By 1933 imports had decreased to 144,000 tons—a record low—partly as a result of the imposition of the 4-cent excise tax in 1932. As business conditions improved in 1934 imports increased despite the duty. Greater receipts of unrefined classes more than offset the drop in refined copper and were largely responsible for the increased imports. Except for 1929, requirements for copper outside the United States in 1936 were the largest on record, and U.S. imports fell to 190,000 tons. From 1939 to 1945 imports rose substantially; the duty did not apply in this period because the Government was purchasing all the copper brought into the United States. Requirements were drastically reduced after the war ended in 1945, and imports fell to 396,000 tons. Imports trended upward from 1947 to 1950 and almost reached wartime levels as 690,000 tons entered the United States in 1950. The large increase was due to anticipated defense requirements after the outbreak of hostilities in Korea in June 1950.

The continuing shortage of domestic supplies resulted in large quantities of foreign materials in 1952 and 1953. Imports fell 12 percent in 1954 and remained at approximately the 1954 level, except for 1958 through 1962.

For a number of years before 1940, entries of refined copper were no more than 5 percent of the imports; in 1941 the refined class accounted for 47 percent of the total. This was due to the unprecedented requirements for copper in the United States and to the disrupted state of ocean transportation; both factors caused metal that normally would have gone to Europe to be shipped to the United States. In the next 4 years (1942–45) refined copper receipts exceeded imports of all unrefined classes. Thereafter, except for 1948, 1949, and 1952, the unrefined classes accounted for most of the imports. Between 1926 and 1962, imports of the unrefined classes accounted for 63 percent of the total; refined classes, 36 percent; and scrap, 1 percent.

Chile supplied virtually all the refined copper from 1926–44, except for 1931 and 1932 when Canada furnished almost 50 percent. In mid-1944 with the United Kingdom in a more abundant supply position, increased quantities of refined metal began to come from Canada, and in 1945 important quantities came from Belgian Congo and Northern Rhodesia. More than 50 percent of the refined metal continued to come from Chile until 1955 when it accounted for only 33 percent of the total and was displaced by Canada. Since then, most of the copper from Chile has been shipped to European countries, and Canada has continued as the chief supplier of refined metal to the United States.

Of the unrefined classes, blister copper has been the principal class, accounting for 45 percent of the total receipts in 35 years. Record receipts were established in 1929. Western Hemisphere countries supplied most of the blister copper; Mexico and Peru outranked Chile as a supplier in 1926–28; Chile was first in 1929, dropped to fourth place in 1930, ranked first from 1935–46, fell to second in 1946, and rose to first in 1948—a position that it has held ever since. The large receipts from Belgian Congo in World War II years were destined largely for the United Kingdom after refining. Peru dropped from the list of principal sources in 1949 but rose to second place in 1960, becoming a major supplier from the newly opened Toquepala unit of Southern Peru Copper Corp. Canada was a major source until 1944, and Rhodesia began sending important quantities in 1950.

Ore and concentrate account for 16 percent of the total foreign materials with the concentrate class the largest—13 percent of the total. Canada has been the principal source of this material, followed by Chile and Cuba. Substantial quantities have been furnished by the Philippines since 1950. Other important suppliers are Mexico and the Republic of South Africa.

Imports of scrap copper are usually negligible and have ranged from less than 200 tons to 13,000 tons. In 1950, however, scrap totaled 39,000 tons, because unusually large tonnages were received from Japan—26,000 tons.

Data on United States imports are given in tables 45–48.

Exports.—Most copper exported is in advanced forms of manufacture, and the copper content cannot be measured. From before 1900 to 1944 refined copper was the principal export class by a substantial margin until it was displaced by the wire class in 1944. The sharp gains in exports of insulated wire and cable furnished a guide to either the war contestants or to the war areas. The principal destinations of this class of exports are shown in table 49 for 1939–48.

U.S. exports of refined copper through 1929 reflected the expanded business activity in the late 1920's. Shipments reached a high of 475,000 tons in 1928, only 8 percent below the record of 515,000 tons in 1917. Germany, the United Kingdom, and France received 59 percent of the total. Exports fell rapidly during the depression; shipments dropped to 111,000 tons in 1932. The principal destination was the United Kingdom; France and Germany were next. In 1933 the copper industry began to recover from the depression and exports rose 12 percent above 1932. In the following years exports increased substantially; refined copper shipments averaged 282,000 tons annually from 1934–38. During this period Japan was the chief recipient, followed by the United Kingdom, Germany, and France. The prewar peak was reached in 1939 when shipments to foreign consumers totaled 373,000 tons. Japan continued to be the largest importer, followed by France, Italy, and Sweden.

TABLE 45.—*Copper (unmanufactured) imported into the United States in terms of copper content,*[1] *short tons*

Year	Ore	Concentrate	Matte	Blister	Refined	Scrap	Total
1926	53, 358	22, 375	1, 065	221, 899	85, 283	5, 501	389, 481
1927	49, 664	34, 096	697	219, 297	51, 640	3, 739	359, 133
1928	53, 096	19, 736	1, 320	271, 595	42, 365	5, 316	393, 428
1929	62, 310	26, 864	1, 052	323, 084	67, 007	6, 799	487, 116
1930	50, 658	28, 435	2, 353	280, 235	43, 105	3, 750	408, 536
1931	11, 790	49, 704	735	140, 925	87, 225	2, 550	292, 929
1932	7, 007	22, 097	866	80, 844	83, 897	1, 265	195, 976
1933	6, 226	18, 916	1, 222	111, 791	5, 432	130	143, 717
1934	6, 278	23, 262	1, 870	154, 234	27, 417	225	213, 286
1935	7, 660	30, 198	2, 733	197, 975	18, 071	545	257, 182
1936	13, 004	30, 969	1, 838	138, 136	4, 782	1, 609	190, 338
1937	16, 148	51, 828	5, 185	195, 884	7, 487	3, 342	279, 874
1938	7, 480	62, 252	2, 519	176, 798	1, 802	1, 313	252, 164
1939	6, 168	62, 161	2, 828	245, 130	16, 264	3, 746	336, 297
1940	11, 293	71, 574	60, 115	278, 212	68, 337	1, 811	491, 342
1941	4, 562	76, 539	47, 958	257, 206	346, 994	2, 286	735, 545
1942	5, 527	65, 188	68, 566	222, 619	401, 436	1, 057	764, 393
1943	7, 784	60, 722	56, 619	186, 380	402, 762	2, 387	716, 654
1944	6, 415	59, 054	50, 857	175, 424	492, 395	1, 066	785, 211
1945	8, 858	48, 632	19, 862	243, 101	531, 367	1, 376	853, 196
1946	4, 895	41, 844	777	193, 387	154, 371	1, 106	396, 380
1947	14, 665	71, 193	5, 223	167, 378	149, 482	5, 953	413, 894
1948	8, 197	81, 301	3, 657	155, 836	249, 124	9, 334	507, 449
1949	6, 818	108, 814	2, 084	152, 376	275, 811	6, 801	552, 704
1950	2, 600	104, 168	3, 233	224, 222	317, 363	38, 803	690, 389
1951	2, 035	97, 591	3, 051	141, 922	238, 972	5, 564	489, 135
1952	3, 198	98, 143	3, 900	162, 193	346, 960	4, 486	618, 880
1953	6, 997	106, 574	7, 019	273, 610	274, 111	7, 793	676, 104
1954	5, 343	107, 438	5, 795	256, 484	215, 086	4, 683	594, 829
1955	8, 132	109, 497	7, 898	253, 693	202, 312	12, 568	594, 100
1956	17, 459	97, 404	7, 311	276, 085	191, 745	5, 743	595, 747
1957	18, 838	99, 755	6, 196	301, 136	162, 309	5, 798	594, 032
1958	8, 217	79, 200	5, 178	268, 182	128, 464	7, 060	496, 301
1959	7, 330	65, 311	8, 949	269, 048	214, 058	6, 195	570, 891
1960	9, 982	65, 536	5, 049	298, 373	142, 709	2, 695	524, 344
1961	8, 937	36, 851	1, 606	339, 189	66, 855	4, 231	457, 669
1962	4, 897	38, 020	635	331, 686	98, 820	4, 793	478, 851

[1] Data are general imports; that is, they include copper imported for immediate consumption plus material entering the country under bond.

Source: U.S. Department of Commerce.

TABLE 46.—*Copper (unmanufactured) imported into the United States, by class and country in terms of copper content,*[1] *short tons*

	1926	1927	1928	1929	1930	1931	1932
Ore and concentrate:							
Australia	124	154	158	93	292	-	(2)
Bolivia	12	21	5	3	60	78	(2)
Canada	27,787	25,517	24,563	30,339	28,135	16,935	9,204
Chile	16,962	20,398	17,302	20,803	14,792	9,241	7,872
Cuba	9,953	14,686	7,089	5,075	13,005	10,498	5,048
France	592	106	202	593	668	129	23
West Germany	366	229	190	1,536	865	507	-
Malta, Gozo, Cyprus	-	71	-	-	-	-	-
Mexico	10,842	15,969	17,026	15,679	13,108	11,533	516
Northern Rhodesia	-	-	-	-	-	-	-
Peru	712	1,004	463	3,528	720	836	796
Philippines	-	-	-	-	-	-	-
Republic of South Africa	-	-	388	105	111	639	1,041
Spain	6,740	4,232	4,557	7,317	4,862	12	5
Other	1,643	1,373	889	4,103	2,475	11,086	4,599
Total	75,733	83,760	72,832	89,174	79,093	61,494	29,104
Matte and blister:							
Australia	70	-	27	-	1,765	2,424	1,195
Republic of the Congo	-	57,241	57,000	27,564	36,031	-	-
Canada	22,535	25,740	47,841	66,369	74,667	19,646	10,768
Chile	15,784	31,856	47,890	82,133	39,554	30,812	1,578
France	587	62	47	1,859	980	28	65
West Germany	108	34	85	3,610	3,229	34	111
Mexico	41,646	42,098	49,114	69,532	59,514	43,579	36,569
Northern Rhodesia	-	-	-	-	-	-	-
Peru	47,004	50,978	57,823	58,923	55,356	43,708	22,422
Republic of South Africa	-	1,349	1,434	-	7	60	3,133
Spain	12,392	-	140	1,123	1,017	72	32
Turkey	-	-	-	-	-	-	-
United Kingdom	13,997	9,762	1,834	7,218	1,799	14	68
Yugoslavia	-	-	-	-	-	-	-
Other	68,841	874	9,680	5,832	8,669	1,283	5,769
Total	222,964	219,994	272,915	324,136	282,588	14,1660	81,710
Refined:							
Republic of the Congo	-	-	-	-	-	-	-
Belgium-Luxembourg	221	-	-	-	-	-	-
Canada	1	413	75	340	3,133	41,845	38,005
Chile	83,436	50,420	41,867	66,541	39,972	45,247	45,270
West Germany	30	279	385	116	-	-	-
Japan	-	-	-	-	-	-	-
Malta, Gozo, Cyprus	-	-	-	-	-	-	-
Mexico	105	-	-	-	-	-	620
Northern Rhodesia	-	-	-	-	-	-	-
Peru	-	-	-	-	-	132	-
Republic of South Africa	-	(2)	-	-	-	-	-
Sweden	-	-	-	-	-	-	-
United Kingdom	1,035	505	-	-	-	1	(2)
Yugoslavia	-	-	-	-	-	-	-
Other	455	23	38	10	-	-	2
Total	85,283	51,640	42,365	67,007	43,105	87,225	83,897
Scrap:							
Canada	3,006	2,829	3,946	5,702	2,900	2 ,013	1,057
Chile	172	136	8	7	-	15	10
Cuba	963	314	275	546	317	71	57
United Kingdom	445	36	692	5	11	16	37
Other	915	424	395	539	522	435	104
Total	5,501	3,739	5,316	6,799	3,750	2,550	1,265

See footnotes at end of table.

TABLE 46.—*Copper (unmanufactured) imported into the United States, by class and country in terms of copper content,[1] short tons*—Continued

	1933	1934	1935	1936	1937	1938	1939
Ore and concentrate:							
Australia	179	524	1,324	858	2,478	2,109	2,721
Bolivia	267	----	----	2,283	2,840	2,616	2,113
Canada	6,187	8,158	8,455	12,314	29,232	31,917	37,067
Chile	9,192	11,382	7,609	7,296	8,764	4,562	5,230
Cuba	8,413	7,975	5,816	11,784	14,069	17,320	9,863
France	2	----	----	----	(2)	----	34
West Germany	----	----	----	----	----	----	----
Matla, Gozo, Cyprus	----	----	----	1,298	4,361	1,429	1,625
Mexico	121	288	980	1,598	2,976	6,736	5,838
Northern Rhodesia	----	----	----	----	----	----	----
Peru	248	265	981	527	809	909	726
Philippines	----	----	----	171	360	1,160	1,518
Republic of South Africa	----	14	----	44	82	262	192
Spain	----	----	----	----	3	1	----
Other	533	934	12,693	5,800	2,002	711	1,402
Total	25,142	29,540	37,858	43,973	67,976	69,732	68,329
Matte and blister:							
Australia	3	35	30	8	26	356	290
Republic of the Congo	----	----	----	----	----	----	----
Canada	10,618	13,821	35,661	1,311	7,753	17,985	17,438
Chile	13,411	36,139	57,600	47,353	82,225	61,076	98,846
France	88	166	546	140	150	136	399
West Germany	80	267	232	----	50	----	----
Mexico	43,082	51,942	45,907	33,380	50,822	40,406	46,682
Northern Rhodesia	----	----	----	----	----	----	----
Peru	25,917	29,513	36,266	34,673	40,136	39,216	37,766
Republic of South Africa	1,485	----	250	11	608	1,659	16,809
Spain	81	13	55	27	----	1	19
Turkey	----	----	----	----	----	2,544	5,035
United Kingdom	93	50	606	568	719	251	276
Yugoslavia	4,429	10,351	21,681	19,033	16,124	10,582	9,527
Other	13,726	13,807	1,874	3,470	2,456	5,105	14,871
Total	113,013	156,104	200,708	139,974	201,069	179,317	247,958
Refined:							
Republic of the Congo	----	----	----	----	----	----	----
Belgium-Luxembourg	----	----	----	----	----	----	----
Canada	----	(2)	(2)	1	1	16	420
Chile	5,431	26,241	18,071	4,556	7,482	1,786	15,844
West Germany	----	(2)	----	----	----	----	----
Japan	----	----	----	----	----	----	----
Malta, Gozo, Cyprus	----	----	----	----	----	----	----
Mexico	----	1,175	----	----	----	----	----
Northern Rhodesia	----	----	----	----	----	----	----
Peru	----	----	----	224	----	----	----
Republic of South Africa	----	----	----	----	----	----	----
Sweden	----	----	----	(2)	----	----	----
United Kingdom	1	1	(2)	1	4	(2)	(2)
Yugoslavia	----	----	----	----	----	----	----
Other	----	----	----	(2)	(2)	----	----
Total	5,432	27,417	18,071	4,782	7,487	1,802	16,264
Scrap:							
Canada	130	139	327	1,048	1,552	533	2,575
Chile	----	12	9	176	1,047	310	----
Cuba	----	1	----	40	127	159	34
United Kingdom	(2)	----	----	3	79	12	357
Other	----	73	209	342	537	299	780
Total	130	225	545	1,609	3,342	1,313	3,746

See footnotes at end of table.

TABLE 46.—*Copper (unmanufactured) imported into the United States, by class and country in terms of copper content,*[1] *short tons*—Continued

	1940	1941	1942	1943	1944	1945	1946
Ore and concentrate:							
Australia	926	1,150	3,431	679	419	102	8
Bolivia	4,104	6,456	5,379	6,300	3,784	4,929	4,573
Canada	35,582	40,466	31,577	27,886	25,912	17,580	12,597
Chile	6,994	2,811	7,195	8,816	8,595	12,375	4,308
Cuba	11,560	8,067	8,867	7,758	7,123	9,422	12,378
France	----	----	----	----	----	----	----
West Germany	----	----	----	----	----	----	----
Malta, Gozo, Cyprus	4,652		----	2,762	3,925	----	----
Mexico	7,787	8,272	5,747	6,425	8,695	7,720	8,322
Northern Rhodesia	----	----	321	147	156	414	260
Peru	3,656	5,269	6,017	4,244	5,804	4,778	3,830
Philippines	2,086	3,964	256	----	----	----	----
Republic of South Africa	2,762	193	16	3,283	1,030	150	137
Spain	14	----	----	----	----	----	----
Other	2,744	4,453	1,909	206	26	20	326
Total	82,867	81,101	7 ,715	68,506	65,469	57,490	46,739
Matte and blister:							
Australia	113	1	162	----	----	909	----
Republic of the Congo	60,815	81,956	89,050	72,490	63,404	47,842	4,469
Canada	23,244	22,833	6,106	6,353	342	456	207
Chile	131,673	114,432	92,247	83,355	89,797	54,855	66,868
France	169	----	----	----	----	----	----
West Germany	----	----	----	----	----	----	----
Mexico	35,604	46,136	51,657	44,844	37,503	58,849	56,362
Northern Rhodesia	----	----	4,224	10	1	64,382	11,682
Peru	38,221	30,882	24,592	27,326	28,251	25,905	26,544
Republic of South Africa	12,959	59	17,889	598	13	6,133	4,361
Spain	136	3	----	----	----	----	----
Turkey	6,224	----	----	2,342	2,756	----	17,414
United Kingdom	21	----	3,258	----	----	----	3,323
Yugoslavia	----	----	----	----	----	----	----
Other	29,148	8,862	2,000	5,681	4,214	3,632	2,934
Total	338,327	305,164	291,185	242,999	226,281	262,963	194,164
Refined:							
Republic of the Congo	----		----	4,405	----	41,782	----
Belgium-Luxembourg	----	----	----	----	----	----	----
Canada	1,673	3,912	820	323	41,323	76,392	17,193
Chile	66,664	343,082	400,616	396,362	450,610	384,843	136,312
West Germany	----	----	----	----	----	----	----
Japan	----	----	----	----	----	----	----
Malta, Gozo, Cyprus	----	----	----	----	----	----	----
Mexico	----	----	----	----	----	44	----
Northern Rhodesia	----	----	----	----	----	25,166	----
Peru	----	----	----	1,672	462	692	----
Republic of South Africa	----	----	----	----	----	783	866
Sweden	----	----	----	----	----	----	----
United Kingdom	----	----	----	----	----	----	----
Yugoslavia	----	----	----	----	----	----	----
Other	----	----	(2)	(2)	----	1,665	----
Total	68,337	346,994	401,436	402,762	492,395	531,367	154,371
Scrap:							
Canada	1,062	1,892	568	476	502	1,186	542
Chile	2	45	----	1,323	----	----	37
Cuba	----	----	227	127	----	----	----
United Kingdom	8	19	2	----	----	----	63
Other	739	330	260	461	564	190	464
Total	1,811	2,286	1,057	2,387	1,066	1,376	1,106

See footnotes at end of table.

TABLE 46.—*Copper (unmanufactured) imported into the United States, by class and country in terms of copper content,*[1] *short tons*—Continued

	1947	1948	1949	1950	1951	1952	1953
Ore and concentrate:							
Australia	322	769	939	699	717	684	1,044
Bolivia	6,752	6,729	4,667	5,206	4,449	3,091	3,955
Canada	22,419	24,425	31,488	24,503	24,743	25,570	31,455
Chile	19,658	19,532	22,799	13,351	12,097	11,853	15,761
Cuba	14,898	16,254	15,605	22,429	21,895	18,921	17,757
France		103	139				
West Germany							
Malta, Gozo, Cyprus		2,689	6,888	6,530	5,556	5,441	3,680
Mexico	9,605	8,473	11,438	9,189	6,425	6,470	9,003
Northern Rhodesia	101	131	108	233	98	167	212
Peru	7,713	5,013	6,708	7,318	7,351	8,859	9,498
Philippines	2,130	2,252	7,910	10,004	12,608	14,787	13,538
Republic of South Africa	1,723	2,430	6,037	6,511	3,626	5,251	7,412
Spain							
Other	537	698	906	795	61	247	256
Total	85,858	89,498	115,632	106,768	99,626	101,341	113,571
Matte and blister:							
Australia							9,414
Republic of the Congo							
Canada	2,154	933	547	980	793	27,274	5,262
Chile	60,206	70,883	51,969	64,951	47,185	56,025	117,520
France			19	126			
West Germany							
Mexico	66,173	48,136	51,792	48,746	40,602	38,686	49,292
Northern Rhodesia		18,930	27,123	87,062	43,717	28,224	85,264
Peru	22,884	14,072	847	6,756	2,325	796	865
Republic of South Africa	7,952	3,353	2,778	3,286	3,719	3,326	166
Spain							
Turkey	1,933		4,572	3,266		3,779	11,894
United Kingdom				44			382
Yugoslavia	10,145	2,298	14,727	10,985	6,223	8,023	
Other	1,154	888	86	1,253	409	10	570
Total	172,601	159,493	154,460	227,455	144,973	166,093	280,629
Refined:							
Republic of the Congo							5,799
Belgium-Luxembourg						646	5,540
Canada	1,180	17,127	47,930	52,099	28,354	28,326	67,487
Chile	143,010	230,288	210,443	213,754	208,444	294,425	147,294
West Germany						8,932	3,570
Japan	3,226		1,112	27,590	852	223	
Malta, Gozo, Cyprus							
Mexico	66	947	1,468	4,782	757	5,839	7,513
Northern Rhodesia						1	2,778
Peru	2,000	233	14,756	14,428	377	1,662	16,157
Republic of South Africa							100
Sweden							1,603
United Kingdom		113	36	232	6	37	1,396
Yugoslavia						6,810	7,775
Other		416	66	4,478	182	59	7,099
Total	149,482	249,124	275,811	317,363	238,972	346,960	274,111
Scrap:							
Canada	4,693	4,782	2,856	4,783	664	762	3,223
Chile	250		175	159	633		499
Cuba	55	16	244	462	407	1,013	449
United Kingdom	(2)	882	1,887	664		(2)	416
Other	955	3,654	1,639	32,735	3,860	2,711	3,206
Total	5,953	9,334	6,801	38,803	5,564	4,486	7,793

See footnotes at end of table.

TABLE 46.—*Copper (unmanufactured) imported into the United States, by class and country in terms of copper content,*[1] *short tons*—Continued

	1954	1955	1956	1957	1958	1959	1960	1961	1962
Ore and concentrate:									
Australia	1,183	1,152	1,022	773	629	3,051	773	793	751
Bolivia	3,901	3,292	4,483	4,450	3,395	----------	1,346	905	1,580
Canada	30,252	26,344	23,149	28,470	6,627	5,636	14,381	13,959	18,028
Chile	12,547	21,436	18,711	17,287	16,381	15,969	14,192	1,992	22
Cuba	17,598	20,356	15,394	16,850	13,992	9,942	6,554	----------	----------
France	----------	----------	----------	----------	----------	----------	----------	----------	----------
West Germany	----------	----------	----------	----------	----------	----------	----------	----------	----------
Malta, Gozo, Cyprus	----------	4,388	6,945	8,937	6,384	3,524	----------	----------	----------
Mexico	11,644	8,079	6,929	3,787	2,958	454	107	158	244
Northern Rhodesia	256	262	244	75	336	----------	----------	----------	----------
Peru	8,563	8,707	11,372	11,673	8,852	7,538	8,008	6,793	6,416
Philippines	19,405	13,321	10,907	13,060	14,519	12,882	17,553	13,891	10,125
Republic of South Africa	7,393	10,269	15,228	13,081	12,918	11,687	12,588	7,275	5,751
Spain	----------	----------	----------	----------	----------	----------	----------	----------	----------
Other	39	23	479	150	434	1,958	16	22	----------
Total	112,781	117,629	114,863	118,593	87,425	72,641	75,518	45,788	42,917
Matte and blister:									
Australia	15,489	10,144	17,437	14,302	4,438	4,421	----------	33	----------
Republic of the Congo	8,045	9,231	4,345	----------	----------	----------	----------	----------	----------
Canada	6,499	1,348	2,619	1,070	1,248	1,075	902	571	201
Chile	128,850	138,050	175,889	208,539	183,051	211,251	190,489	221,520	224,516
France	----------	----------	----------	----------	----------	----------	----------	----------	1
West Germany	77	----------	----------	----------	----------	----------	----------	----------	----------
Mexico	33,250	32,331	41,428	40,928	42,742	22,335	20,434	20,661	23,473
Northern Rhodesia	60,417	62,545	13,452	17,300	16,781	16,226	10	10	----------
Peru	884	4,624	15,468	15,739	10,227	3,982	75,382	83,588	65,717
Republic of South Africa	6,089	2,218	6,063	5,744	13,655	----------	----------	14,402	18,409
Spain	----------	----------	----------	----------	----------	----------	----------	----------	----------
Turkey	2,664	547	5,586	3,496	1,094	----------	----------	----------	----------
United Kingdom	----------	542	----------		----------	17,582	15,640	----------	1
Yugoslavia	----------	----------	----------	----------	----------	----------	----------	----------	----------
Other	15	11	1,109	214	124	1,125	565	10	3
Total	262,279	261,591	283,396	307,332	273,360	277,997	303,422	340,795	332,321
Refined:									
Republic of the Congo	7,494	4,929	8,419	10,221	15,515	----------	----------	----------	----------
Belgium-Luxembourg	718	338	769	447	56	8,504	2,673	----------	----------
Canada	51,241	72,371	93,525	87,482	62,849	103,237	100,641	61,659	76,600
Chile	125,536	67,286	41,915	10,190	713	14,172	3,486	1,983	856
West Germany	4	3,577	2,738	2,545	4,158	24,305	8,727	14	----------
Japan	----------	27	799	(2)	----------	----------	----------	----------	----------
Malta, Gozo, Cyprus	----------	----------	----------	----------	527	----------	----------	----------	----------
Mexico	6,276	7,919	4,033	2,924	4,235	6,575	2,038	34	8
Northern Rhodesia	1,232	10,656	13,866	28,055	18,052	16,396	5,785	----------	18,997
Peru	13,003	17,771	16,001	14,224	11,349	17,205	8,234	54	----------
Republic of South Africa	----------	602	----------	1,120	2,596	1,712	----------	1,797	----------
Sweden	----------	1,024	224	2,688	1,063	3,428	2,789	----------	----------
United Kingdom	----------	11,105	3,348	2,413	6,958	13,366	729	1,312	845
Yugoslavia	3,886	2,149	138	----------	----------	----------	----------	----------	----------
Other	5,696	2,558	5,970	----------	393	5,158	7,607	2	1,514
Total	215,086	202,312	191,745	162,309	128,464	214,058	142,709	66,855	98,820
Scrap:									
Canada	1,919	6,971	1,196	3,202	4,089	2,370	1,717	2,165	3,924
Chile	----------	----------	108	----------	----------	----------	----------	1,476	----------
Cuba	684	766	951	585	472	865	14	----------	----------
United Kingdom	25	3	8	2	227	70	52	4	----------
Other	2,055	4,828	3,480	2,009	2,272	2,890	912	586	869
Total	4,683	12,568	5,743	5,798	7,060	6,195	2,695	4,231	4,793

[1] Data are general imports; that is, they include copper imported for immediate consumption plus material entering country under bond.

[2] Less than 1 ton.

Source: U.S. Department of Commerce.

TABLE 47.—*Copper (unmanufactured) imported into the United States, by countries in terms of copper content, short tons* [1]

	1926	1927	1928	1929	1930	1931	1932
North America:							
Canada	53,329	54,499	76,425	102,750	108,835	80,439	59,034
Cuba	10,916	15,139	7,364	5,621	13,322	10,569	5,105
Mexico	52,628	58,133	66,184	85,285	72,662	55,118	37,715
Other	483	138	231	227	275	151	44
Total	117,356	127,909	150,204	193,883	195,094	146,277	101,898
South America:							
Bolivia	12	21	5	3	60	99	[3]
Chile	116,354	102,810	107,067	169,484	94,318	85,315	54,730
Peru	47,719	52,019	58,286	62,465	56,076	44,676	23,218
Other	793	1,660	413	178	495	1,131	229
Total	164,878	156,510	165,771	232,130	150,949	131,221	78,177
Europe:							
Belgium-Luxembourg	847	[3]	31	547	1,658	45	2
France	1,179	168	279	2,487	1,673	157	96
West Germany	607	625	706	5,338	4,210	587	148
Malta, Gozo, and Cyprus	—	71					
Netherlands	25	5	25	61	30	16	—
Norway	20	—	[3]	2,547	—	7	7
Sweden	37	96	535	—	—	28	—
United Kingdom	15,704	10,403	2,627	7,738	1,901	929	105
Yugoslavia	—	—	—	—	—	—	—
Other	19,972	4,600	4,919	9,169	7,316	124	47
Total	38,391	15,968	9,122	27,887	16,788	1,893	405
Asia:							
Japan	—	1	—	1,409	7,238	—	—
Philippines	2	—	—	[3]	[3]	—	—
Turkey	—	—	—	—	—	—	—
Other	—	—	1	—	—	6	—
Total	2	1	1	1,409	7,238	6	—
Africa:							
Republic of the Congo	—	57,242	57,000	27,678	36,230	—	—
Northern Rhodesia	—	—	—	—	—	—	—
Republic of South Africa	—	1,349	1,838	105	118	699	4,174
Southern Rhodesia	—	—	—	—	—	—	—
Other	68,649	—	9,307	3,931	62	10,409	10,127
Total	68,649	58,591	68,145	31,714	36,410	11,108	14,301
Oceania:							
Australia	194	154	185	93	2,057	2,424	1,195
Other	11	[3]	—	—	—	—	—
Total	205	154	185	93	2,057	2,424	1,195
Grand total	389,481	359,133	393,428	487,116	408,536	292,929	195,976

See footnotes at end of table.

TABLE 47.—*Copper (unmanufactured) imported into the United States, by countries in terms of copper content, short tons* [1]—Continued

	1933	[2] 1934	[2] 1935	1936	1937	1938	1939
North America:							
Canada	16,935	22,119	44,443	14,674	38,538	50,451	57,500
Cuba	8,413	7,976	5,815	11,824	14,204	17,840	9,897
Mexico	43,203	53,410	47,012	34,982	53,827	47,142	52,539
Other				137	254	102	242
Total	68,551			61,617	106,823	115,535	120,178
South America:							
Bolivia	282			2,283	2,840	2,616	2,140
Chile	28,034	73,773	83,289	59,381	99,518	67,734	119,920
Peru	26,165	29,780	37,251	35,424	40,945	40,125	38,551
Other	84			713	520	352	419
Total	54,565			97,801	143,823	110,827	161,030
Europe:							
Belgium-Luxembourg	15			1,461	115	208	114
France	90	180	546	140	150	136	473
West Germany	80	268	233	(3)	50		
Malta, Gozo, and Cyprus				1,298	4,361	1,429	1,625
Netherlands				60	17		35
Norway					8		
Sweden	532			161	229	266	557
United Kingdom	94	50	606	572	897	263	633
Yugoslavia	4,429	10,368	21,681	19,033	16,124	10,582	9,527
Other	5			2,174	19	205	206
Total	5,245			24,899	21,970	13,089	13,170
Asia:							
Japan							
Philippines				171	423	1,327	1,518
Turkey						2,544	5,356
Other					22		
Total				171	445	3,871	6,874
Africa:							
Republic of the Congo							
Northern Rhodesia							
Republic of South Africa	1,485	14	250	55	695	1,921	17,061
Southern Rhodesia							
Other	13,689			4,929	3,595	4,454	14,954
Total	15,174	14	250	4,984	4,290	6,375	32,015
Oceania:							
Australia	182	558	1,359	866	2,523	2,467	3,030
Other							
Total	182	558	1,359	866	2,523	2,467	3,030
Grand total	143,717	213,286	257,182	190,338	279,874	252,164	336,297

See footnotes at end of table.

TABLE 47.—*Copper (unmanufactured) imported into the United States, by countries in terms of copper content, short tons* [1]—Continued

	1940	1941	1942	1943	1944	1945	1946
North America:							
Canada	61,561	69,103	39,071	35,038	68,079	95,614	30,539
Cuba	11,560	8,067	9,094	7,885	7,123	9,422	12,378
Mexico	43,392	54,458	57,404	51,269	46,198	66,613	64,684
Other	325	349	234	450	36	36	306
Total	116,838	131,977	105,803	94,642	121,436	171,685	107,907
South America:							
Bolivia	4,139	6,456	5,379	6,300	3,798	4,929	4,573
Chile	205,333	460,370	500,058	489,856	549,002	452,073	207,525
Peru	42,037	36,184	30,609	33,242	34,517	31,375	30,374
Other	1,909	3,743	1,815	4,975	4,265	3,652	3,153
Total	253,418	506,753	537,861	534,373	591,582	492,029	245,625
Europe:							
Belgium-Luxembourg	6						1
France	169						
West Germany							
Malta, Gozo, and Cyprus	4,652			2,762	3,925		
Netherlands	3						
Norway	532						
Sweden			3,260				
United Kingdom	39	19					3,386
Yugoslavia							
Other		1					
Total	5,401	20	3,260	2,762	3,925		3,387
Asia:							
Japan	16						
Philippines	2,086	3,964	256				
Turkey	6,224		482	2,342	2,756		17,414
Other	2,307	1,830	1,616	10	10	10	2
Total	10,633	5,794	2,354	2,352	2,766	10	17,416
Africa:							
Republic of the Congo	60,815	81,994	89,050	76,977	63,404	[4] 89,624	4,469
Northern Rhodesia					[5] 157	[5] 89,962	[5] 11,942
Republic of South Africa	15,768	273	17,905	3,881	1,043	7,066	5,396
Southern Rhodesia			4,545	157			
Other	27,430	7,583		831		1,672	159
Total	104,013	89,850	111,500	81,846	64,604	188,324	21,966
Oceania:							
Australia	1,039	1,151	3,593	679	898	1,148	79
Other			22				
Total	1,039	1,151	3,615	679	898	1,148	79
Grand total	491,342	735,545	764,393	716,654	785,211	853,196	396,380

See footnotes at end of table.

TABLE 47.—*Copper (unmanufactured) imported into the United States, by countries in terms of copper content, short tons* [1]—Continued

	1947	1948	1949	1950	1951	1952	1953
North America:							
Canada	30,446	47,267	82,821	82,365	54,554	81,932	107,427
Cuba	14,953	16,270	15,849	22,891	22,302	19,934	18,206
Mexico	75,906	57,593	64,706	62,748	47,878	50,997	65,818
Other	264	624	553	524	744	408	629
Total	121,569	121,754	163,929	168,528	125,478	153,271	192,080
South America:							
Bolivia	6,752	6,729	4,671	5,220	4,449	3,097	3,972
Chile	223,124	320,703	285,386	292,215	268,359	362,303	281,074
Peru	32,597	19,318	22,316	28,502	10,054	11,317	26,523
Other	293	1,876	959	878	300	213	328
Total	262,766	348,626	313,332	326,815	283,162	376,930	311,897
Europe:							
Belgium-Luxembourg	27	59	273	474	----------	646	5,615
France	----------	103	158	3,801	1,587	1,806	2,160
West Germany	----------	----------	----------	44	----------	8,932	3,570
Malta, Gozo, and Cyprus	----------	2,689	6,888	6,530	5,556	5,441	3,680
Netherlands	----------	791	234	352	47	41	175
Norway	112	6	37	4,098	----------	1	4,427
Sweden	----------	----------	----------	57	----------	----------	2,217
United Kingdom	----------	995	1,925	940	6	37	2,194
Yugoslavia	10,317	2,298	14,727	10,998	6,223	14,833	7,775
Other	1,127	187	45	367	91	79	----------
Total	11,583	7,128	24,287	27,661	13,510	31,816	31,813
Asia:							
Japan	3,226	2	1,167	54,400	1,908	223	----------
Philippines	2,185	2,252	7,969	10,129	12,608	14,787	13,538
Turkey	1,933	----------	4,572	3,266	----------	3,779	11,894
Other	16	1,078	341	980	140	4	110
Total	7,360	3,332	14,049	68,775	14,656	18,793	25,542
Africa:							
Republic of the Congo	----------	----------	----------	103	----------	(3)	5,799
Northern Rhodesia	101	[5] 19,061	[6] 27,244	84,291	43,717	28,225	88,042
Republic of South Africa	9,765	5,926	8,914	9,859	7,353	8,588	7,678
Southern Rhodesia	----------	----------	----------	[7] 3,009	98	167	212
Other	232	52	8	33	17	----------	----------
Total	10,098	25,039	36,166	97,295	51,185	36,980	101,731
Oceania:							
Australia	518	1,570	941	1,307	1,143	684	13,041
Other	----------	----------	----------	8	1	406	----------
Total	518	1,570	941	1,315	1,144	1,090	13,041
Grand total	413,894	507,449	522,704	690,389	489,135	618,880	676,104

See footnotes at end of table.

TABLE 47.—*Copper (unmanufactured) imported into the United States, by countries in terms of copper content, short tons* [1]—Continued

	1954	1955	1956	1957	1958	1959	1960	1961	1962
North America:									
Canada	89,911	107,034	120,489	120,224	74,813	112,318	117,641	78,354	98,753
Cuba	18,282	21,122	16,345	17,435	14,464	10,807	6,568		
Mexico	51,229	49,642	52,835	47,746	50,023	29,493	22,656	20,963	23,779
Other	406	693	671	543	453	412	190	308	368
Total	159,828	178,491	190,340	185,948	139,753	153,030	147,055	99,625	122,900
South America:									
Bolivia	3,913	3,301	4,500	4,463	3,395	1,790	1,346	905	1,580
Chile	266,933	226,772	236,623	236,016	200,145	241,392	208,167	226,971	225,394
Peru	22,450	31,119	42,841	41,636	30,426	28,725	91,624	90,435	72,133
Other	7	20	772	986	963	464	11	(3)	28
Total	293,303	261,212	284,736	283,101	234,929	272,371	301,148	318,311	299,135
Europe:									
Belgium-Luxembourg	718	383	800	447	56	8,504	2,673		
France	1,587	2,128	991	660	1,188	1,125	526		1
West Germany	81	3,582	2,744	2,552	4,173	24,342	8,739	14	
Malta, Gozo, and Cyprus		4,388	6,945	8,937	6,911	3,524			
Netherlands		2,291	11	22	392	727	506		23
Norway	5,664	149	5,969		20	50	248		
Sweden		1,024	254	2,689	1,063	3,428	2,789		
United Kingdom	25	11,650	3,356	2,415	7,185	13,436	781	1,316	846
Yugoslavia	3,886	2,149	138						
Other	17					1	5,150	11	724
Total	11,978	27,744	21,208	17,722	20,988	55,137	21,412	1,341	1,594
Asia:									
Japan	1	94	799	1	26				
Philippines	19,425	13,321	10,911	13,067	14,583	13,759	17,562	13,898	10,126
Turkey	2,664	547	5,586	3,496	1,094	1,094	547		
Other	32	151	12	21	14	41	2		35
Total	22,122	14,113	17,308	16,585	15,717	14,894	18,111	13,898	10,161
Africa:									
Republic of the Congo	15,539	14,160	12,764	10,221	15,515	4,335	196		
Northern Rhodesia	[6] 61,905	73,464	27,562	45,430	35,169	32,622	5,795	10	18,997
Republic of South Africa	13,482	13,089	21,291	19,945	29,169	30,981	28,228	23,474	24,460
Southern Rhodesia									
Other			1,085			49	625	21	784
Total	90,926	100,713	62,702	75,596	79,853	67,987	34,844	23,505	44,241
Oceania:									
Australia	16,672	11,827	19,453	15,075	5,061	7,472	1,774	826	751
Other				5				163	69
Total	16,672	11,827	19,453	15,080	5,061	7,472	1,774	989	820
Grand total	594,829	594,100	595,747	594,032	496,301	570,891	524,344	457,669	478,851

[1] Data are general imports; that is, they include copper imported for immediate consumption plus material entering the country under bond.
[2] Data not available for all countries.
[3] Less than 1 ton.
[4] Refined copper credited to Portuguese Guiana and Angola by U.S. Department of Commerce has been added to Republic of the Congo.
[5] Tonnages credited to Southern Rhodesia by U.S. Department of Commerce have been added to Northern Rhodesia.
[6] Beginning July 1, 1954, classified as Federation of Rhodesia and Nyasaland.
[7] Chiefly from Northern Rhodesia.

Source: U.S. Department of Commerce.

Production of copper in the British Empire had increased so rapidly in the 1930's that a surplus was available for export by 1939. When war was declared in Europe the United Kingdom situation changed quickly. In 1940 shipments to the United Kingdom tripled, and it was second only to Japan in receipts of copper from the United States. Substantial quantities began going to the U.S.S.R. in 1939, and during the war years most of the refined copper exported from the United States (considerably below prewar levels) went to these two countries.

Exports of refined copper, which resumed its

TABLE 48.—*Brass and copper scrap imported into and exported from the United States, short tons*

	1926	1927	1928	1929	1930	1931	1932	1933	1934
Imports for consumption:									
Brass scrap, gross weight	4,311	3,993	6,077	7,031	3,573	2,212	1,259	40	243
Copper scrap, copper content	5,500	3,739	5,304	6,797	3,750	2,550	1,211	17	24
Exports:									
Brass scrap	[1] 25,132	[1] 45,997	[1] 42,413	26,867	22,613	11,592	15,073	15,348	30,196
Copper scrap	9,713	22,709	27,733	18,818	16,943	33,589	17,179	14,219	12,595

	1935	1936	1937	1938	1939	1940	1941	1942	1943
Imports for consumption:									
Brass scrap, gross weight	190	------	(2)	------	------	1,232	6,113	10,519	9,102
Copper scrap, copper content	------	754	16	(2)	132	135	2,113	912	3,002
Exports:									
Brass scrap	29,792	12,340	18,551	15,988	5,338	5,887	722	168	6
Copper scrap	9,542	13,224	20,914	21,811	17,643	7,149	3,259	1,215	(2)

	1944	1945	1946	1947	1948	1949	1950	1951	1952
Imports for consumption:									
Brass scrap, gross weight	6,226	7,774	24,008	112,431	59,984	23,486	37,537	6,523	10,321
Copper scrap, copper content	1,055	1,348	1,030	5,957	9,334	6,765	34,242	6,792	5,125
Exports:									
Brass scrap [3]	38	421	1,184	3,157	6,584	13,963	9,054	4,857	6,261
Copper scrap	99	133	909	969	2,266	8,284	9,445	7,701	8,941

	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Imports for consumption:										
Brass scrap, gross weight	9,679	5,272	11,758	6,519	7,911	6,763	2,054	566	608	2,141
Copper scrap, copper content	7,827	4,752	12,577	5,410	5,843	5,849	2,984	1,836	1,643	3,846
Exports:										
Brass scrap [3]	33,680	93,972	45,260	50,485	69,996	28,502	29,406	122,175	116,654	36,209
Copper scrap	34,568	75,749	31,137	25,681	48,989	21,861	10,721	58,860	35,257	12,608

[1] Includes ingots.
[2] Less than 1 ton.
[3] Beginning Jan. 1, 1952, classified as copper-base-alloy scrap (new and old).
Source: U.S. Department of Commerce.

prewar position as the most important export class in 1946, almost trebled in 1947. Copper was subject to export controls during most of the period. In September 1956 export restrictions on refined copper were removed, and shipments during 1957 rose 55 percent to 346,000 tons—the highest since 1940. In 1960, exports were the largest since 1929.

Tables 50 and 51 show exports of copper by classes and refined copper by country of destinations. Tables 52, 53, and 54 show exports of copper alloys and copper sulfate.

Foreign Countries

The principal copper-exporting countries are Canada, Chile, Republic of the Congo, and Northern Rhodesia. Exports and reexports for the United Kingdom averaged nearly 46,000 tons a year from 1951–62, but the United Kingdom regularly requires large quantities of copper to meet its needs, and imports are shown in table 55.

Canada.—Most of the copper output is exported. The United States and the United Kingdom are the leading destinations of the refined copper shipped with important quantities going to France and West Germany in recent years. Exports by country of destination are shown in table 56.

Chile.—Chile ranked first as an exporter of copper in 4 of the 10 years under review. Although the United States has been the chief destination for Chilean copper, its share of the total dropped from 94 percent in 1938 to 38 percent in 1960. Substantial quantities have been shipped to the United Kingdom, West Germany, Netherlands, and Italy. Table 57 shows exports by country of destination.

TABLE 49.—*Exports of insulated wire and cable by countries, short ton*

Country	1939	1940	1941	1942	1943
Argentina	118	939	1, 559	396	108
Australia	54	970	806	1, 267	2, 475
Canada	276	655	1, 268	991	1, 440
China	166	747	374	117	362
Colombia	770	669	710	145	698
Cuba	901	727	995	335	961
Egypt	(1)	3	3, 363	8, 788	4, 455
France	8	5, 757	------	------	------
India	80	344	368	5, 278	5, 949
Mexico	395	557	824	1, 157	943
Philippines	1, 442	1, 171	1, 308	------	------
U.S.S.R	1	11	2, 773	31, 940	50, 135
United Kingdom	58	4, 827	1, 786	2, 140	11, 456
Other	3, 156	9, 598	11, 442	7, 881	13, 777
Total	7, 425	26, 975	27, 576	60, 435	92, 759

Country	1944	1945	1946	1947	1948
Argentina	195	169	424	1, 970	1, 546
Australia	1, 444	156	125	81	118
Canada	1, 913	1, 025	1, 243	2, 956	3, 658
China	61	240	570	1, 290	5, 880
Colombia	492	1, 587	969	1, 150	1, 833
Cuba	410	1, 710	1, 122	1, 890	2, 248
Egypt	624	91	------	------	------
France	554	823	688	765	1, 514
India	5, 433	2, 745	223	84	857
Mexico	1, 022	1, 400	1, 186	1, 498	1, 705
Philippines	------	202	1, 106	1, 967	1, 571
U.S.S.R	91, 685	36, 707	13, 351	678	12
United Kingdom	23, 653	2, 702	44	24	235
Other	16, 948	9, 835	9, 317	10, 941	14, 087
Total	144, 434	59, 392	30, 368	25, 294	35, 264

[1] Less than 1 ton. Source: U.S. Department of Commerce.

TABLE 50.—*Copper exported from the United States, short tons*

	1926	1927	1928	1929	1930	1931	1932	1933	1934
Ore, concentrate, matte, copper content	2,733	3,618	1,916	2,790	90	150	16,433	22,714	16,383
Refined	428,062	461,233	474,737	411,227	297,057	202,698	110,977	124,582	262,366
Rods [1]	22,395	29,309	35,663	40,544	37,569	29,415	14,052	7,790	9,772
Scrap	9,713	22,709	27,733	18,818	16,943	33,589	17,179	14,219	12,595
Pipes and tubes	1,627	1,569	1,777	1,723	1,349	1,035	598	401	734
Plates and sheets	2,516	3,537	3,020	3,161	5,492	2,269	836	567	4,761
Wire and cable, bare [2]	6,521	5,144	7,838	8,434	7,875	3,134	944	1,285	2,108
Wire and cable, insulated	9,276	11,245	9,826	12,540	10,274	6,647	3,091	3,070	4,024
Other copper manufactures	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)

	1935	1936	1937	1938	1939	1940	1941	1942	1943
Ore, concentrate, matte, copper content	7,675	3,385	4,088	1,002	62	294	12	3,424	1,240
Refined	260,735	220,390	295,064	370,545	372,777	356,431	103,602	131,406	175,859
Rods [1]	14,271	15,701	15,332	14,678	23,629	20,677	11,151	326	1,482
Scrap	9,542	13,224	20,914	21,811	17,643	7,149	3,259	1,215	(4)
Pipes and tubes	608	848	1,091	822	1,570	3,836	2,132	4,778	9,934
Plates and sheets	3,588	1,110	1,385	550	843	3,727	3,782	1,910	7,291
Wire and cable, bare [2]	1,577	2,146	4,695	5,362	3,630	8,856	7,392	10,490	7,134
Wire and cable, insulated	4,877	5,613	7,748	7,243	7,425	26,975	27,576	60,435	92,759
Other copper manufactures	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)

	1944	1945	1946	1947	1948	1949	1950	1951	1952
Ore, concentrate, matte, copper content	(4)	34	23	115	2,473	200	616	234	648
Refined	68,373	48,563	52,629	147,642	142,598	137,827	144,561	133,305	174,135
Rods [1]	629	5,009	2,452	2,416	8,101	12,678	10,073	521	1,937
Scrap	99	133	909	969	2,266	8,284	9,445	7,701	8,941
Pipes and tubes	7,450	4,197	2,931	5,107	5,246	3,344	1,988	2,160	2,591
Plates and sheets	6,625	3,797	3,687	4,374	2,853	1,088	581	572	553
Wire and cable, bare [2]	9,904	11,464	4,499	11,197	10,694	7,881	7,009	7,983	7,163
Wire and cable, insulated	144,434	59,392	30,368	25,294	35,264	24,888	18,682	14,032	17,070
Other copper manufactures	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)

	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Ore, concentrate, matte, copper content	495	2,369	12,897	13,717	15,656	11,475	2,982	11,111	4,478	1,916
Refined	109,580	215,951	199,819	223,103	346,025	384,868	158,938	433,762	428,718	336,525
Rods [1]	321	344	202	366	1,659	(1)	(1)	(1)	(1)	(1)
Scrap	34,568	75,749	31,137	25,681	48,989	21,861	10,721	58,860	35,257	12,608
Pipes and tubes	1,622	1,199	1,292	1,550	1,354	1,608	799	726	949	864
Plates and sheets	367	300	542	337	265	166	313	500	355	349
Wire and cable, bare [2]	9,313	4,548	6,976	11,104	11,119	5,030	3,378	3,278	1,995	2,875
Wire and cable, insulated	15,622	14,342	19,974	18,434	21,035	14,482	21,863	13,368	15,550	13,364
Other copper manufactures	294	250	234	185	238	2,302	4,352	5,181	7,362	6,768

[1] Beginning Jan. 1, 1958, not separately classified; included in "Other copper manufactures."
[2] Owing to changes in classifications, 1952–62 data not strictly comparable with earlier years.
[3] Weight not recorded.
[4] Less than 1 ton.

Source: U.S. Department of Commerce.

TABLE 51.—*Refined copper exported from the United States, by countries, short tons*

	1926	1927	1928	1929	1930	1931	1932
North America:							
Canada	7,649	7,725	10,587	19,352	7,117	3,579	93
Mexico	709	758	116	745	384	439	368
Other	121	57	19	2,058	648	43	42
Total	8,479	8,540	10,722	22,155	8,149	4,061	503
South America:							
Argentina	169	678	354	355	995	441	1,162
Brazil	86	165	477	1,122	642	73	64
Other	406	437	54	83	28	14	8
Total	661	1,280	885	1,560	1,665	528	1,234
Europe:							
Austria	28	123	56	67	56	---	---
Belgium-Luxembourg	41,029	44,749	38,716	22,875	13,182	12,195	6,244
Czechoslovakia	74	17	(1)	700	163	(1)	---
Denmark	434	500	999	888	1,050	1,131	950
France	87,575	55,979	85,720	87,632	70,619	54,740	31,184
West Germany	76,680	110,921	103,275	89,440	46,930	29,142	15,224
Hungary	---	---	---	---	---	---	---
Italy	41,479	43,135	58,274	42,246	39,354	21,451	11,672
Netherlands	32,143	52,300	32,263	16,267	13,573	8,923	4,410
Norway	476	718	1,203	683	865	233	123
Poland and Danzig	84	431	968	235	112	268	67
Spain	4,828	1,885	1,661	1,126	129	56	---
Sweden	12,356	10,938	14,352	16,248	15,337	14,430	7,795
Switzerland	---	140	353	168	(1)	---	---
U.S.S.R.	4,902	18,937	9,614	8,120	6,348	3,872	---
United Kingdom	90,160	91,283	92,908	87,725	71,395	47,125	29,975
Other	502	383	1,278	3,249	1,061	390	285
Total	392,750	432,439	441,640	377,669	280,174	193,956	107,929
Asia:							
Burma	---	---	---	---	---	---	---
China	4,084	2,820	2,946	2,802	2,813	2,362	370
French Indochina	---	---	---	---	---	---	---
Hong Kong	363	353	243	270	707	778	431
India	2,208	2,997	1,225	2,022	1,340	837	168
Japan	18,672	12,238	16,198	3,977	1,594	94	224
Kwantung	121	190	165	1	---	---	28
Pakistan	---	---	---	---	---	---	---
Taiwan	---	---	---	---	---	---	---
Other	303	249	196	577	389	82	90
Total	25,751	18,847	20,973	9,649	6,843	4,153	1,311
Africa:							
Algeria	---	---	---	---	---	---	---
Other	370	2	482	19	1	---	---
Total	370	2	482	19	1	---	---
Oceania:							
Australia	1	3	6	7	1	---	---
Other	50	122	29	168	224	(1)	---
Total	51	125	35	175	225	(1)	---
Grand total [2]	428,062	461,233	474,737	411,227	297,057	202,698	110,977

See footnotes at end of table.

TABLE 51.—*Refined copper exported from the United States, by countries, short tons*—Continued

	1933	1934	1935	1936	1937	1938	1939
North America:							
Canada	46	81	104	190	2,464	782	98
Mexico	1,728	1,359	886	1,905	1,117	1,019	1,329
Other	12	17	52	202	66	47	120
Total	1,786	1,457	1,042	2,297	3,647	1,848	1,547
South America:							
Argentina	2,387	1,589	919	1,019	2,583	2,514	1,596
Brazil	30	225	872	477	352	1,739	3,769
Other	14	30	35	83	104	189	129
Total	2,431	1,844	1,826	1,579	3,039	4,442	5,494
Europe:							
Austria	------	1	(1)	------	163	499	------
Belgium-Luxembourg	7,241	9,261	12,870	14,707	14,639	9,175	5,804
Czechoslovakia	(1)	20	84	59	5,672	33,414	1,048
Denmark	1,134	1,366	2,231	1,856	3,550	1,295	1,735
France	36,428	58,159	32,173	40,872	39,197	32,111	76,024
West Germany	17,381	36,381	24,916	32,639	37,535	74,333	21,284
Hungary	------	------	------	56	56	1,539	3,679
Italy	15,019	21,521	45,247	23,850	20,812	21,874	28,014
Netherlands	4,570	10,891	8,358	3,256	7,484	6,890	5,422
Norway	501	949	983	1,537	636	691	1,691
Poland and Danzig	1,214	2,828	5,361	6,985	3,687	12,456	12,760
Spain	------	11	11	------	------	------	24
Sweden	6,098	14,193	12,574	15,506	17,360	18,625	24,984
Switzerland	------	------	------	------	------	648	3,253
U.S.S.R.	------	------	168	5	2,197	55	22,748
United Kingdom	13,298	41,208	54,522	30,548	52,791	30,615	22,228
Other	236	622	608	378	586	1,512	182
Total	103,120	197,411	200,106	172,254	206,365	245,732	230,880
Asia:							
Burma	------	------	------	------	------	------	------
China	2,035	1,878	1,743	2,548	4,469	476	1,040
French Indochina	------	------	------	------	------	------	5,264
Hong Kong	703	516	882	302	2,290	2,859	45
India	176	508	1,235	235	890	653	1,590
Japan	14,079	56,885	53,133	39,926	72,844	108,940	124,638
Kwantung	84	168	112	3	486	2,773	1,678
Pakistan	------	------	------	------	------	------	------
Taiwan	------	------	------	------	------	------	------
Other	109	1,386	493	625	773	781	286
Total	17,186	61,341	57,598	43,639	81,752	116,482	134,541
Africa:							
Algeria	------	------	------	------	------	------	------
Other	59	313	161	620	261	2,040	315
Total	59	313	161	620	261	2,040	315
Oceania:							
Australia	------	------	2	1	(1)	1	(1)
Other	------	------	------	------	------	------	------
Total	------	------	2	1	(1)	1	(1)
Grand total [2]	124,582	262,366	260,735	220,390	295,064	370,545	372,777

See footnotes at end of table.

TABLE 51.—*Refined copper exported from the United States, by countries, short tons*—Continued

	1940	1941	1942	1943	1944	1945	1946
North America:							
Canada	327	285	208	162	134	60	67
Mexico	2,788	3,043	3,376	6,404	4,475	5,690	833
Other	342	118	38	9	1	45	51
Total	3,457	3,446	3,622	6,575	4,610	5,795	951
South America:							
Argentina	4,211	892	[1]	5		[1]	1,427
Brazil	5,217	6,718	1,130	726	34	5,674	4,453
Other	91	136	100	191	29	451	259
Total	9,519	7,746	1,230	922	63	6,125	6,139
Europe:							
Austria							
Belgium-Luxembourg	1,187					1,680	728
Czechoslovakia							563
Denmark	560						672
France	30,404					3,646	10,457
West Germany							
Hungary	4,441						
Italy	33,837					4,408	392
Netherlands	3,198						1,288
Norway	65						415
Poland and Danzig							
Spain	38					551	
Sweden	6,035				1,105	1,432	8,674
Switzerland	6,827			110		4,088	6,180
U.S.S.R.	54,478	5,768	15,238	1,403	20,971	221	43
United Kingdom	70,508	53,734	107,949	166,750	41,507	19,281	6,553
Other	4,109	1	1	5		9	1,088
Total	215,687	59,503	123,188	168,268	63,583	35,316	37,053
Asia:							
Burma							
China	4,820	8,461	3,002	13		542	2,010
French Indochina	255						3
Hong Kong	204	14					
India	1,182	2,437	251	3	7	1	5,651
Japan	116,973	16,934					
Kwantung	2,223	251					
Pakistan							
Taiwan							
Other	1,804	1,172	88	2	12	2	84
Total	127,461	29,269	3,341	18	19	545	7,748
Africa:							
Algeria				58	51	595	565
Other	265	271	24	15	40	18	116
Total	265	271	24	73	91	613	681
Oceania:							
Australia	42	3,364		1		169	56
Other		3	1	2	7		1
Total	42	3,367	1	3	7	169	57
Grand total [2]	356,431	103,602	131,406	175,859	68,373	48,563	52,629

See footnotes at end of table.

TABLE 51.—*Refined copper exported from the United States, by countries, short tons*—Continued

	1947	1948	1949	1950	1951	1952	1953
North America:							
Canada	84	47	50	94	37	12,884	833
Mexico	59	558	6	2	28	51	35
Other	43	47	12	5	32	17	8
Total	186	652	68	101	97	12,952	876
South America:							
Argentina	5,043	4,327	1,871	110	1,276	---	4,353
Brazil	601	1,595	3,198	1,356	3,621	5,496	9,635
Other	245	183	74	128	81	104	214
Total	5,889	6,105	5,143	1,594	4,978	5,600	14,202
Europe:							
Austria	---	811	2,481	192	655	1,356	286
Belgium-Luxembourg	3,919	2,576	1,404	578	562	---	560
Czechoslovakia	2,902	3,261	---	---	---	---	---
Denmark	635	1,593	831	1,982	1,372	1,447	917
France	6,746	10,222	23,948	18,401	18,626	35,573	17,834
West Germany	3,864	8,685	10,600	3,417	10,273	20,447	12,035
Hungary	446	---	---	---	---	---	---
Italy	7,646	4,463	19,914	16,640	7,948	17,040	10,971
Netherlands	10,283	8,776	11,611	6,148	8,190	5,994	11,362
Norway	700	896	495	3,217	1,911	1,674	3,266
Poland and Danzig	2,475	1,676	---	---	---	---	---
Spain	---	---	107	---	---	2,352	---
Sweden	9,073	(1)	2,240	2,015	593	2,242	---
Switzerland	8,329	11,317	9,374	5,152	5,415	9,562	6,365
U.S.S.R.	---	---	---	---	---	---	---
United Kingdom	70,855	62,776	26,236	74,245	70,161	48,116	22,367
Other	504	514	241	563	861	921	644
Total	128,377	117,566	109,482	132,550	126,567	146,724	86,607
Asia:							
Burma	---	---	---	---	---	---	---
China	647	326	14	---	---	---	---
French Indochina	---	---	---	---	---	---	---
Hong Kong	65	46	6	---	---	---	---
India	11,083	15,097	20,514	8,989	217	6,243	1,830
Japan	---	---	---	---	---	365	2,350
Kwantung	---	---	---	---	---	---	---
Pakistan	---	56	749	112	---	959	1,430
Taiwan	---	---	---	---	---	---	2,176
Other	14	16	95	35	154	221	1
Total	11,809	15,541	21,378	9,136	371	7,788	7,787
Africa:							
Algeria	168	2,733	1,727	1,174	76	446	---
Other	259	1	3	---	560	454	8
Total	427	2,734	1,730	1,174	636	900	8
Oceania:							
Australia	954	---	---	---	650	166	100
Other	(1)	---	26	6	6	5	---
Total	954	---	26	6	656	171	100
Grand total [2]	147,642	142,598	137,827	144,561	133,305	174,135	109,580

See footnotes at end of table.

TABLE 51.—*Refined copper exported from the United States, by countries, short tons*—Continued

	1954	1955	1956	1957	1958	1959	1960	1961	1962
North America:									
Canada	824	1,164	2,875	3,546	2,650	3,313	1,333	2,441	1,013
Mexico	70	292	104	158	707	27	106	154	107
Other	7	28	6	20	812	9	8	24	10
Total	901	1,484	2,985	3,724	4,169	3,349	1,447	2,619	1,130
South America:									
Argentina	4,736	2,975	----	11,152	13,007	4,268	12,469	12,885	8,931
Brazil	28,613	8,906	8,743	8,776	8,874	4,972	14,892	20,288	4,765
Other	113	29	96	495	342	87	137	289	123
Total	33,462	11,910	8,839	20,423	22,223	9,327	27,498	33,462	13,819
Europe:									
Austria	1,501	1,261	295	224	201	----	----	38	----
Belgium-Luxembourg	742	1,155	55	1,127	2,156	270	3,318	2,164	1,574
Czechoslovakia	----	----	----	----	----	----	----	1,572	----
Denmark	464	270	457	800	806	----	----	----	1,848
France	39,239	65,062	59,969	54,687	91,155	42,567	56,866	60,306	39,044
West Germany	30,236	35,251	32,900	50,773	65,831	38,524	105,998	77,352	67,353
Hungary	----	----	----	----	----	----	----	----	----
Italy	18,081	9,659	26,159	33,535	30,547	15,234	61,459	63,047	54,314
Netherlands	24,343	16,224	8,367	7,846	14,250	7,131	13,658	9,102	6,467
Norway	3,628	2,575	2,472	3,212	4,174	1,820	3,460	2,938	2,658
Poland and Danzig	----	----	----	----	----	----	----	----	----
Spain	----	----	----	2,192	66	----	28	----	418
Sweden	5,941	6,447	1,824	2,519	7,163	1,320	5,314	4,486	3,861
Switzerland	10,587	8,685	15,093	14,620	11,395	1,870	6,945	6,568	4,126
U.S.S.R	----	----	----	----	----	----	----	----	----
United Kingdom	25,347	28,092	15,569	89,649	115,462	26,300	90,664	76,371	52,186
Other	228	----	493	4,603	3,753	3,791	10,726	10,548	7,529
Total	160,337	174,681	163,653	265,787	346,959	138,827	358,436	314,492	241,378
Asia:									
Burma	----	----	----	----	----	----	----	----	----
China	----	----	----	----	----	----	----	----	----
French Indochina	----	----	----	----	----	----	----	----	----
Hong Kong	----	----	----	----	----	----	----	----	----
India	6,237	4,830	15,835	7,617	957	922	5,258	15,557	65,124
Japan	6,841	184	29,606	46,850	8,750	5,333	35,569	60,839	13,134
Kwantung	----	----	----	----	----	----	----	----	----
Pakistan	----	----	----	----	34	----	----	96	3
Taiwan	7	187	969	129	563	----	1,611	631	540
Other	105	7	24	219	541	69	163	5	252
Total	13,190	5,208	46,434	54,815	10,845	6,324	42,601	77,128	79,053
Africa:									
Algeria	174	----	----	----	----	----	----	----	10
Other	167	273	632	716	----	----	6	1,511	382
Total	341	273	632	716	----	----	6	1,511	392
Oceania:									
Australia	7,720	6,263	560	560	672	1,111	3,774	3,041	753
Other	----	----	----	----	----	----	----	----	----
Total	7,720	6,263	560	560	672	1,111	3,774	3,041	753
Grand total [2]	215,951	199,819	223,103	346,025	384,868	158,938	433,762	432,253	336,525

[1] Less than 1 ton.
[2] Includes countries not shown in stub.

Source: U.S. Department of Commerce.

TABLE 52.—*Copper-base alloys, including brass and bronze, exported from the United States,*[1] *by classes*

	1926		1927		1928		1929	
	Short tons	Value, thousands	Short tons	Value, thousands	Short tons	Value, thousands	Short tons	Value, thousands
Bars, rods, and shapes	1,645	$553	1,309	$410	997	$394	1,787	$756
Castings and forgings	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Hardware	(3)	815	(3)	921	(3)	828	(3)	1,145
Ingots	25,132	4,944	45,997	8,824	42,413	7,947	879	268
Pipe fittings and valves	1,718	1,828	1,639	1,807	2,021	2,076	2,296	2,466
Pipes and tubes	1,779	922	1,717	788	2,130	1,075	2,647	1,416
Plates, sheets, and strips	732	332	447	239	1,205	511	1,148	574
Plumbers brass goods	220	232	357	394	484	541	539	636
Powder	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Scrap and other forms	(5)	(5)	(5)	(5)	(5)	(5)	26,867	5,899
Semifabricated forms, n.e.c.	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)
Welding rods and wire	633	407	598	380	678	435	779	544
Other copper-base-alloy manufactures	(3)	3,641	(3)	3,753	(3)	3,811	(3)	3,799
Total	(3)	13,674	(3)	17,516	(3)	17,618	(3)	17,503

	1930		1931		1932		1933	
Bars, rods, and shapes	1,576	$621	1,040	$287	628	$155	385	$114
Castings and forgings	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Hardware	(3)	807	(3)	440	(3)	218	(3)	183
Ingots	1,004	266	585	106	78	11	66	11
Pipe fittings and valves	1,600	1,850	929	1,014	414	486	422	479
Pipes and tubes	2,317	1,059	1,595	557	773	228	428	152
Plates, sheets, and strips	708	344	323	133	216	76	131	54
Plumbers brass goods	492	575	353	376	175	183	216	214
Powder	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Scrap and other forms	22,613	4,157	11,592	1,519	15,073	1,255	15,348	1,368
Semifabricated forms, n.e.c.	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)
Welding rods and wire	671	427	618	315	116	51	120	50
Other copper-base-alloy manufactures	(3)	2,890	(3)	1,546	(3)	902	(3)	743
Total	(3)	12,996	(3)	6,293	(3)	3,565	(3)	3,373

	1934		1935		1936		1937	
Bars, rods, and shapes	625	$209	791	$251	907	$312	8,012	$2,268
Castings and forgings	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Hardware	(3)	282	(3)	324	(3)	375	(3)	491
Ingots	39	9	101	18	175	33	239	71
Pipe fittings and valves	642	720	718	818	952	1,062	1,349	1,707
Pipes and tubes	354	143	498	188	695	300	1,361	706
Plates, sheets, and strips	264	110	272	114	274	117	436	234
Plumbers brass goods	300	306	376	385	465	480	637	679
Powder	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Scrap and other forms	30,196	3,286	29,792	3,299	12,340	1,564	18,551	3,198
Semifabricated forms, n.e.c.	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)
Welding rods and wire	208	99	188	97	283	141	328	186
Other copper-base-alloy manufactures	(3)	1,058	(3)	1,144	(3)	1,283	(3)	1,927
Total	(3)	6,222	(3)	6,638	(3)	5,667	(3)	11,467

	1938		1939		1940		1941	
Bars, rods, and shapes	1,156	$411	4,546	$1,183	31,590	$8,895	[7] 8,603	$3,139
Castings and forgings	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Hardware	(3)	331	(3)	395	(3)	543	(3)	833
Ingots	118	24	813	230	674	188	124	42
Pipe fittings and valves	986	1,257	1,270	1,572	1,472	1,787	1,527	2,101
Pipes and tubes	693	311	1,119	501	2,134	1,149	1,540	952
Plates, sheets, and strips	549	242	1,117	534	58,644	21,719	30,770	11,378
Plumbers brass goods	499	576	722	802	712	796	655	793
Powder	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Scrap and other forms	15,988	2,295	5,338	743	5,887	1,057	722	116
Semifabricated forms, n.e.c.	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)
Welding rods and wire	184	104	678	336	4,656	2,686	3,769	1,897
Other copper-base-alloy manufactures	(3)	2,394	(3)	2,622	(3)	6,409	(3)	5,304
Total	(3)	7,945	(3)	8,918	(3)	45,229	(3)	26,555

See footnotes at end of table.

TABLE 52.—*Copper-base alloys, including brass and bronze, exported from the United States,*[1] *by classes*—Continued

	1942		1943		1944		1945	
	Short tons	Value, thousands	Short tons	Value, thousands	Short tons	Value, thousands	Short tons	Value, thousands
Bars, rods, and shapes	10,893	$3,835	22,579	$8,828	23,096	$7,831	8,691	$3,266
Castings and forgings	184	182	137	186	147	171	359	299
Hardware	(3)	463	(3)	309	(3)	251	(3)	449
Ingots	268	85	227	64	329	111	5,935	1,517
Pipe fittings and values[8]	1,694	1,862	1,153	1,935	1,007	1,864	285	470
Pipes and tubes	2,752	1,784	5,952	3,876	5,791	3,544	1,759	1,083
Plates, sheets, and strips	63,172	24,056	75,640	29,160	110,045	40,443	25,181	9,288
Plumbers brass goods	230	361	160	308	103	208	372	559
Powder	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Scrap and other forms	168	28	6	1	38	6	421	83
Semifabricated forms, n.e.c.	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)
Welding rods and wire	3,517	1,497	4,490	2,327	3,882	2,107	1,548	1,080
Other copper-base-alloy manufactures	(3)	6,101	(3)	4,599	(3)	4,937	(3)	2,949
Total	(3)	40,254	(3)	51,593	(3)	61,473	(3)	21,043

	1946		1947		1948		1949	
Bars, rods, and shapes	4,348	$1,855	5,400	$2,955	2,075	$1,387	1,563	$1,045
Castings and forgings	333	288	400	392	346	379	304	373
Hardware	(3)	801	(3)	1,814	(3)	1,146	(3)	981
Ingots	1,708	485	1,287	521	424	191	794	348
Pipe fittings and valves[8]	360	549	467	778	595	1,032	696	1,053
Pipes and tubes	1,712	1,080	2,895	2,367	2,484	2,303	1,574	1,523
Plates, sheets, and strips	3,038	1,616	5,976	4,224	3,931	2,967	1,930	1,688
Plumbers brass goods	913	1,724	1,885	4,085	1,594	3,384	1,571	3,138
Powder	(4)	(4)	(4)	(4)	(4)	(4)	(4)	(4)
Scrap and other forms	1,184	301	3,157	1,062	6,584	2,247	13,963	4,674
Semifabricated forms, n.e.c.	(6)	(6)	(6)	(6)	(6)	(6)	(6)	(6)
Welding rods and wire	2,338	1,769	3,201	3,257	2,455	2,639	1,447	1,596
Other copper-brass-alloy manufactures	(3)	4,729	(3)	6,428	(3)	4,767	(3)	4,145
Total	(3)	15,197	(3)	27,883	(3)	22,442	(3)	20,564

	1950		1951		1952		1953	
Bars, rods, and shapes	866	$653	914	$866	2,212	$2,371	1,259	$1,232
Castings and forgings	264	309	498	633	739	965	607	912
Hardware	(3)	781	(3)	924	(3)	1,597	(3)	2,661
Ingots	531	203	2,077	1,299	2,377	1,945	2,553	1,503
Pipe fittings and valves[8]	814	1,339	707	1,571	726	1,665	727	1,720
Pipes and tubes	1,029	1,040	1,485	1,679	1,400	1,817	2,858	2,707
Plates, sheets, and strips	937	839	829	787	925	1,109	641	834
Plumbers brass goods	1,922	4,010	2,242	5,771	(9)	5,248	2,657	6,454
Powder	(4)	(4)	(4)	(4)	62	74	66	89
Scrap and other forms	9,054	2,654	4,857	2,091	6,261	2,360	33,680	13,066
Semifabricated forms, n.e.c.	(6)	(6)	(6)	(6)	(6)	70	17	31
Welding rods and wire	1,153	1,294	1,446	1,960	1,532	2,337	634	1,334
Other copper-base-alloy manufactures	(3)	4,085	(3)	5,160	(3)	569	(3)	421
Total	(3)	17,207	(3)	22,741	(3)	22,127	(3)	32,964

	1954		1955		1956		1957	
Bars, rods, and shapes	455	$519	648	$821	734	$1,039	585	$864
Castings and forgings	435	709	468	777	405	773	435	699
Hardware	(3)	2,486	(3)	3,399	(3)	3,784	(3)	3,864
Ingots	2,601	1,762	810	1,186	662	1,243	373	656
Pipe fittings and valves[8]	983	2,222	1,302	3,047	1,197	3,266	1,301	3,362
Pipes and tubes	865	1,215	1,157	1,715	1,420	2,293	1,461	2,367
Plates, sheets, and strips	436	643	717	1,193	837	1,562	789	1,424
Plumbers brass goods	2,920	6,980	3,081	7,839	2,887	8,198	2,801	7,681
Powder	68	71	196	237	181	239	209	222
Scrap and other forms	93,972	38,469	45,260	24,507	50,485	29,815	69,996	32,968
Semifabricated forms, n.e.c.	16	43	22	57	34	63	27	63
Welding rods and wire	760	1,444	823	1,642	890	2,192	777	1,660
Other copper-base-alloy manufactures	(3)	523	(3)	556	(3)	380	(3)	489
Total	(3)	57,086	(3)	46,976	(3)	54,847	(3)	56,319

See footnotes at end of table.

TABLE 52.—*Copper-base alloys, including brass and bronze, exported from the United States,*[1] *by classes*—Continued

	1958		1959		1960		1961		1962	
	Short tons	Value, thousands	Short tons	Value, thousands	Short tons	Value, thousands	Short tons	Value, thousands	Short tons	Value, thousand
Bars, rods, and shapes	565	$772	515	$804	571	$927	658	$1,132	910	$1,463
Castings and forgings	245	443	136	260	276	688	502	1,014	933	2,354
Hardware	(10)	(10)	(10)	(10)	(10)	(10)	(10)	(10)	(10)	(10)
Ingots	276	505	383	898	699	1,646	469	905	343	466
Pipe fittings and valves [8]	1,528	3,454	1,691	3,851	1,400	3,391	1,398	3,416	1,376	3,384
Pipes and tubes	1,198	1,595	1,273	1,849	1,035	1,488	1,343	1,744	1,763	2,496
Plates, sheets, and strips	555	951	573	1,172	650	1,663	578	1,622	1,138	2,299
Plumbers brass goods	2,670	6,998	2,453	6,694	2,202	5,872	2,151	5,889	2,008	5,489
Powder	283	273	391	402	325	385	483	518	519	576
Scrap and other forms	28,502	10,457	29,406	12,497	122,957	52,220	116,654	52,226	36,209	15,525
Semifabricated forms, n.e.c	34	76	62	161	13	40	13	36	46	127
Welding rods and wire	709	1,382	724	1,414	794	1,588	689	1,738	785	1,845
Other copper-base-alloy manufactures	(10)	(10)	(10)	(10)	(10)	(10)	(10)	(10)	(10)	(10)
Total	36,565	26,906	37,607	30,002	130,922	69,908	124,938	70,240	46,030	36,024

[1] 1952–60 data known to be not comparable with earlier years.
[2] Beginning August 1941 castings and forgings separately classified; formerly included with "Other manufactures."
[3] Weight not recorded.
[4] Not separately classified prior to 1952; included with "Other manufactures."
[5] Not separately classified prior to 1929; included with "Ingots."
[6] Not recorded.
[7] Beginning July 1941 shapes separately classified; formerly included with "Other manufactures."
[8] Beginning January 1, 1945, valves not separately classified; included in "Industrial machinery."
[9] Weight not recorded from January through June; July through December 1, 138 tons valued at $2,841,000.
[10] Beginning January 1, 1958, not separately classified.
Source: U.S. Department of Commerce.

TABLE 53.—*Unfabricated copper-base alloy*[1] *ingots*[2]*, bars, rods, shapes, plates, and sheets exported from the United States*

Year	Short tons	Value, thousands
1926	2,377	$885
1927	1,756	649
1928	2,202	905
1929	3,814	1,598
1930	3,288	1,231
1931	1,948	525
1932	922	242
1933	582	180
1934	928	328
1935	1,164	383
1936	1,356	463
1937	8,687	2,573
1938	1,823	678
1939	6,476	1,947
1940	90,908	30,802
1941	39,497	14,558
1942	74,333	27,977
1943	98,446	38,052
1944	133,470	48,385
1945	39,807	14,071
1946	9,094	3,956
1947	12,663	7,701
1948	6,430	4,545
1949	4,287	3,081
1950	2,334	1,694
1951	3,820	2,952
1952 [3]	5,514	5,425
1953 [3]	4,453	3,569
1954 [3]	3,492	2,924
1955 [3]	2,175	3,201
1956 [3]	2,333	3,844
1957 [3]	1,747	2,944
1958 [3]	1,396	2,229
1959 [3]	1,471	2,874
1960 [3]	1,920	4,236
1961 [3]	1,705	3,659
1962 [3]	2,391	4,228

[1] Includes brass and bronze.
[2] Ingots not separately classified before 1929, included with scrap.
[3] 1952–62 data known to be not strictly comparable with earlier years.
Source: U.S. Department of Commerce.

TABLE 54.—*Copper sulfate (blue vitriol) exported from the United States*

Year	Short tons	Value, thousands
1926	2,399	$231
1927	3,103	321
1928	4,333	455
1929	3,210	368
1930	2,531	253
1931	3,595	277
1932	2,066	115
1933	1,375	93
1934	1,929	129
1935	2,254	142
1936	5,367	343
1937	11,764	1,212
1938	15,625	1,229
1939	14,620	1,157
1940	27,740	2,294
1941	34,511	2,951
1942	35,082	3,444
1943	30,367	3,075
1944	28,922	2,844
1945	34,967	3,419
1946	41,345	4,077
1947	34,021	4,100
1948	42,135	6,515
1949	31,717	4,321
1950	30,149	4,151
1951	43,129	8,754
1952	43,421	8,483
1953	32,659	6,250
1954	29,762	5,781
1955	37,382	8,382
1956	30,177	8,036
1957	33,644	6,534
1958	7,248	1,176
1959	2,672	675
1960	14,841	3,377
1961	7,575	1,542
1962	1,916	456

Source: U.S. Department of Commerce.

TABLE 55.—*Imports of copper into the United Kingdom, by countries, short tons*

Country	1951			1952		
	Blister	Electrolytic	Fire-refined	Blister	Electrolytic	Fire-refined
Belgium		15, 735			31, 061	
Canada		51, 536			41, 915	5
Chile	3, 864		6, 046	1, 820		3, 727
Republic of the Congo					66	
West Germany		18, 472			17, 922	
Northern Rhodesia	142, 725	86, 424		189, 221	85, 548	
Norway		1, 428			1, 483	
Peru						
Republic of South Africa					2	1, 680
United States		71, 852			49, 974	
Other countries	54	19	150		4, 153	
Total	146, 643	245, 466	6, 196	191, 041	232, 124	5, 412
	1953			1954		
Belgium		17, 339			16, 046	
Canada		53, 526			72, 240	
Chile				7, 103	21, 492	12, 116
Republic of the Congo		2, 716			9, 182	
West Germany		22, 883			12, 876	
Northern Rhodesia	121, 037	125, 663		139, 626	125, 694	
Norway		549			1, 327	
Peru		11			3, 044	
Republic of South Africa			5, 694			2, 134
United States		22, 734	1, 949		16, 811	4, 732
Other countries	635	1, 831	13	1, 829	1, 500	693
Total	121, 672	247, 252	7, 656	148, 558	280, 212	19, 675
	1955			1956		
Belgium		7, 577			5, 473	
Canada		71, 432			65, 706	
Chile	8, 000	30, 663	29, 100		48, 648	37, 392
Republic of the Congo		5, 684			8, 624	
West Germany		8, 679			1, 887	
Northern Rhodesia	124, 505	117, 784		116, 872	144, 803	
Norway		3, 147			548	
Peru		6, 356			2, 959	
Republic of South Africa			1, 520		271	953
United States		28, 170	3, 839		10, 599	
Other countries	3, 994	6, 890	349	2, 453	1, 075	266
Total	136, 499	286, 382	34, 808	119, 325	290, 593	38, 611

TABLE 55.—*Imports of copper into the United Kingdom, by countries, short tons*—Continued

Country	1957			1958		
	Blister	Electrolytic	Fire-refined	Blister	Electrolytic	Fire-refined
Belgium	-----	675	-----	-----	1, 337	-----
Canada	-----	85, 795	-----	-----	89, 201	-----
Chile	3, 298	45, 210	40, 634	16, 072	24, 212	49, 840
Republic of the Congo	-----	3, 359	-----	-----	3, 920	-----
West Germany	-----	84	-----	-----	-----	-----
Northern Rhodesia	124, 624	118, 094	-----	90, 583	120, 400	-----
Norway	-----	1, 226	-----	-----	1, 858	-----
Peru	-----	2, 671	-----	-----	2, 873	-----
Republic of South Africa	-----	226	533	-----	-----	840
United States	-----	82, 629	10, 640	-----	104, 767	6, 517
Other countries	1, 633	561	-----	729	141	336
Total	129, 555	340, 530	51, 807	107, 384	348, 709	57, 533
	1959			1960		
Belgium	-----	452	-----	-----	1, 688	-----
Canada	-----	81, 576	-----	-----	115, 246	-----
Chile	32, 422	23, 228	46, 984	47, 759	29, 884	50, 371
Republic of the Congo	-----	4, 541	-----	-----	3, 134	-----
West Germany	-----	6	-----	-----	2, 658	-----
Northern Rhodesia	74, 744	182, 143	-----	76, 371	200, 865	-----
Norway	-----	3, 455	-----	-----	2, 464	-----
Peru	-----	588	-----	693	2, 552	-----
Republic of South Africa	-----	280	5, 683	-----	-----	3, 349
United States	-----	31, 057	1, 959	1, 120	66, 009	6, 213
Other countries	5	627	-----	17	4, 893	139
Total	107, 171	327, 953	54, 626	125, 960	429, 393	60, 072
	1961			1962		
Belgium	-----	815	-----	-----	772	-----
Canada	-----	112, 890	-----	-----	98, 240	-----
Chile	50, 402	21, 506	33, 861	50, 250	36, 541	29, 215
Republic of the Congo	-----	4, 043	-----	-----	3, 080	-----
West Germany	34	547	-----	-----	22, 789	-----
Northern Rhodesia	80, 560	202, 470	829	43, 194	213, 078	1, 540
Norway	-----	1, 463	-----	-----	342	-----
Peru	22, 408	-----	-----	23, 024	6, 718	-----
Republic of South Africa	-----	101	593	-----	-----	1, 960
United States	1, 025	49, 276	4, 481	-----	53, 275	1, 063
Other countries	3	4, 825	19	-----	5, 282	275
Total	154, 432	397, 936	39, 783	116, 468	440, 117	34, 053

TABLE 56.—*Exports of refined copper from Canada, short tons*

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Australia		1,707		1,126	3,993		1,007	56	280	1,847	2,239	1,288
Belgium								1,008	3,738	4,481	5,745	4,951
Brazil	2,688	2,835	2,345	5,751	496	257	1,541	1,994	334	302	1,169	38
France	5,700	8,537	2,940	7,728	8,957	9,860	12,502	20,806	10,038	12,880	15,885	13,928
West Germany	1,258	480	84	404	937		1,315	14,051	9,510	12,940	13,355	11,907
India	3,649	2,582		2,211	1,724	3,972	3,968	11,652	7,619	10,908	673	3,440
Italy	2,451				112		1,092	6,137	1,400	2,516	3,497	2,160
Japan							2	276	110	4,861	11,207	2,937
Netherlands			22		196		341	9,089	2,939	5,318	8,992	4
Sweden	3,998	1,786		56	25		3,381	785	224	2,522	4,894	5,376
Switzerland	224		224	168	308		1,567	2,380		843	674	4
United Kingdom	51,918	41,643	51,384	77,867	69,198	63,990	84,672	90,927	83,487	110,540	115,859	93,693
United States	28,843	52,630	74,655	60,814	67,071	96,747	86,300	63,865	101,501	104,602	64,189	76,506
Other	1,103	1,475	340	5	182	18	1,106	1,612	1,257	3,506	17,869	6,811
Total	101,832	113,675	131,994	156,130	153,199	174,844	198,794	224,638	222,437	278,066	266,247	223,043

TABLE 57.—*Exports of copper from Chile, short tons*

Destination	1951				1952			
	Refined		Standard (blister)	Total	Refined		Standard (blister)	Total
	Electrolytic	Fire-refined			Electrolytic	Fire-refined		
Argentina								
Austria	55	402		457	1,246	16,480		17,726
Belgium		419		419				
Brazil	6,261	1,245		7,506	4,309	88		4,397
France	5,376	11,292		16,668		3,869	551	4,420
West Germany	115	3,349	5,520	8,984		1,404	11,459	12,863
Italy	5,173	1,023	10,626	16,822	7,543	364	9,713	17,620
Netherlands	83	56		139				
Spain						2,195		2,195
Sweden	4,742	13		4,755	22	551		573
Switzerland		924		924	220	650		870
United Kingdom		6,803	4,219	11,022		2,968	1,456	4,424
United States	106,335	113,878	43,980	264,193	130,748	133,951	56,314	321,013
Other	2,304	2,101	224	4,629	2,218	468		2,686
Total	130,444	141,505	64,569	336,518	146,306	162,988	79,493	388,787
	1953				1954			
Argentina						1,102		1,102
Austria								
Belgium					2,533			2,533
Brazil	2,379		165	2,544				
France	110			110	100			100
West Germany		323	11,791	12,114	4,646	276	15,093	20,015
Italy	4,575		168	4,743	11,234	56	10,299	21,589
Netherlands					17,075	112		17,187
Spain							7,984	7,984
Sweden					1,875			1,875
Switzerland						1,367		1,367
United Kingdom					53,107	15,850	5,096	74,053
United States	70,061	104,655	126,818	301,534	33,607	71,026	105,683	210,316
Other	55	20		75	3,512	169		3,681
Total	77,180	104,998	138,942	321,120	127,689	89,958	144,155	361,802
	1955				1956			
Argentina	2,205			2,205	2,203			2,203
Austria								
Belgium	1,427	56		1,483	224			224
Brazil	44	330		374	45	202		247
France	165			165	1,100	1,653		2,753
West Germany	9,314	4,867	26,499	40,680	17,635	3,516	27,293	48,444
Italy	18,833	667	15,643	35,143	6,594	5,924	7,008	19,526
Netherlands	29,721	409	392	30,522	30,010	2,417	1,427	33,854
Spain			1,764	1,764			4,960	4,960
Sweden	1,167			1,167	336			336
Switzerland	224	2,603		2,827		2,911		2,911
United Kingdom	49,855	39,387	7,941	97,183	40,366	40,376	783	81,525
United States	2,134	64,449	141,059	207,642	1,140	40,557	138,169	179,866
Other	3,304	504		3,808	1	84		85
Total	118,393	113,272	193,298	424,963	99,654	97,640	179,640	376,934

TABLE 57.—*Exports of copper from Chile, short tons*—Continued

Destination	1957				1958			
	Refined		Standard (blister)	Total	Refined		Standard (blister)	Total
	Electrolytic	Fire-refined			Electrolytic	Fire-refined		
Argentina	660			660				
Austria								
Belgium								
Brazil	32			32				
France	1,654	1,654		3,308				
West Germany	41,032	5,432	26,287	72,751	31,099	6,467	45,393	82,959
Italy	17,204	7,757	7,675	32,636	11,172	3,829	4,491	19,492
Netherlands	48,288	3,471	3,946	55,705	38,901			38,901
Spain			10,345	10,345			9,285	9,285
Sweden	11,248			11,248	8,778			8,778
Switzerland		2,941		2,941	132	3,877		4,009
United Kingdom	43,367	44,647	3,644	91,658	23,427	43,774	16,672	83,873
United States	4,376	4,238	207,530	216,144	61	250	200,116	200,427
Other	305	450		755	117	112		229
Total	168,166	70,590	259,427	498,183	113,687	58,309	275,957	447,953
	1959				1960			
Argentina	138			138				
Austria								
Belgium	2,326			2,326	1,260	1,456		2,716
Brazil								
France	6,671			6,671	16,590	276		16,866
West Germany	32,667	9,055	42,159	83,881	25,163	16,833	49,577	91,573
Italy	16,905	12,076	1,291	30,272	12,807	11,620	2,690	27,117
Netherlands	58,554	1,755	56	60,365	49,677	2,632		52,309
Spain			3,426	3,426				
Sweden	11,823			11,823	20,987	56	642	21,685
Switzerland		1,597		1,597				
United Kingdom	23,057	50,128	33,690	106,875	24,704	48,262	45,882	118,848
United States	13,993	2,804	201,417	218,214	600	1,251	201,999	203,850
Other	6	944		950				
Total	166,140	78,359	282,039	526,538	151,788	82,386	300,790	534,964
	1961				1962			
Argentina		460		460	3,208	1,174		4,382
Austria								
Belgium	924	3,256		4,180	111	2,273	8,618	11,002
Brazil		1,079		1,079	10,786	9,792		20,578
France	10,442	332		10,774	10,447	1,054		11,501
West Germany	22,766	17,396	46,795	86,957	27,732	12,562	39,358	79,652
Italy	11,872	12,273	1,498	25,643	16,570	19,448	771	36,789
Netherlands	67,384	3,792		71,176	52,297	3,419	84	55,800
Spain								
Sweden	22,871	604	2,405	25,880	24,182	1,513	2,104	27,799
Switzerland								
United Kingdom	25,536	34,736	52,938	113,210	36,021	28,316	44,841	109,178
United States	400	1,750	229,256	231,406	883		228,771	229,654
Other		1,243		1,243		3,010		3,010
Total	162,195	76,921	332,892	572,008	182,237	82,561	324,547	589,345

Republic of the Congo.—Belgium is the principal destination of copper from the Republic of the Congo. Except for 1959, France was second and Italy third. Table 58 shows substantial quantities shipped to the Beira and Lobito depots in 1959 and 1960. It is believed that most of this copper was shipped ultimately to Belgium.

Federation of Rhodesia and Nyasaland.—In all but 4 of the last 10 years, Rhodesia has exported more copper than any other country. The United Kingdom received most of the shipments; the United States was second from 1951 until 1958 when it was displaced by West Germany. Other European countries have taken most of the remainder. Shipments by country of destination are given in table 59.

PRICES

U.S. copper prices are reported in terms of electrolytic copper, cents per pound, f.o.b. refinery, and cover the ordinary forms of wire bars and ingot bars. Small differentials exist for standard ingots, slabs, and billets, depending on dimensions and quality, and for cakes, depending on weight and dimensions. There is also a primary price of producers that before 1954 was quoted as-delivered-Connecticut Valley. In mid-1950, one producer began selling

TABLE 58.—*Exports of copper from Republic of the Congo, short tons*

Destination	1951	1952	1953	1954	1955
Algeria	2, 205	3, 307	3, 197	3, 386	3, 316
Australia	18, 638	4, 751	---	---	---
Belgium	132, 267	131, 126	150, 558	159, 175	171, 465
France	34, 932	53, 780	37, 168	42, 846	41, 945
West Germany	---	---	---	---	56
India	2, 389	10, 453	3, 846	6, 534	2, 115
Italy	3, 401	13, 470	11, 336	10, 949	11, 690
Netherlands	---	---	748	---	---
Republic of South Africa	6, 385	6, 548	3, 908	3, 422	5, 216
United Kingdom	---	66	4, 480	5, 638	5, 851
United States	---	---	7, 685	16, 362	13, 141
Beira Depot	---	---	---	---	---
Lobito Depot	---	---	---	---	---
Other	2, 286	2, 239	5, 379	1, 653	148
Total	202, 503	225, 740	228, 305	249, 965	254, 943
	1956	1957	1958	1959	1960 [1]
Algeria	1, 102	291	---	---	---
Australia	---	---	---	---	---
Belgium	187, 855	175, 097	173, 454	54, 057	38, 732
France	46, 414	41, 189	39, 389	34, 661	19, 072
West Germany	168	3, 365	89	4, 428	1, 254
India	1, 802	3, 205	1, 524	---	---
Italy	14, 989	19, 365	22, 898	39, 684	15, 006
Netherlands	364	1, 896	---	5, 455	2, 976
Republic of South Africa	4, 508	6, 227	8, 631	8, 722	3, 845
United Kingdom	8, 007	3, 639	4, 518	3, 426	1, 680
United States	13, 929	11, 263	13, 390	5, 200	---
Beira Depot	---	---	---	90, 863	47, 697
Lobito Depot	---	---	---	63, 445	33, 301
Other	494	1, 091	667	764	1, 213
Total	279, 632	266, 628	264, 560	310, 705	164, 776

[1] January–September.

copper priced as-delivered to United States consuming points; in 1954 other producers changed to this policy, and it became representative of the industry. Shipment costs were 0.125 cent per pound for American Metal Market quotations and 0.300 cent per pound for E&MJ Metal and Mineral Market prices. In 1957 the differentials between delivered and f.o.b. prices were increased to 0.175 and 0.400 cent per pound, respectively. Beginning with 1955 custom smelters of copper began quoting their price separately (table 60). Table 61 shows average weighted prices of domestic copper deliveries by selling agencies.

The U.S. price for copper in 1929 was the highest for any year after 1920, continuing high until April 1930. The price had been stabilized in April 1929 at 17.775 cents per pound by Copper Exporters, Inc. The worldwide industrial depression in 1930 brought a severe decline in copper consumption and a nearly compensating curtailment in production, but it did not prevent an increase in stocks. The price of copper fell from a little less than 18 cents in April 1930 to less than 10 cents in October, and in 1932 to the lowest average for all time—5.7 cents per pound. A tariff of 4 cents a pound was placed on imports effective June 21, 1932.

TABLE 59.—*Exports of copper from Federation of Rhodesia and Nyasaland, short tons*

Destination	1951				1952			
	Ore and concentrate	Blister	Electrolytic	Total	Ore and concentrate	Blister	Electrolytic	Total
Argentina								
Australia		3,363		3,363		5,936	4,648	10,584
Belgium		11,202		11,202		19,993	420	20,413
Brazil								
France								
West Germany		16,294		16,294		7,952		7,952
India		392		392		560	672	1,232
Italy								
Japan								
Netherlands						3,125		3,125
Republic of South Africa			13,309	13,309			14,410	14,410
Spain								
Sweden			16,801	16,801	6,761		15,006	21,767
Switzerland			106	106				
U.S.S.R.								
United Kingdom		139,195	85,969	225,164		192,278	87,543	279,821
United States		38,866		38,866		27,294		27,294
Other			124	124		4	225	229
Total		209,312	116,309	325,621	6,761	257,142	122,924	386,827

Destination	1953				1954			
Argentina							1,100	1,100
Australia							8,946	8,946
Belgium		10,917	4,900	15,817		2,073	1,511	3,584
Brazil								
France			3,497	3,497			6,802	6,802
West Germany		10,585		10,585		15,363	448	15,811
India		112	39	151		829	169	998
Italy			4,647	4,647			14,550	14,550
Japan								
Netherlands			336	336		4,699	3,785	8,484
Republic of South Africa			7,444	7,444		536	11,385	11,921
Spain								
Sweden			14,102	14,102			22,145	22,145
Switzerland						168	1,650	1,818
U.S.S.R.								
United Kingdom		140,214	126,919	267,133		143,941	125,953	269,894
United States		86,580		86,580		62,165	1,232	63,397
Other		6,358	47	6,405		560	350	910
Total		254,766	161,931	416,697		230,334	200,026	430,360

Destination	1955				1956			
Argentina			1,137	1,137				
Australia							672	672
Belgium		1,303	4,259	5,562		1,170	5,943	7,113
Brazil							2,184	2,184
France		30	15,334	15,364			13,418	13,418
West Germany		21,413	2,290	23,703	461	25,457	2,662	28,580
India						1,284	6,352	7,636
Italy		336	11,585	11,921		2,505	14,158	16,663
Japan					129			129
Netherlands		337	2,099	2,436	45	728	448	1,221
Republic of South Africa		115	10,546	10,661	5,073		15,033	20,106
Spain						1,848		1,848
Sweden			16,432	16,432	236		16,980	17,216
Switzerland			560	560			112	112
U.S.S.R.								
United Kingdom		110,734	117,167	227,901		123,912	146,439	270,351
United States		59,350	7,277	66,627	1,452	14,003	16,210	31,665
Other		28	488	516			282	282
Total		193,646	189,174	382,820	7,396	170,907	240,893	419,169

TABLE 59.—*Exports of copper from Federation of Rhodesia and Nyasaland, short tons*—Continued

Destination	1957				1958			
	Ore and concentrate	Blister	Electrolytic	Total	Ore and concentrate	Blister	Electrolytic	Total
Argentina	-----	-----	5,893	5,893	-----	-----	9,743	9,743
Australia	-----	-----	1,681	1,681	-----	-----	-----	-----
Belgium	1,627	56	7,088	8,771	1	101	6,124	6,226
Brazil	-----	-----	10,098	10,098	-----	-----	8,386	8,386
France	-----	1,056	16,361	17,417	-----	1,779	24,548	26,327
West Germany	-----	39,914	7,674	47,588	5,601	35,788	10,420	51,809
India	-----	1,587	24,944	26,531	-----	2,265	22,764	25,029
Italy	-----	2,547	10,225	12,772	-----	448	11,789	12,237
Japan	2,498	2,128	-----	4,626	1,333	-----	-----	1,333
Netherlands	8	7,396	7,941	15,345	8	5,905	11,495	17,408
Republic of South Africa	5,053	175	19,182	24,410	5,480	204	12,357	18,041
Spain	6,000	2,958	-----	8,958	2,250	560	-----	2,810
Sweden	20	-----	14,450	14,470	2,262	-----	17,512	19,774
Switzerland	-----	-----	-----	-----	-----	-----	-----	-----
U.S.S.R.	-----	-----	-----	-----	-----	-----	-----	-----
United Kingdom	-----	116,334	110,404	226,738	-----	99,560	133,096	232,656
United States	880	17,558	29,683	48,121	732	15,584	17,926	34,242
Other	-----	-----	310	310	-----	336	963	1,299
Total	16,086	191,709	265,934	473,729	17,667	162,530	287,123	467,320
	1959				1960[1]			
Argentina	-----	-----	4,756	4,756	-----	-----	10,940	10,940
Australia	-----	-----	1,122	1,122	-----	-----	-----	-----
Belgium	10,009	6,720	3,724	20,453	-----	1,344	616	1,960
Brazil	-----	-----	3,371	3,371	-----	-----	4,669	4,669
France	-----	402	21,021	21,423	-----	140	22,249	22,389
West Germany	-----	49,438	30,606	80,044	-----	39,533	33,484	73,017
India	-----	8,715	21,181	29,896	-----	13,622	15,629	29,251
Italy	-----	6,048	21,097	27,145	-----	5,573	24,873	30,446
Japan	18,505	-----	12,252	30,757	21,179	-----	11,965	33,144
Netherlands	-----	5,057	17,179	22,236	-----	-----	1,792	1,792
Republic of South Africa	6,756	194	8,627	15,577	4,129	328	9,329	13,786
Spain	-----	2,489	402	2,891	-----	582	-----	582
Sweden	48	-----	26,072	26,120	40	672	16,660	17,372
Switzerland	-----	224	4,341	4,565	-----	532	8,841	9,373
U.S.S.R.	-----	5,972	16,800	22,772	-----	10,640	6,442	17,082
United Kingdom	-----	78,770	188,159	266,929	910	55,980	134,815	191,705
United States	-----	14,554	13,460	28,014	-----	-----	14,304	14,304
Other	-----	816	2,541	3,357	240	1,456	8,677	10,373
Total	35,318	179,399	396,711	611,428	26,498	130,402	325,285	482,185

[1] January-September.

Prices continued low, almost without exception, until after World War II. Despite the strain on supplies of copper in 1941, large producers maintained a price of 12 cents for electrolytic copper delivered Connecticut Valley (11.87 f.o.b. refinery) until August 12, when a ceiling of 12 cents was established. In 1942 bonus payments for overquota production were established.

Ceiling prices were raised, effective June 3, 1946, to 14.375 cents per pound, delivered Connecticut Valley, and on November 10 all price controls were removed. The price rose immediately to 17.5 cents and by the end of the year to 19.5 cents, the highest since April 1929. Prices continued to advance in 1947 and into 1948; the excise tax was suspended in April 1947 and the Premium Price Plan was ended June 30, 1947.

The postwar period was one of continuing demand, except for part of 1949. An upsurge in prices followed the outbreak of hostilities in Korea in June 1950, and the quotation for electrolytic copper was 24.5 cents a pound at the end of the year. The excise tax at 2 cents a pound was reimposed July 1, 1950—see the section on tariff. In 1951 the average quoted price was 24.5 cents a pound for electrolytic copper, delivered Connecticut Valley, the highest in any year since 1918. Ceiling prices were established by the General Ceiling Price Regulation effective January 26, 1951, at 24.5 cents, the price at which primary producers had been selling electrolytic copper.

Mobilization plans in foreign countries called for increased quantities of copper, and world consumption in 1951 was rising. Efforts of all countries to obtain sufficient supplies of metal led to increasing world prices. Rumors stated that prices up to 60 cents a pound were paid for copper on the European continent. The United States was unable to increase imports or even maintain them at the 1950 rate, and an agreement was made in May with Chile whereby an additional 3 cents more than the U.S. ceiling would be paid for Chilean copper sold in the United States. Later on, all copper refined from imported materials was paid for on the

TABLE 60.—*Monthly average copper prices of customer smelters, cents per pound, delivered*[1]

Month	1955	1956	1957	1958	1959	1960	1961	1962
January	30.14	50.20	34.86	24.55	29.43	35.00	29.29	31.00
February	33.00	52.13	32.22	23.56	30.36	35.00	29.00	31.00
March	33.26	53.38	30.93	23.33	33.14	33.40	29.00	31.00
April	36.00	49.00	31.30	23.65	32.84	33.00	29.00	31.00
May	36.00	44.14	30.17	23.85	32.00	33.00	30.48	31.00
June	36.00	40.00	29.60	25.48	31.48	33.00	31.00	31.00
July	36.00	38.19	28.40	26.23	29.52	33.00	31.00	31.00
August	37.74	39.34	27.87	26.52	30.06	33.00	31.00	31.00
September	48.00	39.00	25.91	26.35	33.00	33.00	31.00	31.00
October	46.07	37.14	25.72	28.64	[2] 33.00	30.35	31.00	31.00
November	45.87	35.95	25.44	29.84	([2])	30.00	31.00	31.00
December	49.13	35.47	25.26	28.86	35.00	30.00	31.00	31.00
Average	38.93	42.83	28.97	25.91	31.48	32.65	30.31	31.00
High	50.25	54.50	35.00	30.00	35.00	35.00	31.00	31.00
Low	30.00	35.00	25.00	23.00	29.00	30.00	29.00	31.00

[1] Not reported separately before September 12, 1955.
[2] Nominal.

Source: American Metal Market.

basis of 27.5 cents a pound. Maintenance-of-production contracts based on production costs were granted to avoid loss of production from high-cost mines, and additional sets of prices were established. Chile abrogated its agreement in May 1952 and embargoed exports to the United States. On May 21 importers were authorized to pay higher prices on foreign copper and to pass on to consumers 80 percent of costs above 27.5 cents, and shipments to the United States were resumed. Early in June the increases were permitted to be calculated at more than 24.5 cents instead of 27.5.

Supplies became more plentiful in 1953, and price controls were abandoned in February. By the end of April domestic and foreign prices, except Chilean, were each about 30 cents a pound. The price for Chilean copper from the three large U.S. mines was held, under Chilean Government direction, at 35.5 cents a pound in Chile—about 36.5 cents in the United States—until December. Despite accelerated rates of production in 1954 and 1955, the supply of copper was inadequate to meet increased demand. Gains in new productive capacity were offset by serious work stoppages in both years, and by August 1955 copper was quoted at 43 cents a pound—the highest in 90 years. Custom smelters, whose price was quoted separately for the first time in 1955, were quoting 50 cents a pound in September and 50.25 cents in December.

Prices continued to advance in 1956; by February primary producers were quoting 46 cents a pound, and custom-smelter quotations ranged from 50.5 to 51.5 cents; for a short time custom smelters quoted 55 cents. A downward trend began with a 4-cent decrease in late March and extended through early July, when the price was 37.5 cents. Reduced prices abroad and the declining custom smelter price exerted pressure upon primary producers, and their price was lowered to 40 cents a pound by mid-July, the first reduction in more than two years. In the latter half of 1956 a slight slackening in industrial demand and a high rate of mine production indicated development of an oversupply, and the price was further reduced to 36 cents. At the end of the year custom smelters were quoting 35.5 to 36 cents.

Despite efforts by most copper producers in 1957 to bring supply in balance with demand by curtailed output, the industry was faced with oversupply throughout the year. In slightly more than seven months the producer price dropped from 36 cents to 27 cents, the lowest since February 1953. Custom-smelter prices declined also; by the end of 1957 the quotation was 25.5 cents. Fluctuations in prices in 1958 resulted in a 13-percent decrease in the annual average primary producer price. By late October producers were quoting 29 cents, and in late November custom smelters were on the 29-cent basis.

Operations at most of the principal copper properties were halted by the longest strike in history which began in August 1959 and continued into 1960. Mine production was the lowest annual total since 1949, and the price rose to 33 cents on November 12. This price held until October 12, 1960, when it fell 3 cents a pound to 30 cents. A custom smelter posted a 33-cent price on August 31 but withdrew the price on October 23 because of the strikes. About mid-March 1960 custom smelters established a 33-cent price, which was reduced to 31 cents on October 3 and to 30

TABLE 61.—*Average yearly quoted prices of electrolytic copper, average weighted prices of refined copper delivered in the United States, including prices adjusted by the wholesale index, and for spot copper at London, cents per pound*

Year	Electrolytic domestic f.o.b. refinery [1]	Electrolytic domestic f.o.b. refinery [2]	Electrolytic export f.o.b. refinery [2]	Refined copper: Weighted, f.o.b. refinery [3]	Refined copper: Adjusted by wholesale index [4]	London spot copper [2 5]
1926	13. 93	13. 795	(6)	14. 0	25. 5	14. 200
1927	13. 05	12. 920	(6)	13. 1	25. 0	13. 468
1928	14. 68	14. 570	(6)	14. 4	27. 2	15. 040
1929	18. 23	18. 107	(6)	17. 6	33. 8	18. 413
1930	13. 11	12. 982	(6)	13. 0	27. 5	13. 355
1931	8. 24	8. 116	(6)	9. 1	22. 8	8. 522
1932	5. 67	5. 555	(6)	6. 3	17. 7	5. 629
1933	7. 15	7. 025	6. 713	6. 4	17. 7	6. 877
1934	8. 53	8. 428	7. 271	8. 0	19. 5	7. 496
1935	8. 76	8. 649	7. 538	8. 3	18. 9	7. 753
1936	9. 58	9. 474	9. 230	9. 2	20. 8	9. 465
1937	13. 27	13. 167	13. 018	12. 1	25. 6	13. 097
1938	10. 10	10. 000	9. 695	9. 8	22. 8	9. 912
1939	11. 07	10. 965	10. 727	10. 4	24. 6	7 10. 066
1940	11. 40	11. 296	10. 770	11. 3	26. 3	(8)
1941	11. 87	11. 797	10. 901	11. 8	24. 7	(8)
1942	11. 87	11. 775	11. 684	11. 8	21. 9	(8)
1943	11. 87	11. 775	11. 700	11. 8	20. 9	(8)
1944	11. 87	11. 775	11. 700	11. 8	20. 7	(8)
1945	11. 87	11. 775	11. 700	11. 8	20. 4	(8)
1946	13. 92	13. 820	14. 791	14. 4	21. 8	(8)
1947	21. 15	20. 958	21. 624	20. 9	25. 7	(8)
1948	22. 20	22. 038	22. 348	21. 7	24. 7	(8)
1949	19. 36	19. 202	19. 421	19. 7	23. 6	(8)
1950	21. 46	21. 235	21. 549	20. 8	24. 0	(8)
1951	24. 37	24. 200	26. 258	24. 2	25. 0	(8)
1952	24. 37	24. 200	31. 746	24. 2	25. 7	(8)
1953	28. 92	28. 798	30. 845	28. 7	31. 0	(9)
1954	29. 82	29. 694	29. 889	29. 5	31. 8	10 31. 20
1955	37. 39	37. 491	39. 115	37. 3	40. 0	10 43. 83
1956	41. 88	41. 818	40. 434	42. 5	44. 2	10 41. 03
1957	29. 99	29. 576	27. 157	30. 1	30. 4	10 27. 36
1958	26. 13	25. 764	24. 123	26. 3	26. 2	10 24. 79
1959	30. 82	31. 182	28. 892	30. 7	30. 5	10 29. 80
1960	32. 16	32. 053	29. 894	32. 1	31. 9	10 30. 81
1961	30. 14	29. 921	27. 919	30. 0	29. 9	10 28. 73
1962	30. 82	30. 600	28. 514	30. 8	30. 6	10 29. 33

[1] American Metal Market.
[2] E&MJ Metal and Mineral Markets.
[3] Reported by copper selling agencies. 1951-53 includes substantial quantity of copper sold delivered to consumers; beginning in 1954 all deliveries were made on that basis and the delivered price is reflected in averages shown.
[4] Weighted price divided by Bureau of Labor Statistics wholesale price index (1947-49=100).
[5] Based on average rates of exchange by Federal Reserve Board.
[6] Not available. Export quotation established after imposition of tariff in 1932.
[7] Average for 8 months; thereafter, London Metal Exchange dealings suspended.
[8] No quotations.
[9] London Metal Exchange trading resumed August 5, but official quotation not available.
[10] Metal Bulletin (London).

cents on October 12. On May 19, 1961, the price of copper was established at 31 cents per pound, delivered, and remained at that level through 1962.

The average weighted price of copper deliveries reported by copper selling agencies covers copper produced in the United States and delivered here and abroad and copper produced abroad and delivered in the United States. It excludes copper both produced and delivered abroad and deliveries to domestic consumers. Also it excludes deliveries of foreign copper to Metals Reserve Co. and bonus payments, applicable from February 1942 to June 30, 1947.

In the years immediately preceding World War II, London spot quotations of copper were slightly below those in the United States. Transactions on the London Metal Exchange (LME) were suspended at the outbreak of the war, and in December 1939 the price for electrolytic copper delivered was fixed by the British Ministry of Supply at £62 per long ton (12.29 cents per pound). Statutory maximum prices were revoked as of November 15, 1949.

Increases in the first half of 1950 raised the British price about 1 cent higher than the United States price. A £16 per ton drop in August, however, made the United Kingdom price temporarily lower than the U.S. price. On August 22 the price was £202 (25.25 cents). On August 23 the price dropped to £186 (23.25 cents) but the £202 quotation was reinstated effective September 1. By May 1951 the official maximum price was £234 (29.25 cents); a drop of £7 to £227 (28.375 cents) was announced in September by the British Ministry of Materials, which took over metal-purchasing functions from the Ministry of Supply in July.

In May 1952 the British Government began to base its selling price of metals and other raw materials on New York market prices plus a differential for freight, and other charges. By June 16 the official maximum price was £281 (35.125 cents), and on June 20 an agreement with producers was announced to purchase copper at 33 cents a pound. The British Ministry of Materials price was £285 (35.625 cents) on July 31, and British purchases from producers were 33.5 cents a pound f.a.s. New York, beginning August 1. Selling prices on the European Continent were reported to be about this level.

Free trading in copper on the London Metal Exchange was resumed August 5, 1953, after a lapse of nearly 14 years. The British Ministry of Metals continued to handle sales of copper until May 31, 1954. World supplies of copper temporarily failed to cover requirements in the second half of the year, and this, combined with the removal of the influence of the Government broker, caused widely fluctuating prices on the LME. The price rose to a record high in October—£310 per long ton (38.75 cents a pound). The British Ministry of Materials was dissolved August 16, and its remaining functions were transferred to the Board of Trade.

Prices on the LME substantially exceeded those in the United States throughout 1955. By August the price had reached £400 (50 cents), and in mid-December was a record high of £405 (50.625 cents); it dropped to 50 cents at the end of the month. On March 6, 1956, the price rose to a new record of £434 to £437 (54.25 to 54.625 cents). The price dropped the equivalent of 6 cents a pound in the latter part of March. Following a slight advance in August, prices dropped gradually to a monthly average of £273 (34.125 cents) in December 1956. By December 11, 1957, the price had dropped to £175 10s. (21.9 cents)—the lowest since June 5, 1950, when the Government-controlled price was £170 (21.25 cents). On November 6, 1958, following increases from February on, the LME price was £260 (32.5 cents). During the spring and summer of 1960 the price was equivalent to 30 or 31 cents a pound. Corresponding to the decrease in the U.S. price, the London price fell to the equivalent of 27.89 cents in October.

On May 6, 1955, the Roan Antelope Copper Mines, Ltd., and the Mufulira Copper Mines, Ltd., large copper producers in Northern Rhodesia, announced that effective May 9 they would offer copper at a fixed basic price of £280 a long ton (35 cents per pound), c.i.f. United Kingdom, to those of their consumers who were willing and able to instill a degree of stability into resale prices of copper and brass products. Prices were fixed for 30 days, then they were to be fixed for another definite period, and in June the Rhodesian Selection Trust Co., (RST) representing the two producers, announced that the price of £280 would continue, subject to change on 24 hours notice. In early September the RST price was raised to £360 (45 cents), and on February 27, 1956, to £385 (48.125 cents). This price held until April 30, when it was reduced to £350 (43.75 cents); it was further lowered to £320 (40 cents) on May 28, again on June 18 to £300 (37.5 cents), and on July 2 to £275 (34.375 cents). On August 1, the price was increased to £300 and reduced on October 15 to £280 (35 cents), which equaled the original price. Effective October 24, the price was cut to £265 (33.125 cents); rose to £280 on November 12; and was lowered to £270 (33.75 cents) on December 17. The RST continued to reduce the price in 1957; on February 1 to £250 (31.25 cents); February 19 to £240 (30 cents); June 17, £230 (28.75 cents); July 1, £220 (27.5 cents); August 12, £210 (26.25 cents); September 5, £200 (25 cents); and on September 19 to £190 (23.75 cents). The RST group announced that, effective October 7, it would price copper on the LME price basis; this changeover ended the dual pricing of Rhodesian copper that had been in effect for more than two years.

STOCKS

Producers stocks include refined copper, blister copper, and materials in process of refining (table 62). During the depression years of the 1930's when consumption was low, stocks of refined copper rose substantially. In the latter part of 1939 demand for copper increased due to war needs and stocks fell 47 percent by yearend. Requirements continued high during World War II, and stocks continued to decrease. Inventories rose 60 percent by the end of 1945 following the surrender of Germany in May and the collapse of Japanese resistance in August. Fears of a flood of war stocks from war-stimulated mines throughout the world,

TABLE 62.—*Stocks of copper at primary smelting and refining plants in the United States at end of year, short tons*

Year	Refined copper [1]	Blister and materials in process of refining [2]	Year	Refined copper [1]	Blister and materials in process of refining [2]	Year	Refined copper [1]	Blister and materials in process of refining [2]
1926	73, 000	227, 500	1939	95, 500	260, 000	1952	26, 000	185, 000
1927	85, 500	200, 500	1940	91, 500	243, 000	1953	49, 000	223, 000
1928	57, 000	211, 500	1941	77, 500	240, 000	1954	25, 000	189, 000
1929	153, 000	250, 000	1942	84, 000	235, 500	1955	34, 000	201, 000
1930	307, 500	225, 000	1943	68, 500	241, 000	1956	78, 000	261, 000
1931	462, 300	174, 000	1944	81, 000	311, 000	1957	109, 000	274, 000
1932	502, 000	189, 000	1945	130, 000	331, 000	1958	48, 000	257, 000
1933	406, 500	194, 000	1946	96, 000	254, 000	1959	18, 000	253, 000
1934	284, 500	194, 500	1947	60, 000	213, 000	1960	98, 000	261, 000
1935	175, 000	236, 000	1948	67, 000	183, 000	1961	49, 000	236, 000
1936	110, 000	195, 500	1949	61, 000	261, 000	1962	71, 000	246, 000
1937	179, 000	214, 000	1950	26, 000	232, 000			
1938	181, 000	233, 000	1951	35, 000	182, 000			

[1] May include some copper refined from scrap. [2] Includes copper in transit from smelters in the United States to refineries therein.

TABLE 63.—*Stocks of copper held by fabricators at end of year, short tons*

	1934	1935	1936	1937	1938	1939	1940
Stocks of refined copper [1]	296, 439	309, 352	334, 143	362, 115	323, 439	300, 543	339, 376
Unfilled purchases of refined copper from producers	53, 927	152, 200	377, 704	86, 328	112, 254	189, 687	326, 269
Total	350, 366	461, 552	711, 847	448, 443	435, 693	490, 230	665, 645
Working stocks	151, 921	151, 346	190, 248	203, 664	182, 465	184, 833	240, 740
Unfilled sales to customers	59, 568	151, 322	378, 851	126, 760	177, 286	237, 752	414, 892
Total	211, 489	302, 668	569, 099	330, 424	359, 751	422, 585	655, 632
Excess stocks over orders booked	138, 877	158, 884	142, 748	118, 019	75, 942	67, 645	10, 013

	1941	1942	1943	1944	1945	1946	1947
Stocks of refined copper [1]	292, 973	414, 668	353, 948	334, 017	375, 618	411, 013	423, 432
Unfilled purchases of refined copper from producers	241, 335	135, 481	90, 807	53, 538	44, 100	59, 421	103, 765
Total	534, 308	550, 149	444, 755	387, 555	419, 718	470, 434	527, 197
Working stocks	291, 515	340, 547	299, 796	289, 160	268, 490	286, 418	293, 859
Unfilled sales to customers	547, 468	613, 005	465, 258	285, 654	362, 436	526, 648	338, 260
Total	838, 983	953, 552	765, 054	574, 814	630, 926	813, 066	632, 119
Excess stocks over orders booked	−304, 675	−403, 403	−320, 299	−187, 259	−211, 208	−342, 632	−104, 922

	1948	1949	1950	1951	1952	1953	1954
Stocks of refined copper [1]	379, 346	354, 992	290, 241	280, 402	331, 499	380, 881	360, 526
Unfilled purchases of refined copper from producers	81, 496	82, 793	92, 372	32, 147	32, 652	25, 022	58, 125
Total	460, 842	437, 785	382, 613	312, 549	364, 151	405, 903	418, 651
Working stocks	295, 958	285, 298	288, 392	295, 385	292, 157	309, 664	304, 619
Unfilled sales to customers	315, 944	189, 407	313, 052	303, 050	275, 608	170, 917	136, 581
Total	611, 902	474, 705	601, 444	598, 435	567, 765	480, 581	441, 200
Excess stocks over orders booked	−151, 060	−36, 920	−218, 831	−285, 886	−203, 614	−74, 678	−22, 549

	1955	1956	1957	1958	1959	1960	1961	1962
Stocks of refined copper [1]	389, 974	437, 187	430, 171	446, 358	414, 757	456, 094	461, 252	465, 592
Unfilled purchases of refined copper from producers	139, 094	117, 601	75, 627	90, 401	130, 324	75, 222	89, 745	81, 297
Total	529, 068	554, 788	505, 798	536, 759	545, 081	531, 316	550, 997	546, 889
Working stocks	314, 145	336, 217	347, 465	326, 438	340, 349	370, 055	361, 286	385, 239
Unfilled sales to customers	293, 264	183, 834	138, 631	177, 869	202, 775	126, 260	144, 344	138, 089
Total	607, 409	520, 051	486, 096	504, 307	543, 124	496, 315	505, 630	523, 328
Excess stocks over orders booked	−78, 341	34, 737	19, 702	32, 452	1, 957	35, 001	45, 367	23, 561

[1] Includes in-process metal and primary fabricated shapes. Also includes small quantities of refined copper held at refineries for fabricators accounts.
Source: U.S. Copper Association.

TABLE 64.—*Consumer stocks of copper-base scrap at yearend, gross weight, short tons*

	1940	1941	1942	1943	1944	1945	1946
Alloyed copper scrap	56, 283	57, 220	75, 111	56, 974	53, 456	57, 104	62, 622
Low-grade scrap and residues	23, 733	34, 402	34, 924	34, 567	39, 686	37, 913	38, 813
Unalloyed copper scrap	15, 606	15, 981	9, 235	10, 234	10, 660	16, 145	23, 034
Total	95, 622	107, 603	119, 270	101, 775	103, 802	111, 162	124, 469

	1947	1948	1949	1950	1951	1952	1953
Alloyed copper scrap	72, 780	59, 924	46, 011	33, 518	39, 192	59, 470	84, 065
Low-grade scrap and residues	66, 936	47, 574	34, 999	55, 778	16, 038	30, 787	55, 136
Unalloyed copper scrap	15, 830	15, 241	12, 937	16, 521	10, 735	16, 448	17, 580
Total	155, 546	122, 739	93, 947	105, 817	65, 965	106, 705	156, 781

	1954	1955	1956	1957	1958	1959	1960	1961	1962
Alloyed copper scrap	67, 047	78, 328	65, 367	62, 077	71, 264	74, 315	60, 602	58, 257	65, 841
Low-grade scrap and residues	20, 993	49, 669	60, 322	40, 206	33, 067	67, 950	58, 133	33, 362	57, 411
Unalloyed copper scrap	19, 551	23, 524	24, 511	20, 659	25, 248	30, 452	27, 610	26, 990	28, 335
Total	107, 591	151, 521	150, 200	122, 942	129, 579	172, 717	146, 345	118, 609	151, 587

however, did not materialize. Demand in 1946 exceeded many expectations, and the supply from domestic sources fell short of capacity as a result of serious strikes in the copper industry. Consumption continued high through 1948. A reversal began in 1949 due to an industrial recession, and supply exceeded demand.

The recovery begun in the late months of 1949 continued into 1950 and was accelerated after the outbreak of war in Korea. Stocks of refined copper at the end of 1950 were the smallest they had been since 1906. The industry was faced then with inadequate supplies until 1954 when consumption declined, and more than enough copper was available for all needs. Four new properties came into production in 1954 but this new capacity was more than offset by labor strikes from August to October. Refined-copper stocks fell 49 percent to less than the 1950 quantity. In 1957 an oversupply developed, and stocks were higher than they had been since 1938. Voluntary cutbacks in output were begun in 1957 and continued in 1958. As a result of the 1959 strike, stocks of refined copper at yearend were 63 percent less than those at the beginning of the year and the lowest since before 1900. Settlement of the strikes and the return to near capacity output at primary refineries caused inventories to rise from April through December 1960.

Fabricators stocks of refined metals (including in-process copper and primary fabricated shapes) are shown in table 63 for 1934 to 1962. The data show that stocks were insufficient to fill orders from 1941 through 1955; stocks failed to cover booked orders by a high of 403,000 tons in 1942 and a low of nearly 23,000 tons in 1954. By May 1956 the deficit was reduced to 1,800 tons and, thereafter fabricators reported stocks in excess of orders booked. The excess was less than 2,000 tons at the end of 1959 but rose to 45,000 tons at the end of 1961.

Consumers also maintain stocks of copper-base scrap which include unalloyed copper, copper-base alloy scrap, and low-grade scrap and residues. Total data for all consumers by these main categories are given in table 64 for 1940 to 1962.

During World War II, the Metals Reserve Company (MRC), a Reconstruction Finance Corporation subsidiary, maintained a stockpile of copper for emergency use (table 65). No copper remained in the MRC stockpile at the end of 1948, having been sold to industry or shipped to the stragetic stockpile.

Inventories of refined copper in the United Kingdom are shown in table 66. Stock data for other countries are not available by individual countries, but total refined stocks outside the United States, published in Yearbooks of the American Bureau of Metal Statistics, are shown in table 67.

TABLE 65.—*Government stocks of copper, 1942–1962*

Yearend	Short tons	Yearend	Short tons
1942	91,472	1953	661,404
1943	224,081	1954	860,691
1944	412,635	1955	884,294
1945	565,710	1956	931,847
1946	92,758	1957	1,011,391
1947	9,986	1958	1,136,145
1948	(1)	1959	1,140,591
1949	292,005	1960	1,146,634
1950	531,653	1961	1,141,579
1951	598,876	1962	1,134,162
1952	553,017		

[1] Not available.

TABLE 66.—*Stocks of refined copper in the United Kingdom, short tons*

	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Consumers	32,800	22,000	23,100	25,400	36,500	29,000	31,700	27,300	25,200	37,500	38,800	40,100
LME warehouses			2,300	1,200	4,000	4,700	22,700	6,200	6,000	16,100	19,100	14,400
Other [1]	[2] 64,900	[2] 80,500	16,300	24,800	22,900	17,300	25,000	22,400	18,000	54,700	65,300	88,700
Total	97,700	102,500	41,700	51,400	63,400	51,000	79,400	55,900	49,200	108,300	123,200	143,200

[1] Government stocks included for 1951; thereafter they are excluded and the "Other" stocks are mainly stocks at ports, in transit to consumers in United Kingdom, and at refineries—except that stocks at consumer-operated refineries are included in consumer stocks.

[2] Includes wire rods.

Source: World Non-Ferrous Metals Statistics, the British Bureau of Non-Ferrous Statistics.

TABLE 67.—*Stocks of refined copper outside the United States, 1947–62*

Yearend	Short tons	Yearend	Short tons
1947	143,979	1955	159,777
1948	175,669	1956	233,775
1949	147,972	1957	277,316
1950	139,919	1958	181,822
1951	152,203	1959	228,243
1952	130,103	1960	288,510
1953	280,530	1961	332,479
1954	181,529	1962	358,856

CHAPTER 7.—STRUCTURE OF THE INDUSTRY

UNITED STATES COPPER INDUSTRY

The primary copper industry of the United States is composed of approximately 200 firms engaged in producing and selling copper. The major producers are vertically integrated and have mining, smelting, refining, fabricating, and marketing interests. Other large producers mine and have processing facilities through the smelting or refining stages, and many companies mine and concentrate their ores and ship the product to custom plants for smelting and refining. The principal operations of the industry in the United States are shown in table 68.

Location and Description

The copper producing areas are principally in the Western States. Arizona, in recent years, has led all other States in production by a wide margin. In 1962, Arizona supplied almost 52 percent of the U.S. total, and Utah was second with 18 percent—followed in descending order by Montana, New Mexico, Nevada, and Michigan. Arizona output comes from several important mines, whereas that of Utah comes from only one mine, the largest producer in the United States. Approximately 2 percent of the 1962 output was produced in eastern United States by three mines—one each in North Carolina, Pennsylvania, and Tennessee.

With the major copper mines centered in the Western States, most of the smelting capacity is in that area. There is some capacity in Michigan for the mines there, some on the east coast for eastern production and imports, and one smelter in Tennessee. Of the total annual smelting capacity of 8,847,000 tons, 8,165,000 tons is in the Western States, 515,000 tons is on the east coast and in Tennessee, and 167,000 tons is in Michigan.

Total refining capacity in the United States, electrolytic and fire-refined, amounted to 2,334,500 tons in 1962. The greater part of electrolytic refining capacity is on the Atlantic seaboard in New York, New Jersey, and Maryland. Low-cost power (so important to electrolytic refining), large nearby markets, and ocean transportation have combined to produce this concentration. Of a total electrolytic capacity of 1,963,500 tons, 1,129,000 is on the east coast, 792,000 tons is in the Western States, and 42,500 tons is in St. Louis, Mo. Fire refining capacity of 357,000 tons is in Michigan, Carteret, N.J., Hurley, N. Mex., and El Paso, Texas.

Mining.—In the United States, 360 mines produced copper in 1962. Copper ore was the principal product of 196 mines, and the others, mostly lead and zinc mines, produced copper as a byproduct or coproduct. The 25 largest mines accounted for 97 percent of the total domestic output; the top 5 mines produced 48 percent; and the leading 10 mines furnished 74 percent. Table 69 lists the 25 mines in order of 1962 output, and the principal producing companies with their 1962 production are given in table 70.

Smelting.—The primary copper-smelting companies, the locations of their smelters, and the approximate capacity of each plant (tons of charge) in 1962 are shown in Table 71.

Refining.—The primary copper refining companies and the location, type, and capacity of each refinery are shown in Table 72.

Fabrication.—Fabricators are the principal customers of the primary copper producers. It is in the fabricating plants that the bulk of the new copper is put into semifinished forms of sheet, strip, rod, tube, wire, and extruded and rolled shapes that constitute the raw materials for a vast industry of manufacturers of articles for final consumption or of parts for the products of other industries.

About 35 companies in the United States are recognized as the important fabricators and users of raw copper, the latter being, for the most part, the primary brass mills and wire mills. The larger fabricators, representing more than 50 percent of the total volume of business, are affiliated with the major copper producers, who thus have facilities for processing ores from the mines to the finished copper and brass products. Lists of affiliated and independent copper fabricating companies and associated producers are given on page 258.

Secondary Copper.—Old scrap is collected by several hundred scrap dealers who sell to secondary smelters, primary smelters, and brass mills. Secondary copper smelters use chiefly old copper-alloy scrap and make copper-alloy ingot; the metals remain in alloy form throughout the process. The ingot is used mostly by foundries. The various grades of copper scrap and copper-alloy scrap ordinarily sell at prices below the value of the constituent metals.

TABLE 68.—*Principal copper producers in the United States and disposition of their copper, 1962*

Operating company	Mine	Rank	Smelted by	Refined by	Sold by
American Smelting and Refining Company.	Mission	13	Own plant: Hayden, Ariz	Own plant: Perth Amboy, N.J	American Smelting and Refining Company.
	Silver Bell	15	do	do	
The Anaconda Company	Butte Mines (Mont.)	3	Own smelter: Anaconda, Mont	Own plant: Great Falls, Mont	Anaconda Sales Co.
	Yerington (Nev.)	11	do	do	
Appalachian Sulfides, Inc	Ore Knob	25	White Pine Copper Co., (White Pine Mich.)	White Pine Copper Co., (White Pine, Mich.)	Appalachian Sulfides, Inc.
Bagdad Copper Corp	Bagdad	21	American Smelting and Refining Company (Hayden, Ariz.).	American Smelting and Refining Company (Perth Amboy, N.J.).	American Smelting and Refining Company.
Banner Mining Co	Daisy	24	do	do	
	Palo Verde	23			
Calumet & Hecla, Inc	Calumet & Hecla	20	Calumet & Hecla, Inc. (Hubbell, Mich.).	Calumet & Hecla, Inc. (Hubbell, Mich.).	Calumet & Hecla, Inc.
Duval Sulphur & Potash Co	Esperanza	14	American Smelting and Refining Company (Hayden, Ariz. and El Paso, Tex.).	American Smelting and Refining Company (Perth Amboy, N.J.).	American Smelting and Refining Company.
Inspiration Consolidated Copper Co.	Inspiration	10	Own smelter: Miami, Ariz	Own plant: Inspiration, Ariz. International Smelting and Refining Company, Raritan Copper Works (Perth Amboy, N.J.).	Anaconda Sales Co.
Kennecott Copper Corp	Utah Copper (Utah)	1	Own smelters: Garfield, Utah	Own refineries: Garfield, Utah	Kennecott Sales Corp.
	Chino (N. Mex.)	5	Hurley, N. Mex	Hurley, N. Mex	
	Ray Pit (Ariz.)	8	Hayden, Ariz	Kennecott Refining Corp. (Anne Arundel Co., Md.).	
	Liberty Pit (Nev.)	12	McGill, Nev	American Smelting and Refining Company (Baltimore, Md.).	
Magma Copper Co	Magma	18	Own plant: Superior, Ariz	Phelps Dodge Refining Corp	International Minerals & Metals Corp.
	San Manuel	4	San Manuel, Ariz	do	
Phelps Dodge Corp	Morenci (Ariz.)	2	Own smelter: Morenci, Ariz	Phelps Dodge Refining Corp	Phelps Dodge Corp.
	New Cornelia (Ariz.)	7	Ajo, Ariz	(El Paso, Tex.)	
	Copper Queen-Lavender Pit (Ariz.)	6	Douglas, Ariz	(Laurel Hill, L.I., N.Y.)	
Pima Mining Co	Pima	17	American Smelting and Refining Company (Hayden, Ariz.).	American Metal Climax, Inc. (Carteret, N.J.).	American Metal Climax, Inc.
Tennessee Corp	Copper Cities	16	Inspiration Consolidated, Copper Co. (Miami, Ariz.).	Raritan Copper Works & Phelps Dodge Refining Corp.	Adolph Lewisohn Selling Corp.
Miami Copper Co. Division	Miami	22			
Tennessee Copper Co. Division	Burra-Boyd	19	Own plant: Copperhill ,Tenn		
White Pine Copper Co	White Pine	9	Own smelter: White Pine, Mich	Own plant: White Pine, Mich	Copper Range Sales Co.

TABLE 69.—*Twenty-five leading copper-producing mines in the United States in 1962, order of output*

Rank	Mine	District or region	State	Operator	Source of copper
1	Utah Copper	West Mountain (Bingham)	Utah	Kennecott Copper Corp	Copper ore.
2	Morenci	Copper Mountain (Morenci)	Arizona	Phelps Dodge Corp	Copper, gold-silver ores.
3	Butte Mines (includes Kelley, Berkeley).	Summit Valley (Butte)	Montana	The Anaconda Company	Copper, silver-zinc ores.
4	San Manuel	Old Hat	Arizona	Magma Copper Co	Copper ore.
5	Chino	Central	New Mexico	Kennecott Copper Corp	Do.
6	Copper Queen-Lavender Pit	Warren (Bisbee)	Arizona	Phelps Dodge Corp	Do.
7	New Cornelia	Ajo	do	do	Copper, gold-silver ores.
8	Ray Pit	Mineral Creek (Ray)	do	Kennecott Copper Corp	Copper ore.
9	White Pine	Lake Superior	Michigan	White Pine Copper Co	Do.
10	Inspiration	Globe-Miami	Arizona	Inspiration Consolidated Copper Co.	Do.
11	Yerington	Yerington	Nevada	The Anaconda Company	Do.
12	Liberty Pit	Robinson (Ely)	do	Kennecott Copper Corp	Do.
13	Mission	Pima	Arizona	American Smelting and Refining Co.	Do.
14	Esperanza	do	do	Duval Sulphur & Potash Company.	Do.
15	Silver Bell	Silver Bell	do	American Smelting and Refining Co.	Do.
16	Copper Cities	Globe-Miami	do	Tennessee Corp	Do.
17	Pima	Pima	do	Pima Mining Co	Do.
18	Magma	Pioneer (Superior)	do	Magma Copper Co	Copper, gold-silver ores.
19	Copperhill	Polk County	Tennessee	Tennessee Copper Co	Copper-zinc ore.
20	Calumet & Hecla, Inc	Lake Superior	Michigan	Calumet & Hecla, Inc	Copper ore and tailings.
21	Bagdad	Eureka (Bagdad)	Arizona	Bagdad Copper Corp	Copper ore.
22	Miami	Globe-Miami	do	Tennessee Corp	Copper precipitates.
23	Palo Verde	Pima	do	Banner Mining Co	Copper ore.
24	Daisy	do	do	Pima Mining Co	Do.
25	Ore Knob	Ashe County	North Carolina	Appalachian Sulfides, Inc	Do.

TABLE 70.—*Principal copper producing companies in the United States, 1962*

Company	Mine production, short tons
American Smelting and Refining Company	65, 008
The Anaconda Company	134, 188
Bagdad Copper Corp	11, 056
Banner Mining Co	10, 765
Calumet & Hecla, Inc	14, 266
Duval Sulphur & Potash Co	22, 974
Inspiration Consolidated Copper Co	52, 291
Kennecott Copper Corp	393, 902
Magma Copper Co	14, 913
Phelps Dodge Corp	265, 779
Pima Mining Co	19, 700
San Manuel Copper Corp	84, 208
Tennessee Corp.-Miami Copper Division	28, 793
White Pine Copper Co	54, 651

Source: American Bureau of Metal Statistics, 1962.

Secondary copper smelters produce a minor proportion of secondary refined copper; the remainder is the product of the primary smelters and refiners, which use scrap as well as primary raw materials. The other large group of scrap-metal consumers is the brass mills, which use chiefly new scrap generated in manufacturing articles from new sheet, tube, wire, and other brass-mill products. Much brass-mill scrap passes directly from the generators back to the mills from which the sheet and other shapes were purchased, without being handled by dealers. Certain quantities of brass-mill scrap customarily move through dealers, but since little or no preparation of such material is necessary, the principal operation of the dealer consists in accumulating and sorting material from small manufacturers and fabricators and reselling it in quantities that can be conveniently handled by the brass mills.

Marketing

Mining produces ores that are milled to concentrates; concentrates are smelted to produce impure blister copper; refining eliminates impurities and produces copper conforming to established specifications; and fabricating produces sheet, strip, rod, bar, wire, tube, and shapes. Marketing is not a major operation until after the refining stage; however, firms engaged in only one or more of the processes preceding refining sell their product in the form made. Therefore, there are market transactions involving ores, concentrates, and blister copper, as well as refined metal.

Ores and Concentrates.—The majority of the copper-mining companies in the United States (producing about 25 percent of the annual output) do not have the smelters with which to treat the products of their mines. Large companies that include smelting in their operations or that are primarily engaged in the smelting business either purchase the ores and concentrates from these independent companies or treat them on toll. The practice of buying and treating ores and concentrates or of treating them on toll in a smelter is known as custom smelting.

Purchase of ores and concentrates is facilitated by a schedule, that is, a contract between the buyer and seller. The sale is affected by

TABLE 71.—*United States primary copper smelters*

Company	Location	Annual capacity
		Short tons of charge
American Metal Climax, Inc	Carteret, N.J	168, 000
American Smelting & Refining Company	El Paso, Tex	420, 000
Do	Hayden, Ariz	360, 000
Do	Tacoma, Wash	600, 000
The Anaconda Company	Anaconda, Mont	1, 000, 000
Inspiration Consolidated Copper Co	Miami, Ariz	360, 000
Kennecott Copper Corp.:		
Nevada Mines Division	McGill, Nev	440, 000
Chino Mines Division	Hurley, N. Mex.[1]	400, 000
Ray Mines Division	Hayden, Ariz	400, 000
Utah Mines Division	Garfield, Utah	1, 225, 000
Magma Copper Co.:		
Magma Division	Superior, Ariz	150, 000
San Manuel Division	San Manuel, Ariz	360, 000
Phelps Dodge Refining Corp	Laurel Hill, N.Y	[2] 200, 000
Phelps Dodge Corp.:		
Douglas Reduction Works	Douglas, Ariz	1, 250, 000
Morenci Branch	Morenci, Ariz	900, 000
New Cornelia Branch	Ajo, Ariz	300, 000
Tennessee Copper Co	Copperhill, Tenn	90, 000
Total		8, 623, 000
		Tons of product
Calumet & Hecla, Inc	Hubbell, Mich	100, 000
Quincy Mining Co	Hancock, Mich	12, 000
White Pine Copper Co	White Pine, Mich	65, 000
Total		177, 000

[1] Produces fire-refined copper as well as blister.
[2] Closed August 1963.

Source: American Bureau of Metal Statistics, 1962.

local conditions as well as predetermined standards set down by the smelters. By utilizing this contract as a vehicle to obtain minimum and maximum quantities of ores and concentrates, the custom smelter assures itself of a relatively constant source of supply.

The contract specifies all conditions of settlement, such as the percentage of the total metal to be paid for, the basic smelting charge, penalties for impurities, bonuses for higher grade and time and rate of payment. As a general practice, a custom smelter purchases ores or concentrates outright and pays the producer the going rate after sampling and analyzing to determine the metal content. The contained metals then become the property of the smelter, which reduces, refines, and markets them under what it considers the most favorable conditions. Ownership of metal recovered from ores or concentrates treated on a toll basis, is, however, retained by the original producer (mining company).

Often, although individual items in the schedules of individual smelters may vary considerably, the net return to the shipper is much the same under the several types of contracts. If a seller has a large quantity of material that can be supplied at a constant rate he will usually obtain a more favorable contract or schedule from the smelter to cover these transactions than he will for smaller quantities that are supplied at a less constant rate. For smaller shipments, smelters usually maintain a public or open schedule. Unless the shipper

TABLE 72.—*United States primary copper refineries*

Company	Location	Annual capacity refined copper, short tons
	Electrolytic refineries	
American Metal Climax, Inc	Carteret, N.J	150, 000
American Smelting and Refining Company	Baltimore, Md	198, 000
	Perth Amboy, N.J	168, 000
	Tacoma, Wash	103, 000
The Anaconda Company	Great Falls, Mont	150, 000
Inspiration Consolidated Copper Co	Inspiration, Ariz	45, 000
International Smelting and Refining Co	Raritan, Perth Amboy, N.J	240, 000
Kennecott Copper Corp	Garfield, Utah	204, 000
Kennecott Refining Corp	Anne Arundel County, Md	198, 000
Cerro Copper & Brass Co., Division of Cerro Corp	St. Louis, Mo	42, 500
Phelps Dodge Refining Corp	El Paso, Tex	290, 000
Do	Laurel Hill, L.I., N.Y	175, 000
Total		1, 963, 500
	Fire refineries	
American Metal Climax, Inc	Carteret, N.J	125, 000
Calumet & Hecla, Inc	Hubbell, Mich	60, 000
Kennecott Copper Corp	Hurley, N. Mex	84, 000
Quincy Mining Co	Hancock, Mich	12, 000
Phelps Dodge Refining Corp	El Paso, Tex	25, 000
White Pine Copper Co	White Pine, Mich	65, 000
Total		371, 000

Source: American Bureau of Metal Statistics, 1962.

has a separate contract, he is paid according to this open schedule.

The difference between the gross value of the marketable constituents of the ore as determined by analyses on the date of settlement, and the amount paid to the producer is made of two elements: (1) Smelting charges (including unavoidable metallurgical losses), and (2) marketing charges. The latter are definite charges against the ore that, for convenience, are paid by the smelter. Marketing charges usually include freight on ore from mine to smelter, demurrage, extra sampling costs and umpire assaying, freight to the refinery, and duties and customs charges if the ore is of foreign origin. The freight on metal to New York or to any other refinery point may be calculated as a separate item or may be provided for in the deduction from the metal quotation used for settlement. Under the first agreement, the seller gains or loses by changes in the freight rate. The cost of refining and marketing the refined metals, whether done by the smelter or by a separate company, usually is covered by an arbitrary deduction from the metal quotation and virtually becomes part of the smelting charge.

There are three principal smelting charges:

1. Nominal treatment charge, which often fluctuates with the value of the ore, the content of some constituent, or the market quotation for some constituent.
2. Deduction from the metal content (metallurgical losses usually covered here) or from the market quotations of the various salable metals.
3. Various penalties imposed because of the presence of undesirable constituents.

Fabricating Company:	Associated Copper Producer
Chase Brass and Copper Co., Inc	Kennecott Copper Corp.
The Okonite Co	Do.
The Anaconda American Brass Co	The Anaconda Co.
Anaconda Wire and Cable Co	Do.
Phelps Dodge Copper Products Corp	Phelps Dodge Corp.
Calumet & Hecla, Inc.-Wolverine Tube Division	Calumet & Helca, Inc.
C. G. Hussey & Co., Division Copper Range Co	Copper Range Co.
New Haven Copper Co	Tennessee Corp.
Cerro Copper & Brass Co., Division of Cerro Corp., St. Louis Works.	Cerro Corp.
Circle Wire and Cable Corp	Do.

American Smelting & Refining Co. has substantial stock interests in General Cable Corp. (31.7 percent) and Revere Copper & Brass Co. (35 percent).

The more important fabricators not affiliated with the copper producers are:

	Address
Brass Mills:	
Bohn Aluminum & Brass Corp	1400 Lafayette Bldg., Detroit 26, Mich.
Bridgeport Brass Co., Division of National Distillers & Chemical Corp.	30 Grand Street, Bridgeport 2, Conn.
Bridgeport Rolling Mills Co	Bridgeport 1, Conn.
The Bristol Brass Corp	580 Broad Street, Bristol, Conn.
Chicago Extruded Metals Co	1821 S. 54th Avenue, Cicero 50, Ill.
Detroit Gasket & Mfg. Co	Belding, Mich.
The Electric Materials Co	Clay & Washington Streets, North East, Pa.
International Silver Co	500 S. Broad Street, Meriden, Conn.
Miller Co	99 Center Street, Meriden, Conn.
Mueller Brass Co	Port Huron, Mich.
New England Brass Co	Taunton, Mass.
Olin Mathieson Chemical Corp	Shamrock Street, East Alton, Ill.
H. K. Porter Co., Inc., Riverside-Alloy Metal Division.	1 Pavillion Avenue, Riverside, N.J.
Reading Tube Co., Division Progress Mfg. Co	Seventh & South Streets, Reading, Pa.
Scovill Mfg. Co	99 Mill Street, Waterbury 20, Conn.
Triangle Conduit & Cable Co., Inc	Jersey Avenue, New Brunswick, N.J.
U.S. Mint Service	Washington 25, D.C.
Volco Brass & Copper Co	Kenilworth, N.J.
Western Electric Co., Inc	222 Broadway, New York 38, N.Y.
Wire Mills:	
Hatfield Wire & Cable Division, Continental Copper & Steel Industries, Inc.	Hillside, N.J.
Rods, Inc	23rd Street, Marion, Ind.
Rome Cable Corp	332–400 Ride Street, Rome, N.Y.
Triangle Conduit & Cable Co., Inc	Jersey Avenue, New Brunswick, N.J.
Western Electric Co., Inc	222 Broadway, New York 38, N.Y.

The principal secondary copper smelters in the United States in 1963 are:

Company:	Address
Barth Smelting & Refining Co	99–129 Chapel St., Newark 5, N.J.
Benjamin Harris & Co	11th & State Sts., Chicago Heights, Ill.
W. J. Bullock, Inc	Box 539, Fairfield, Ala.
Colonial Metals Co	Second & Linden Sts., Columbia, Pa.
Elesco Smelting Corp	3401 S. Lawndale Ave., Chicago 23, Ill.
Federal Metal Co	7250 Division St., Bedford, Ohio.
Federated Metals Division, American Smelting & Refining Co.	120 Broadway, New York 5, N.Y.
George A. Avril Smelting Corp	Este Ave. & B. & O. R.R., Cincinnati 32, Ohio.
H. Kramer & Co., including Ajax Metal Division	Frankford Ave. and Richmond St., Philadelphia, Pa.
I. Schumann & Co	4391 Bradley Road, Cleveland 9, Ohio.
Interstate Smelting & Refining Co	9651 S. Torrence Ave., Chicago 17, Ill.
Liberman & Gittlen Metal Co., Inc	322 Front Ave., S.W., Grand Rapids 2, Mich.
Nassau Smelting & Refining Co	1 Nassau Place, Tottenville 7, N.Y.
North American Smelting Co	Marine Terminal, Wilmington 99, Del.
R. Lavin & Sons, Inc	3426 S. Kedsie Ave., Chicago 23, Ill.
River Smelting & Refining Co	P.O. Box 5755, Cleveland 1, Ohio.
Roessing Bronze Co	Butler Plank Rd. (Etna), Pittsburgh 23, Pa.
North Chicago Refiners & Smelters, Inc	2028 S. Sheridan Rd., N. Chicago, Ill.
Northwestern Metal Co	9th & T Sts., Lincoln 1, Nebr.

The following is a typical schedule or contract for the purchase of copper ores and concentrates.

SCHEDULE OF PRICES, PENALTIES, AND DEDUCTIONS FOR A TYPICAL COPPER SMELTER

Charges:

Base treatment charge per ton.	Ore: $9.50 per short dry ton of ore based on a copper content of 12 percent or less. For each 1 percent that the copper content is in excess of 12 percent, increase the base charge by $0.50 per short dry ton up to a maximum base charge of $13.50 per short dry ton, fractions in proportion. Concentrates: $13.50 per short dry ton of 2,000 pounds.
Handling charge per ton.	Charge $1.50 per ton for material received in bags or other containers.
Freight and advances.	Seller shall reimburse buyer for freight paid and advances made to seller or for seller's account.

Payments:

Gold	If .03 of a troy ounce per short dry ton or over, pay for 96.75 percent of the gold content at the net price realized by the U.S. Mint on the 15th day following the date of arrival of product at buyer's smelter.
Silver	If one troy ounce per short dry ton or over, pay for 95 percent of the silver content at the Handy & Harman New York silver quotations, as published in the Engineering & Mining Journal, averaged for the calendar week following the date of arrival of product at buyer's plant. The amount of silver retained by buyer and not paid for will be a minimum of 1 troy ounce per short dry ton.
Copper	Deduct from the wet assay 1.3 units and pay for 100 percent of the remaining copper at the daily net export refinery quotations for electrolytic wirebars, as published in the Engineering & Mining Journal, averaged for the calendar week following the date of arrival of product at buyer's smelter, less a deduction of $0.03 per pound copper paid for. Nothing paid for copper if less than 1.3 percent by net assay.

No payment will be made for any metal or content except as above specified.

Penalties per ton of ore:

Arsenic	Allow 1 percent free, charge for excess at $1.00 per unit.
Antimony	Allow 1 percent free, charge for excess at $1.00 per unit.
Bismuth	Allow .05 percent free, charge for excess at $0.50 per unit.

Settlement:

Buyer will make 80 percent advance of the net estimated smelter value of product within 10 days after arrival at buyer's smelter. Buyer will make cash settlement on all shipments on the earliest practical date following the obtaining of all necessary information.

Refined Copper.—Copper fabricators provide the principal domestic market for refined copper produced in the United States. At times the brass-ingot makers are in the market for refined copper, but their needs usually are filled from the scrap market.

The market for refined copper in the United States consists of a limited number of buyers. Principal users are the fabricators affiliated with the large producers, the independent fabricators, and the large electrical manufacturers. The independent fabricators and electrical manufacturers buy directly from the large producers, their selling agents, and from time to time on the open market.

More than 60 percent of the copper delivered by the refineries is as wirebars. Cakes, cathodes, and billets make up the next largest groups, with about 10 percent each. Ingots, ingot bars, and other shapes comprise the remainder.

Copper usually is sold on 30- to 90-day deliveries from the refineries and priced during the month of shipment. Copper producers handle their transactions with the consumers through their sales agents which, in the case of the large producers, are usually subsidiaries or affiliated companies. American Metal Climax, Inc., and American Smelting and Refining Company, both custom smelters and refiners, are the principal independent selling organizations. Adolph Lewisohn Selling Corp., also is an important seller of copper, acting as the sales agent for the Tennessee Copper Co. Division and Miami Copper Co. Division of Tennessee Corp. Calumet & Hecla, Inc.; Copper Range Sales Co.; and International Minerals & Metals Corp. are other notable primary copper sellers. Table 73 shows the principal sellers and brands of copper sold in the United States.

Prices.—There are various price quotations for copper. In the United States, the three main ones are the U.S. producers price, the custom smelter price, and the Engineering & Mining Journal quoted price. There are also the New York Commodity Exchange price and the American Metal Market price. Copper prices are expressed in cents a pound and are quoted for the ordinary forms of wirebars and ingots; cathodes sell at a discount of 0.125 of a cent per pound, and small differentials exist for

TABLE 73.—*Principal sellers of copper in the United States and brands sold, 1962*

Selling agent	Sells copper for—	Brand	Type
American Metal Climax, Inc	American Metal Climax, Inc	D.R.W[1]	Electrolytic.
	Chibuluma Mines Ltd	AMCO[1]	Do.
	Cyprus Mines Corp	OFHC	Do.
	International Nickel Co. of Canada, Ltd.	OFHC Certified	Do.
	Mazapil Copper Co	AMPHOS	Do.
	Mulfulira Copper Mines, Ltd	ORC[1]	Do.
	O'okiep Copper Co., Ltd		Do.
	Pima Mining Co	MCM	Do.
	Roan Antelope Mines, Ltd	N.C.R[1]	Do.
	Tsumeb Corp., Ltd	AMCO RHC&R[1]	Fire-refined.
American Smelting and Refining Company.	American Smelting and Refining Company.	T[1]	Electrolytic.
	Banner Mining Co	B.E.R[1]	Do.
	Bagdad Copper Corp	P.A[1]	Do.
	Duval Sulphur & Potash Co	I.S.A[1]	Do.
	Lepanto Consolidated Mining Co, Ltd	U.M.K[1]	Do.
	Northern Peru Copper Corp		
	Southern Peru Copper Corp		
	Various		
Anaconda Sales Company	The Anaconda Company	B. & M[1]	Electrolytic.
	Andes Copper Mining Co	N.E.C	Do.
	Compania Minera de Cananea S.A. de C.V.	N.E.C	Do.
	Chile Exploration Co	C.C.C[1]	
	Inspiration Consolidated Copper Co		
Calumet & Helca, Inc	Calumet & Helca, Inc	C. & H[1]	Lake.
Cerro Sales Corp	Cerro Corp		Electrolytic.
Copper Range Sales Co	Copper Range Co	C.R[1]	Lake.
	White Pine Copper Co		Do.
International Minerals & Metals Corp.	Various	L.N.S[1]	Electrolytic.
Kennecott Sales Corp	Kennecott Copper Corp	K.E	Do.
	Braden Copper Co	B.E.R[1]	Do.
		K.U.E[1]	Do.
		K.C.M	Fire refined.
Adolph Lewisohn Selling Corp	Tennessee Copper Company Division	L.N.S[1]	Electrolytic.
	Miami Copper Company, Division of Tennesse Corp.	A.L.S[1]	Do.
		N.E.C[1]	Do.
Magma Copper Sales Corp	Magma Copper Co., Magma Division		Do.
Phelps Dodge Corp. and Phelps Dodge Refining Corp.	Phelps Dodge Corp. and subsidiary companies; also custom.	P.D. & L.N.S[1]	Do.
		P.D. & L.N.S[1]	Do.
		D.D.M	Fire refined.
Quincy Mining Co	Quincy Mining Co	Q. & Q.M. Co[1]	Lake.
Cerro Copper & Brass Co. Division Cerro Corp.	Cerro Copper & Brass Co. Division Cerro Corp.	L.M.C[1]	Electrolytic.
Nassau Smelting & Refining Co	Nassau Smelting & Refining Co	N.H.E[1]	Do.
		C.T.C	Casting.
Reading Metals Refining Corp	Reading Metals Refining Corp	R.M.R	Electrolytic.

[1] Approved brands for delivery against Commodity Exchange contracts.

Sources: American Metal Market, Metal Statistics 1962: pp. 317–319. American Bureau of Metal Statistics, Yearbook 1962, p. 23.

other refinery shapes. The producers price and the custom smelter price are set quotations, whereas the Engineering & Mining Journal price is a weighted average historical price, calculated for a day, week, month, or year based on sales reported by producers and their agencies.

The primary producers quotation is the most important as it covers the largest volume of metal. All the primary copper produced in the United States and that delivered in the United States from U.S.-owned Chilean properties is marketed by the producers quotations. These prices are fixed with regard to interests of the companies for a long period.

The custom smelter price is governed by short-term supply-demand factors and, of course, fluctuates more frequently than the primary producers price. Custom smelters sell refined metal in ratio to ore intake to protect the difference between their buying and selling prices. This involves more frequent changes in the custom smelter price, which on a falling market puts pressure on primary producers to lower their quotation.

The Engineering & Mining Journal quotations, domestic and foreign or export, are based on reported sales and reflect open market prices. Domestic prices are net at the refineries after the average shipment costs have been deducted. Foreign or export quotations are based on sales in the foreign market reduced to the f.o.b. refinery equivalent. The export quotation is calculated by reducing sales made c.i.f. Europe by the U.S. lighterage figure (0.125 cent a pound) and by the freight charged from the United States to the main European ports (0.82 cent a pound).

The New York Commodity Exchange (COMEX) prices are rarely, if ever, used as a pricing medium. COMEX, however, provides a facility for hedging as far ahead as twelve months and attracts some speculative business.

The American Metal Market price is the net price at New York refineries, derived by reducing the producers quotation by an average delivery cost (0.175 cent a pound).

Prices of copper scrap are quoted for numerous grades and specifications. Most scrap either is purchased directly by consumers, refined by the large primary refineries and marketed by them as refined copper, or is smelted and marketed as brass and bronze ingots by secondary producers. Quotations for such ingots bear no fixed relationship to the price of copper quoted by the large producers, as the content of alloying metals and supply-demand factors have a marked influence on ingot prices.

The international trade in copper is essentially based on three pricing systems: (1) The quotations published by the London Metal Exchange (referred to as the LME price), (2) the export quotations published by Engineering & Mining Journal (referred to as the E&MJ price), and (3) the quotations by Union Minière du Haut Katanga (often referred to as the Katanga quotation or the Belgian price).

The LME price and the Katanga quotation adequately reflect European copper prices. The London Metal Exchange offers each metal for a period of 5 minutes; offers and bids are made by interested parties until a satisfactory price is agreed upon. Copper is offered twice during the morning session and twice in the afternoon.

The London Metal Exchange was founded in 1881 and has dealt in copper since, except from 1939 to 1953. Briefly, its function is providing facilities for hedging rather than dealing in physical deliveries. In this respect, it is not a physical market place like those for certain other commodities but rather an exchange dealing on a standard contract and concerned mainly with marginal quantities. Its facilities enable the buying and selling of copper for delivery on any of 1 to 90 days ahead.

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The prices which the Exchange quotes daily are based either on the last transaction entered into or on the closing bids and offers made during the short period when dealings occur; the official LME prices thereby reflect dealings covering what may be only small tonnages of copper. However, these quotations are used for pricing infinitely greater quantities of copper on a direct producer-to-fabricator basis outside the Exchange. These producers and fabricators adopt the official LME quotations as their pricing basis in the same way one might use official stock exchange quotations for a private share deal. This mechanism creates an ultrasensitive market, and some times prices fluctuate violently from day to day.

Fabricators of copper-base products often trade in copper on the LME to protect themselves against loss due to price fluctuations.

The Katanga quotation is a price fixed unilaterally by the Union Minière du Haut Katanga in relation to its view of current market conditions and trends. One of the objectives of this organization has been to bring more stability into the market. The same price is quoted for f.o.b. Antwerp and c.i.f. New York.

E&MJ Metal and Mineral Markets is published weekly on Thursdays, and the daily prices shown are for the preceding week and cannot be used for day-to-day sales. However, these prices are useful for making average-price contracts because they reflect the prices at which much of the international trade in copper was conducted.

Cartels.—Several organized efforts at price control in the copper industry have been made since the 1880's. An early and spectacular attempt known as the Secretan corner was organized and financed in Europe in the autumn of 1887; it temporarily succeeded in more than doubling the price of copper. However, the syndicate in charge was unable to maintain this level in the face of bitter consumer resistance and in competition with the flood of new and scrap copper that poured into the market; in the spring of 1889 the enterprise ended disastrously.

Ten years later, the Amalgamated Pool—organized by U.S. mining and financial interests and supported by most foreign producers—for a time was able to raise the price of copper and hold it well above its former level. But again, the high price resulted in decreased consumption, increased offerings of scrap, and an unexpected increase in output from independent producers. There was a severe price decline in 1901, but this time a crash was avoided by the receipt of financial aid from London. By 1906, the Amalgamated group again felt strong enough to force up the price of copper. Once more, however, the success was short lived, coming to an end during the financial panic of 1907.

One concerted effort to control the copper price has been generally judged a success. This was a combination including practically all U.S. producers formed into the Copper Export Association. It was organized in December 1918 under the authority of the Webb-Pomerene Act, having three large companies acting as leaders to deal with the problems that confronted the industry after World War I. Large stocks of new metal had piled up, and millions of tons of recoverable scrap littered the battlefields of Europe. In addition surplus production capacity, developed during the war, threatened to become an important factor in price cutting. Suspension of government price control and government buying shifted attention from the problem of production to one of markets.

Under control of the newly-organized Association, production was curtailed, particularly during the depression of 1921; the war surplus of new and scrap metal was liquidated, and—in line with the provisions of the Webb-Pomerene Act—foreign orders were prorated among the organization members. But after accomplishing the purpose for which it had been organized, the Association was unable to extend its harmonious existence. Companies purely domestic in character and those with important foreign holdings were unable to agree regarding the future policy of the organization. Accordingly, the Association was disbanded in 1923, following the withdrawal of the Guggenheim interests and their affiliates, representing at that time 45 percent of the U.S. output.

Organization of Copper Exporters, Inc., in October 1926, marked the beginning of another unsuccessful attempt at price control. This group, under the leadership of the large U.S. companies, accounted for 95 percent of the world production. At this time, the copper industry was in a favorable position, and U.S. interests were by far the most important factors in the industry; stocks were at reasonably low levels, and demand was rising sharply. However, producers charged that harmful speculation by brokers caused wide fluctuation in price. Therefore, when the cartel was formed it announced that it planned to bypass these brokers and sell directly to consumers at prices to be fixed daily in accordance with general business conditions.

For a year and a half the cartel operated to the apparent satisfaction of consumers, and with an actual small decline in price. Then it adopted a different policy—one that eventually lost to U.S. producers the control they previously had over the industry.

In late 1928 and early 1929 European consumers, principally copper fabricators, were rationed almost from day to day. In their efforts to obtain the metal required to meet their own commitments, these buyers bid up the price—a cent a day in March 1929—until, at 24 cents a pound, a buyers strike began. The detailed story of subsequent events is long—involving the antagonism of European consumers; the efforts made to protect the fabricators interests; the struggle to withstand the inevitable price decline; the expansion of competitive capacity in Northern Rhodesia, Belgian Congo, and Canada; the substitution of aluminum for copper in substantial amounts; the usual increase in offerings of scrap; and, eventually, drastic reductions in domestic output in 1931 and 1932. Finally, after the United States raised a tariff wall against copper imports in June 1932, four of the most important foreign producers withdrew from the cartel.

In 1935 a new cartel was formed, its membership representing producers of about 50 percent of the copper then being mined in countries outside the United States, Canada, Russia, and Japan. The cartel was formed to adjust production of its members to meet consumption requirements outside the United States. There was no participation by United States or Canadian producers.

During its relatively short life, this cartel alternately tightened and relaxed its restriction on the industry. During the first year, for example, the output of the group was cut to roughly 70 percent of theoretical capacity. Expanding consumption in 1935 brought a corresponding increase in quotas and some expansion in output. In 1937, restrictions were again tightened. Thereafter, production pressed hard against the limits imposed by the cartel, until the outbreak of war in September 1939 brought to an end the whole cooperative arrangement.

Physical and Financial Corporate Structure by Companies

On the following pages are descriptions and pertinent data regarding those companies engaged in mining, smelting, and refining. The information has been compiled from published sources such as company reports, Skinner's

Mining Yearbook (1960), Moody's Industrial Manual (1961), and reputable trade publications, together with information from government sources that has been released for administrative use. It has not been possible to describe each company and operation with the desired detail and accuracy because (1) there are differing policies regarding release of information, (2) some of the available information is conflicting, and (3) better information is available about some companies than about others.

The larger copper producing corporations are vertically integrated, in greater or lesser degree, from mines through smelting, refining, fabricating, and marketing. Some of them have interests in foreign operations, many produce metals other than copper, and some have diversified industrial interests. Where possible, descriptions of the various companies include references to all affairs in which they participate. Some of the references are not as complete as in others owing to the lack of similar information in source material.

American Metal Climax, Inc.———1270 Avenue of The Americas, New York 20.—American Metal Co., Ltd. (incorporated 1887) was organized by Metallgesellschaft of Frankfort-on-the-Main and Henry R. Merton and Company, Ltd., of London. Management of the company was undertaken by men previously connected with Metallgesellschaft. The company grew rapidly and developed from a purely trading concern into a factor in the mining and smelting industry in the United States and Mexico.

World War I forced a dissolution of the relationship with Metallgesellschaft and Henry R. Merton and Company, and in 1920 the Metallgesellschaft shares were sold to U.S. investors. In conjunction with this sale L. Vogelstein and Company was consolidated with American Metal Company.

In 1928, the company acquired its first interest in the Rhodesian copper mines, an interest that had grown tremendously by 1960.

On December 31, 1957, American Metal Co., Ltd., and Climax Molybdenum Co. merged under the name American Metal Climax, Inc. The corporation is both a holding and operating concern engaged in mining, metallurgical, and petroleum enterprises through subsidiaries and stock interests in many companies. Industrial operations of the subsidiaries are principally in the United States, Mexico, and Northern Rhodesia, but metal-trading activities are virtually worldwide.

The principal products and byproducts are copper, copper-powder, gold, silver, palladium, platinum, selenium, tellurium, and arsenic; lead, lead powder, solder, terne metal, zinc, cadmium, bismuth, and germanium; molybdenum sulfide (concentrates), molybdenum trioxide, calcium molybdate, molybdenum, and ferromolybdenum; and potash, uranium, vanadium, and iron powder.

The subsidiaries and affiliated companies involved in production of copper are:

(1) United States Metals Refining Co., a wholly owned subsidiary, operating a copper smelter and refinery at Carteret, N.J., which produces refined copper from domestic and foreign ores, concentrates, blister, copper, and copper scrap. The total annual refining capacity of 275,000 short tons consists of 150,000 tons of electrolytic capacity and 121,000 tons of fire-refining capacity. This company is the only domestic producer of commercial oxygen-free high-conductivity (OFHC) copper in refinery shapes (wirebars, billets, cakes), producing between 30,000 and 35,000 tons of these shapes per year.

(2) Rhodesian Selection Trust, Inc., 50.60 percent owned, a holding company controlling Mufulira Copper Mines, Ltd., and Chibuluma Mines, Ltd., operating mines, a smelter, and a refinery in Northern Rhodesia.

(3) Roan Antelope Copper Mines, Ltd., 32.65 percent owned, operates a mine and smelter and has two-thirds interest in Ndola Copper Refineries, Ltd., which has an electrolytic refinery at Ndola, Northern Rhodesia, having an annual capacity of 121,000 short tons of refined copper.

(4) Tsumeb Corporation, Ltd., 29.13 percent owned, mines a rich complex ore containing lead, copper, and zinc, with important values of cadmium, silver, and germanium. The mine is in the Grootfontein district of South-West Africa. A copper smelter under construction is scheduled for completion in 1962.

(5) O'okiep Copper Company, Ltd., 19.72 percent owned, operates several mines and a smelter in Namaqualand, Cape Province, Republic of South Africa. O'okiep owns 9.5 percent of Tsumeb Corporation, Ltd.

Other enterprises in which American Metal Climax, Inc. has substantial interests are:

Companies 100 percent owned:

- Amax Sales Co. of Canada, Ltd.
- American Climax Petroleum Corp.
- Ametal, S.A., Switzerland.
- Blackwell Zinc Co., Inc.
- Climax Molybdenum Co. of Michigan.
- Climax Uranium Co.; unit, merged 1961.
- Southwest Potash Corp.
- The American Metal Co. of Canada.
- The Anglo Metal Co., Ltd., England.
- The South American Metal Co., Chile.

Companies less than 100 percent owned:	Percent
American Lithium Chemicals, Inc	18. 22
Bikita Minerals (Private), Ltd	21. 25
Cerro Corp	1. 54
Copper Range Company	17. 49
Heath Steele Mines, Ltd., Canada; mine inactive	75. 00
Metalurgia Mexicana Penoles, S.A., Metmax Penoles	49. 00
San Antonio Chemicals, Inc	18. 22
San Francisco Mines of Mexico, Ltd	37. 69
The Mazapil Copper Company, Ltd	29. 41

There are also several other wholly owned but separately incorporated sales, exploration, and service organizations in the United States, Canada, Mexico, and Europe.

Capitalization:

4½ percent cumulative preferred stock—authorized 127,692 shares, outstanding 70,610 shares. Common stock—authorized 20,000,000 shares, outstanding 14,184,634, December 31, 1960.

Assets and liabilities:

December 31, 1960—total current assets, $180,189,819; total current liabilities, $62,325,782.

		1958	1959	1960
Sales of nonferrous and precious metals:				
Copper	tons	$531,000	$627,000	$586,000
Lead	do	242,000	245,000	232,000
Zinc	do	172,000	169,000	180,000
Tin	do	15,000	15,000	14,000
Silver	ounces	42,132,000	39,854,000	40,385,000
Gold	do	867,000	664,000	546,000
Production of ferrous metals:				
Molybdenum		25,079,000	36,556,000	49,631,000
Tungsten		435,000	890,000	975,000
Sales of uranium and vanadium			8,282,000	7,649,000

Employees:

December 31, 1960, 9,300, of whom 3,000 were outside the United States, chiefly in Mexico.

American Smelting and Refining Company.——120 Broadway, New York 5.—Incorporated in New Jersey, April 4, 1899, consolidating a number of mines, smelters, and refineries. The company and subsidiaries are primarily engaged in custom smelting and refining nonferrous mineral commodities and in selling refined metals. In addition, the company operates owned, leased, and managed mines; buys and processes nonferrous scrap and sells secondary metals; and mines coal and produces coke, principally for company use. In 1960 the company operated copper, lead, and zinc smelters and refineries with refined metal capacities of 480,000 tons of copper, 528,000 tons of lead, and 214,000 tons of zinc annually. It also operates cadmium plants at Corpus Christi, Tex., and Denver, Colo.; a zinc dust plant at Sand Springs, Okla.; and sulfuric acid plants at Selby, Calif., Tacoma, Wash., Corpus Christi, Tex., and San Luis Potosi, Mexico. It also has lead-fabricating plants at Selby and San Francisco, Calif., Barber, N.J., and Houston, Tex. It recovers arsenic as a byproduct at the Tacoma and San Luis Potosi plants.

Principal products produced include: Copper, lead, zinc, gold, silver, antimony, arsenic, bismuth, cadmium, germanium, selenium, tellurium, asbestos, fluorspar, indium, coal and coke, zinc dust, zinc sulfate, copper sulfate, nickel salts, sulfuric acid, mixed and semifabricated metals (aluminum, brass, and copper ingots, babbits, special alloys, tin products, etc.), and fabricated lead products.

The company owns or has controlling interest in the following subsidiaries, as well as lesser holdings in many other operations:

Companies 100 percent owned:
- Ardco, Inc.
- Asarco Exploration Co. of Canada, Ltd.
- Asarco International Corp.
- Asarco Mercantile Co., Tex.
- Compania American Smelting, S.A., Chile.
- Compania American Smelting Boliviana, S.A.
- Compania Minera Asarco, S.A., Mexico.
- Compania de Terrenos e Inversiones de San Luis Potosi, S.A., Mexico.
- Compania Minera y Beneficiadora de San Antonio y Anexas, S.A., Mexico.
- Federal Mining & Smelting Co.; inactive.
- Federated Metals Canada, Ltd.
- Federated Metals Corp., Pa.; inactive.
- Great Western Smelting & Refining Co.; inactive.
- Incar, Inc.
- International Metal Co., N.Y.
- Lake Asbestos of Quebec, Ltd., Del.

Companies 100 percent owned—Continued
- Lone Star Lead Construction Corp., N.Y.
- Mines Trading Co., Ltd., England.
- Northern Peru Mining Corp., Peru.
- Union Smelting and Refining Co., N.Y.; inactive.

Companies less than 100 percent owned:	Percent
Alta Mining and Development Co., Utah	62.4
Blackhawk Mining and Development Co., Ltd	99.7
Compania Metalurgical Mexicana	60.3
Compania Minera de Jesus Maria, S.A., Mexico	77.9
Fairview Mining Co., Ltd., Canada	78.0
Garfield Chemical & Manufacturing Corp., N.Y	50.0
Government Gulch Mining Co., Ltd., Idaho	72.4
Green Hill Cleveland Mining Co., Nev	50.0
Liard River Mining Co., Ltd., Canada	70.0
Mount Isa Mines, Ltd., Australia	53.8
Neptune Gold Mining Co	51.8
Sociedad Minera Milluschaqui, Ltd	94.0
Southern Peru Copper Corp	51.5
Southern Peru Copper Sales Corp	51.5
Wyoming Mining & Milling Co., Idaho	95.6

The company and/or subsidiaries have various stockholdings in other corporations (in which company denies any effective control) among which are:

Company:	Percent owned
Compania Minera de Osidro y Anexas, S.A., Mexico	49.0
General Cable Corp	31.5
Revere Copper & Brass, Inc	35.0
United Park City Mines Co	9.8
Kennecott Copper Corp	0.9
Zinc Industrial, S.A., Mexico	50.0

Capitalization:

Preferred stock (7 percent cumulative preferred par $100) authorized and outstanding 500,000 shares. Common stock, authorized 8,000,000 shares; outstanding Dec. 31, 1960, 5,446,602 shares; reserved for option, 108,200 shares; no par.

Assets and liabilities:

December 31, 1960; total current assets $200,842,000; total current liabilities $66,014,000; net current assets $134,828,000.

Employees:

As of December 31, 1959, 25,729.

Mine production:	Metal content of concentrates and shipping ore					
Year:	*Tons ore mined*	*Tons copper*	*Tons lead*	*Tons zinc*	*Ounces gold*	*Ounces silver*
1951	2, 453, 071	16, 568	98, 318	159, 119	35, 429	11, 193, 029
1955	5, 828, 133	40, 091	107, 524	187, 704	57, 755	13, 331, 536
1960	5, 292, 768	41, 531	86, 335	159, 743	28, 270	11, 706, 526

Refinery production:						
Year:	*Tons copper*	*Tons lead*	*Tons zinc*	*Tons other zinc* [1]	*Ounces gold*	*Ounces silver*
1951	414, 226	503, 851	146, 588	116, 984	1, 196, 096	72, 370, 258
1955	353, 554	459, 789	186, 436	132, 986	1, 006, 183	72, 646, 739
1960	433, 111	387, 564	201, 694	119, 317	940, 421	95, 401, 945

[1] Zinc content of zinc concentrates, zinc dust, zinc fume, and slag shipped to others.

Mines in the United States:
- *Galena Unit.*—Wallace, Idaho—silver, copper, lead, zinc.
- *Ground Hog Mine.*—Vanadium, N.M.—silver, lead, zinc; operations suspended.
- *Jack Waite Mining Co.*—Duthie, Idaho—silver, lead, zinc.
- *Keystone Unit.*—Crested Butte, Colo.—silver, lead, zinc; operations suspended.
- *Mission Mine.*—Near Tucson, Ariz.—copper.
- *Page Unit.*—Kellogg, Idaho—silver, lead, zinc.
- *Silver Bell Unit.*—Near Tucson, Ariz.—copper.

Mines in Mexico:
- *Charcas Unit.*—Charcas, San Luis Potosi, Mexico—silver, copper, lead, zinc.
- *Concepcion del Oro Unit.*—Zacatecas, Mexico—copper.
- *Encantada Unit.*—Agujita, Coahuila, Mexico—fluorspar.
- *Montezuma Lead Co.*—Santa Barbara, Chihuahua, Mexico—gold, silver, copper, lead, zinc; owned by CiaMetalurgica Mexicana.
- *Nuestra Senora Unit.*—Cosalo, Sinaloa, Mexico—lead, zinc, silver.
- *Parral Mines.*—Parral, Chihuahua, Mexico—gold, silver, copper, lead, zinc.
- *Plomosas Mines.*—Picachos, Chihuahua, Mexico—silver, lead, zinc.
- *Rosita, Agumita, and Cloete Mines.*—Near Rosita, Coahuila, Mexico—coal and coke.
- *San Martin Unit.*—Sombrerete, Zacatecas, Mexico—silver, copper, lead, zinc.
- *Santa Barbara Mine.*—Santa Barbara, Chihuahua, Mexico—gold, silver, copper, lead, zinc.
- *Santa Eulalia Mines.*—Santa Eulalia, Chihuahua, Mexico—silver, lead, zinc.
- *Taxco Mine.*—Taxco, Guerrera, Mexico—gold, silver, lead, zinc.
- *Vesper Unit.*—Parral, Chihuahua, Mexico— silver, lead, zinc.

Mines in Other Foreign Countries:
- *Buchans Mine.*—Buchans, Newfoundland, Canada—lead, zinc, copper, gold, silver.
- *Lake Asbestos of Quebec, Ltd.*—Black Lake, Quebec, Canada—asbestos fibre; capacity approximately 100,000 tons per year.
- *Mt. Isa Mines, Ltd.*—Mt. Isa, Queensland, Australia—silver, copper, lead, zinc.
- *Neptune Gold Mining Co.*—Bonanza, Nicaragua—gold.
- *Northern Peru Mining Co.*—Trujillo, Peru—copper, zinc, lead, gold, silver.
- *Southern Peru Copper Corp.*—Toquepala mine, Peru—copper.

Smelters:	Capacity, tons of charge		
Location:	*Copper*	*Lead*	*Zinc*
Mt. Isa, Australia [1]	470, 000	165, 000	-------
El Paso, Tex	420, 000	360, 000	-------
Hayden, Ariz	360, 000	-------	-------
Tacoma, Wash	600, 000	-------	-------
San Luis Potosi, Mexico	300, 000	[2] 300, 000	-------
Ilo, Peru [3]	500, 000	-------	-------
East Helena, Mont	-------	360, 000	-------
Selby, Calif	-------	192, 000	-------
Chihuahua, Mexico	-------	500, 000	-------
Amarillo, Tex	-------	-------	100, 000
Rosita, Mexico	-------	-------	120, 000
Corpus Christi, Tex	-------	-------	165, 000

[1] Owned by Mt. Isa Mines, Ltd.
[2] Operations discontinued August 1959.
[3] Owned by Southern Peru Copper Corp.

Refineries:	Capacity, tons per year		
Location:	*Copper*	*Lead*	*Zinc*
Perth Amboy, N.J	168, 000	96, 000	-------
Baltimore, Md	198, 000	-------	-------
Tacoma, Wash	114, 000	-------	-------
Omaha, Nebr	-------	180, 000	-------
Selby, Calif	-------	72, 000	-------
Monterey, Mexico	-------	180, 000	-------
Amarillo, Tex	-------	-------	49, 000
Corpus Christi, Tex	-------	-------	105, 000
Rosita, Mexico	-------	-------	60, 000
Townsville, Australia [1]	80, 000	-------	-------

[1] Owned by Mt. Isa Mines, Ltd.

The Anaconda Company.———25 Broadway, New York.—Incorporated June 18, 1895, in Montana, as Anaconda Copper Mining Co.; name was changed to The Anaconda Company June 18, 1955. The company and subsidiaries are engaged in mining, milling, and smelting nonferrous metal ores; refining and selling the metals obtained from these ores; fabricating semifinished and finished copper and brass products; producing and fabricating aluminum; mining and processing uranium and manganese ores; and recovering, treating, and selling byproduct metals. The principal metals recovered from ores treated are copper, lead, and zinc; however, silver, gold, arsenic, cadmium, chromium, vanadium, selenium, and tellurium, also are recovered.

The company is both an operating and holding organization, having control of substantial stockholdings in the following subsidiaries:

Companies 100 percent owned:
- Anaconda Aluminum Co.
- Anaconda-American Brass Co.
- Anaconda-American Brass, Ltd., Canada.
- Anaconda Building Materials Co.
- Anaconda Iron Ore (Ontario) Ltd.
- Anaconda Sales Co.
- Butte Anaconda & Pacific Railway Co.
- International Smelting and Refining Co.
- Montana Hardware Co.

Companies less than 100 percent owned:	*Percent owned*
Andes Copper Mining Co	99. 446
Butte Water Co	99. 995
Chile Copper Co	99. 756
Chile Exploration Co	99. 756
Chile Steamship Co	99. 756
Greene Cananea Copper Co	99. 505
Inspiration Consolidated Copper Co	28. 17
Santiago Mining Co	96. 673

Capitalization:

$600,000,000 in 12,000,000 shares of $50 each; 10,715,127 shares outstanding, December 31, 1960.

Assets and liabilities:

December 31, 1960, total current assets, $276,211,000; total current liabilities, $58,145,353.
Employees, 1960: 37,000.

Mines:

Principal mining operations in the United States are at Butte, Mont.; Yerington, Nev.; and near Grants, N.M. At Butte large low-grade copper deposits were developed in the noted Greater Butte Project:

Kelley Mine.—This was started as a block-caving operation in 1952; an average of 11,500 tons of ore per day was mined in 1960.

Berkeley Mine.—The open-pit, 32,610 tons of ore was produced daily in 1960, a 14-percent increase over 1959. Projects in preparation for working the high-grade vein deposits at deeper levels were initiated in 1960 as plans for deepening the Kelley No. 1, Steward, and Mountain Con shafts got under way.

Yerington Mine.—At Weed Heights, Lyon County, Nev., production was started in November 1953. The oxide ore is leached and the copper is recovered by cementation on scrap iron; the sulfide ore is concentrated in a newly constructed flotation mill. Precipitation from the cementation process and the sulfide concentrate are shipped to the company smelter at Anaconda, Mont.

The company also produces uranium bearing ores from the open-pit Jackpile mine in New Mexico and a 3,000-ton-per-day uranium processing plant at Bluewater, New Mexico.

Company subsidiaries own and operate the following large mines in Chile:

Chuquicamata Mine.—The largest copper mine in the world, Chuquicamata, is operated by Chile Exploration Co., a wholly owned subsidiary of Chile Copper Co., which in turn is 99.756-percent owned by The Anaconda Company. Plant facilities consist of a leaching plant, concentrator and molybdenum recovery unit, smelter, electrolytic refinery, and electrowinning refinery.

El Salvador Mine.—Operated by Andes Copper Mining Co., the mine and plants have a productive capacity of 115,000 tons of copper per year. Operations began in April 1959. Concentrate is transported by pipeline and rail for treatment in the company Potrerillos smelter.

La Africana Mine.—Operated by Santiago Mining Co., the mine is about 15 miles west of Santiago, Chile. A 400-ton-per-day concentrator was erected, and production was started in September 1957.

In Mexico, Compania Minera de Cananea, S.A. de C.V., formerly the Cananea Consolidated Copper Company, a 99.97 percent owned subsidiary of Greene Cananea Copper Company, has an open-pit and underground mine, a concentrator, and a smelter near Cananea, Sonora. A small portion of the copper is produced from leaching-in-place of waste dumps and mined-out portions of the underground mine. The concentrator treats 16,000 tons of ore a day and furnishes the smelter with 650 to 700 tons of concentrate daily. Blister copper cakes, containing significant recoverable quantities of gold and silver, are the end product of Cananea operations. Cananea blister is refined and fabricated in plants near Mexico City in which Anaconda has a substantial interest. Cananea is the source of all the copper refined and fabricated in Mexico, and the major portion of this copper is consumed in Mexico.

Smelters and refineries:

In the United States The Anaconda Company has a copper smelter at Anaconda, Mont., having an annual capacity of 1 million tons of charge, and a lead smelter at Tooele, Utah, having a capacity of 300,000 tons of lead. Copper refineries are at Great Falls, Mont., 150,000 tons capacity; and Perth Amboy, N.J.; International Smelting and Refining Co., 240,000 tons capacity. The company also has an electrolytic zinc plant at Great Falls, Mont., having an annual capacity of 162,000 tons of slab zinc. Production by The Anaconda Company, copper, short tons:

Appalachian Sulphides, Inc.———Jefferson, N.C.—Appalachian Sulphides, Inc., a wholly owned subsidiary of Nipissing Mines Company, Ltd., incorporated in Ontario, Canada, in 1952, owns and operates the Ore Knob mine at Jefferson, N.C., which ranked 22d as a copper producer in the United States in 1960. Concentrates produced in its 750-ton-per-day mill are shipped to U.S. Metals Refining Co. (American Metal Climax, Inc) at Carteret, N.J., for smelting and refining; the refined metal is marketed by Phillips Bros. Division of Minerals & Chemicals, Phillips Corp.

Production in 1960 was 5,438 tons of copper, 26 percent greater than in 1959; 23,300 ounces of silver; and 1,694 ounces of gold. From the beginning of operations in March 1957 until December 31, 1960, the mine produced 17,482 tons of copper, 93,355 ounces of silver, and 6,143 ounces of gold. (This mine was acquired by Copper Range Co. in 1960 and was closed in 1962.)

Bagdad Copper Corp.———Bagdad, Ariz.—Incorporated February 28, 1927, in Delaware. The corporation operates an open-pit mine and flotation mill in the Eureka mining district, Yavapai County, Ariz. The mill has a capacity of 3,500 tons daily and concentrates are shipped to the American Smelting and Refining Co. smelter at Hayden, Ariz.

Two miles west of the present mill, construction of a $2 million leaching plant and auxiliary sulfuric acid plant was started in July 1960, to recover copper from low-grade copper ore; estimated production from this unit will amount to about 20 tons of copper per day.

Capitalization:

800,000 shares authorized; 558,458 shares outstanding; 241,542 shares in treasury; par $5, changed from $1 par in 1934.

Assets and liabilities:

Total current assets, December 31, 1960, were $1,917,367; total current liabilities, $794,873.

Employees: December 31, 1960, 351.

Production:

Copper—1960, 11,931 tons; 1959, 11,975 tons. The Bagdad mine ranked 20th as a copper producer in the United States in 1960.

Production by The Anaconda Company, copper, short tons:

	1959	1960
Domestic:		
Montana:		
Vein mines	18,403	26,336
Kelley mine	18,130	19,458
Berkeley pit	32,634	44,281
Other	1,029	922
Total	70,196	90,997
Nevada: Yerington mine	20,332	42,697
Total	90,528	133,694
Foreign:		
Chile:		
Chuquicamata	306,497	254,778
El Salvador	60,314	86,859
La Africana	3,558	5,907
Total	370,369	347,544
Mexico: Cananea	32,182	30,976

All production, short tons:

	1956	1957	1958	1959	1960
Copper:					
Company mines	469,276	451,248	415,120	490,200	511,805
Purchased and toll material	99,985	99,788	84,148	86,575	85,869
Total	569,261	551,036	499,268	576,775	597,674
Zinc:					
Company mines	46,504	37,297	16,534	18,021	6,669
Purchased and toll material	175,494	175,188	142,599	75,344	135,913
Total	221,998	212,485	159,133	93,365	142,582
Aluminum	61,512	52,056	49,846	50,743	56,625
Lead	44,788	41,310	22,336	14,864	17,035
Silver, ounces	12,006	11,042	7,374	6,688	8,946
Gold, ounces	79	78	59	62	90
Manganese oxide nodules, about 60 percent Mn	72,834	65,223	61,409	--------	7,369
Ferromanganese, about 80 percent Mn	39,671	22,407	25,825	2,502	11,017
Arsenic trioxide	2,121	1,960	2,699	2,137	1,974
Cadmium	978	857	623	309	620

Banner Mining Co.———2042 Conner Stravenue, Tucson, Ariz.—Incorporated under Nevada laws September 27, 1935. The company owns two mines and a 400-ton-per-day mill at Lordsburg, N. Mex.; three mines and a 1,000-ton-per-day mill near Tucson, Ariz.; and mining claims near Lordsburg, N. Mex., and in Pima County, Ariz.

Mines:

New Mexico.—Bonney and Misers Chest.
Arizona.—Mineral Hill, Daisy, and Palo Verde.

Production:

		1959	1960
Copper	tons	3,109	3,200
Gold	ounces	354	902
Silver	do	74,576	61,477

Employees: December 31, 1960, 245.

Capitalization:

December 31, 1960, 600,000 shares authorized; 580,030 shares outstanding; par $1.

Assets and liabilities:

December 31, 1960, total current assets, $579,480; total current liabilities, $324,309.

Bethlehem Cornwall Corp.———Bethlehem, Pa.—The corporation is a wholly owned subsidiary of Bethlehem Steel Co., operating the Cornwall mine, Cornwall, Lebanon County, Pa. The mine is mainly an iron producer, but considerable copper, gold, and silver are recovered as byproducts, and it ranked 25th among copper producers in the United States in 1960. Ore is mined by block caving. Daily capacity of the magnetic separation plant is 6,000 tons; the flotation plant, 2,200 tons; and the sintering plant, 2,400 tons. The copper concentrate is shipped to Phelps Dodge Refining Corp. at Laurel Hill, N.Y. Production of copper increased in 1960 to 3,085 short tons from 1,935 tons in 1959.

Calumet & Hecla, Inc.———122 South Michigan Ave., Chicago 3, Ill.—Incorporated as Calumet & Hecla Consolidated Copper Co., September 10, 1923, consolidating Calumet & Hecla Mining Co., Ahmeek Mining Co., Allouez Mining Co., Centennial Copper Mining Co., and Osceola Consolidated Mining Co. Present name was adopted October 31, 1952.

Calumet & Hecla, Inc., is primarily an operating company that is completely integrated with respect to copper, having mining, smelting, refining, and fabricating operations. It operates deep-shaft copper mines and related processing facilities on the Keweenaw Peninsula of upper Michigan. It also has a uranium mine in the Ambrosia Lake district, near Grants, N.M. However, the company is primarily a metal fabricator—having principal plants in Detroit, Mich.; London, Ontario, Canada, and Decatur, Ala.

The Wolverine Tube Division (formerly Wolverine Tube Corp.) is one of the largest single units producing seamless nonferrous tubing. A wholly owned subsidiary, Canada Vulcanizer & Equipment Co., Ltd., London, Ontario, Canada, manufactures fin tubing, Unifin, used in heat transfer equipment. Calumet &

Hecla of Canada, Ltd., London, Ontario, Canada, 100 percent owned, produces nonferrous tubing and tube products.

Other important divisions and subsidiaries are:

Goodman Lumber Division—an integrated lumbering operation involved in the selective cutting and processing of mature timber for the building trades, furniture plants, and other wood-using industries.

Flexonics Corp. of Canada, Ltd., Brampton, Ontario—producing aeronautical and missile products, industrial and automotive hose, expansion joints, and bellows.

Flexonics Division at Bartlett, Ill.—producing the same materials as the Canadian plant.

Alabama Metallurgical Corp. (Alamet), 70-percent owned—with plants at Ryan and Selma, Ala., for mining dolomite and for producing primary magnesium and calcium.

Lake Chemical Co., Mich., 50-percent owned—producing and marketing chemical products. (Other 50 percent owned by Harshaw Chemical Co.)

Capitalization:

100,000 shares of $4.75 cumulative preferred stock, Series A, no par value and 5,000,000 common shares of $5 each authorized; 41,220 shares of preferred and 2,159,571 shares of common stock outstanding, December 31, 1960.

Assets and liabilities:

December 31, 1960, total current assets, $23,577,130; total current liabilities, $5,844,132.

Employees: December 31, 1960, 3,928.

Production:

Calumet & Hecla, Inc., ranked 17th among the major copper producers in the United States in 1960. Production of primary copper was 16,163 short tons, a decrease from 17,407 tons in 1959. Total production of refinery shapes from primary, secondary, and toll copper was 26,648 tons.

Cerro Corp.———300 Park Ave., New York 22.—Incorporated in New York, October 27, 1915, as Cerro de Pasco Copper Corp.; name changed to Cerro de Pasco Corp. May 31, 1951, and to present title December 30, 1960. The company is an operating and holding company with interests in the United States, Peru, and Chile.

By a reorganization of the company, January 1, 1957, the mining properties, concentrators, smelters, and refineries in Peru were transferred to a wholly owned subsidiary, Cerro de Pasco Corp., incorporated in Delaware. Also, all petroleum exploration concessions in Peru formerly owned by the parent company were acquired by another wholly owned subsidiary, Cerro de Pasco Petroleum Corp. Other wholly owned subsidiaries are: Cerro Sales Corp., Circle Wire and Cable Corp., and Fairmont Aluminum Co.

The Lewin-Mathes Company was acquired in 1957 and was operated as a division of Cerro Corp. for secondary smelting and refining of nonferrous metals and manufacture of brass tube and pipe. In 1959, all assets of Consolidated Coppermines Corp. were acquired and its subsidiaries Rockbestos Wire & Cable Co. and Titan Metal Manufacturing Co. operated as divisions of the parent company. The Viking Copper Tube Company, a specialized manufacturer of high-quality seamless copper tube in Cleveland, Ohio, was acquired in June 1961. Early in 1962 Lewin-Mathes, Titan, and Viking were unified into a single division of the parent corporation and called the Cerro Copper & Brass Company Division. Cerro Corp. owns 96.7 percent of the capital stock of Rio Blanco Copper Corp., Ltd., which controls ownership of the Rio Blanco orebody in Chile and holds a 22¼ percent interest in the capital stock of Southern Peru Copper Corp.

Capitalization:

$46,250,000; 4,250,000 shares of common stock $5 par value and 250,000 shares preferred stock $100 par value. Issued December 31, 1960, 2,646,132 shares common stock.

Mining, smelting, and refining facilities:

In the United States:

Lewin-Mathes Company Division; secondary smelter and electrolytic refinery, Monsanto, Ill.

In Chile:

Compania Minera Andina, S.A., Rio Blanco copper mining project, near Santiago, Chile; in initial development.

In Peru:

Cerro de Pasco Corp., incorporated in Delaware; see Peru.

Southern Peru Copper Corp., 22¼ percent interest:

Toquepala mine, mill, and smelter in southern Peru.

Compania de Minas Buenaventura, S.A., 32.5 percent interest; metal mining.

Explosives, S.A., 31.4 percent interest; explosives manufacture.

Refractarios Peruanos, S.A., 42 percent interest; manufacture of refractory brick.

Compania Minera Raura, S.A., 60 percent interest; metal mine in development stage.

Copper and brass mills in the United States:

Cerro Copper & Brass Company Division, copper and brass tube mill, Monsanto, Ill.; brass rod and wire mills, Bellefonte, Pa.; fabricated brass products mill, Bellefonte, Pa.; brass rod and brass forging mill, Newark, Calif.

Wire and cable mills:

Circle Wire & Cable Corp.:

Wire and cable mill, Maspeth, Long Island, N.Y.

Copper rod and steel-strip mills, Hicksville, Long Island, N.Y.

Electrical metallic-tube plant, Hicksville, Long Island, N.Y.

Rockbestos Wire & Cable Co. Division:

Wire and cable mill, New Haven, Conn.

Industrias de Cobre, S.A., 46 percent interest:

Copper wire and cable mill, Lima, Peru.

Aluminum rolling mills:

Fairmont Aluminum Co.:

Aluminum rolling mill, Fairmont, W. Va.

United Pacific Aluminum Co. Division:

Aluminum rolling mill, Los Angeles, Calif.

	1959			1960		
Metal production:	*From corporation ores*	*From purchased ores*	*Total*	*From corporation ores*	*From purchased ores*	*Total*
Copper tons	26,701	10,182	36,883	26,918	9,878	36,796
Lead do	26,362	35,899	62,261	33,186	46,757	79,943
Zinc do	29,595	----	29,595	35,156	----	35,156
Silver 1,000 ounces	5,023	7,112	12,135	6,044	8,920	14,964
Gold do	23	13	36	22	20	42

Principal nonferrous metal products:

Electrolytic copper. Electrolytic-lead-corroding, chemical and antimonial grades: Electrolytic zinc, special high-grade and die-casting grade: Refined silver, gold, refined bismuth, bismuth alloys, cadmium, tellurium, selenium, crude antimony, and zinc concentrates.

Brass mill and wire mill products: Copper and copper alloy sheet, strip, tube, pipe, rod, bar, circles, and other semifabricated shapes. Also aluminum sheet, strip, circles, and blanks.

Cerro de Pasco Corp. produces about 16 percent of the bismuth consumed annually in the world; about 60 percent is used in producing fusible alloys, and the remainder is used for pharmaceutical and industrial purposes.

Copper Range Company.———24 Federal St., Boston 10, Mass.—Incorporated in Michigan, January 20, 1899. Since incorporation the company has acquired:

- Copper Range Consolidated Co., 1915.
- Baltic Mining Co., 1917.
- Trimountain Mining Co., 1923.
- Atlantic Mining Co., 1925.
- Whealkate Mining Co., 1928; mineral rights.
- South Range Mining Co., 1928; mineral rights.
- White Pine Copper Co., 1929.
- Victoria Copper Co., 1929.
- National Mining Co., 1929.
- Copper Range Motor Bus Co., 1929.
- Champion Copper Co., 1931.
- Naumkeag Copper Co., 1931.
- St. Mary's Mineral Land Co., 1931.
- St. Mary's Canal Mineral Land Co., 1931.
- C. G. Hussey & Co., 1936.
- Globe Properties, 1937.
- Copper Range R.R. Co.; company owns 78 percent of issued stock.
- Alloyd Corp., Cambridge, Mass.; minority interest, 1959.

The company acquired control of C. G. Hussey and Company of Pittsburgh, manufacturers of sheet copper in 1931 and acquired the remainder of the stock in 1936.

Capitalization:

Authorized 3,000,000 shares of $5 each; outstanding December 31, 1960, 1,877,473 shares.

Assets and liabilities:

December 31, 1960, total current assets, $30,187,875; total current liabilities, $4,036,732.

Employees: December 31, 1960, 2,364.

Copper production, 1960:

Champion mine .... short tons	2,482
White Pine mine .... do	37,463
Total	39,945

Mines and plants:

White Pine Mine.—Located at White Pine, Mich., about 50 miles southwest of the Champion mine. Operated by White Pine Copper Co., a wholly owned subsidiary, which was organized in 1950 to develop the White Pine ore body. November 15, 1951, the Reconstruction Finance Corp. approved 20-year, 5-percent mortgage loans totaling $64,395,599 to finance development and for constructing mining, milling, smelting, and housing facilities. On December 31, 1960, the loan had been reduced to $39,080,731. The mill has a capacity of 10,500 tons daily, and the smelter is capable of producing 50,000 tons of refined copper annually. Production commenced January 31, 1955. On February 15, 1952, the Government contracted with White Pine to purchase 275,000 tons of refined copper at 25½ cents per pound plus escalations due to increases in government cost indexes (labor, etc.). In December 1957, White Pine Copper Co. exercised its option under this contract to deliver its production to the Government. The price of copper had dropped to 27 cents per pound, and the escalated contract price was 28.5 cents per pound.

Champion Mine.—Located at Painsdale, Mich.; ore is shipped to the company Freda mill. Production amounted to 2,482 tons in 1960.

Freda Mill.—Freda, Mich., 2,100 ton gravity and flotation plant treats ore from the Champion mine and Redridge tailings. Concentrates are shipped to the White Pine smelter.

Douglas Mine.—Keweenaw County, Mich. Leased to Calumet & Hecla, Inc.

Copper and Brass Rolling Mills.—Operated by C. G. Hussey & Company, a wholly owned subsidiary, at Pittsburgh, Pa.

Cyprus Mines Corp.———523 West 6th St., Los Angeles 14, Calif.—Incorporated March 10, 1916, in New York. Operates the Old Dick mine near Bagdad, Ariz., and has a 50-percent interest in Pima Mining Co., which has the Pima open-pit mine near Tucson, Ariz. Has leasehold concessions on copper and pyrite mines on the Island of Cyprus. These mines are the Mavrovouni, Skouriotissa, and Apliki. The corporation also has interests in 43 producing oil wells and gas wells in Kansas, Texas, and Louisiana; owns sawmills and plywood plants at Medford, Oreg., and timberlands in Oregon, California, Alabama, and British Columbia. It is affiliated with Marcona Mining Co., 43.75 percent, and Cia. San Juan, S.A., 44.65 percent; Albatross Sulfuric Acid & Chemical Works, Rotterdam, 45 percent; Hawaiian Cement Corp., 42 percent; and Titanium Dioxide Works, Ltd., Rotterdam, 22.50 percent.

Capitalization:

Authorized 7,500,000 shares of $4 each, outstanding December 31, 1960, 4,883,000 shares.

Assets and liabilities:

December 31, 1960, total current assets, $58,584,644: total current liabilities, $8,452,852.

Employees: December 31, 1960, 3,311.

Production, short tons:

	1959	1960
United States:		
Pima mine:		
Ore	1,200,606	1,327,473
Concentrate	56,590	50,044
Old Dick mine:		
Ore	76,111	80,940
Copper concentrate	8,078	11,028
Zinc concentrate	19,350	12,661
Cyprus, island mines:		
Ore		888,094
Copper concentrate		104,807
Flotation pyrite		509,976
Cupreous pyrite		195,237
Copper precipitate		224,112

Reserves, December 31, 1960:

	Short tons	Copper, percent	Zinc, percent
United States:			
Pima mine	6,600,000	1.64	-----
Old Dick mine	353,000	3.30	11.3
Cyprus:			
Mavrovouni	2,058,000	3.6	47.5
Skouriotissa	2,800,000	2.0	40.0
Apliki	1,848,000	1.8	36.0

Duval Sulphur & Potash Co.———1906 First City National Bldg., Houston 2, Tex.—Incorporated as Duval Texas Sulphur Co. under Texas laws August 18, 1926. Present name adopted February 13, 1950. Company is controlled by United Gas Corp., which owns 75 percent of the outstanding stock. It is engaged in mining, processing, and marketing sulphur, potash, and copper concentrates.

Copper ore is mined and concentrated at the company Esperanza open-pit mine about 28 miles south of Tucson, Ariz. Stripping of waste overlying the ore body commenced in 1957 and continued into 1959. Construction of the 12,000-ton-per-day mill was completed in February, and production began in March 1959. The concentrate is treated for recovery of molybdenite, and the copper concentrate is shipped to the American Smelting and Refining Co. smelter at Hayden, Ariz. The production of copper-in-concentrate was 17,036 tons in 1959 and 25,368 tons in 1960.

Capitalization:

Authorized, 2,000,000 shares; outstanding, 1,300,000 shares on Dec. 31, 1960.

Assets and liabilities:

December 31, 1960, total current assets, $15,064,746; total current liabilities, $4,676,795.

Employees: December 31, 1960, 742.

Inspiration Consolidated Copper Co.———25 Broadway, New York 4, N.Y.—Incorporated December 18, 1911, in Maine, as a consolidation of Inspiration Copper Co. and Live Oak Development Co. Subsequently other properties were acquired from Warrior Copper, New Keystone Copper, Porphyry Consolidated Copper, and Southwestern Development companies. In 1955 the Christmas mine was purchased from Christmas Copper Corp., and the Miami, Ariz., smelter of International Smelting and Refining Co. was purchased on April 1, 1960.

Capitalization:

Authorized 1,500,000 shares of $20 each; outstanding on December 31, 1960, 1,181,967 shares.

Assets and liabilities:

December 31, 1960, total current assets, $21,162,747; total current liabilities, $3,112,785.

Employees: December 31, 1960, 1,503.

Mines and Plants:

The Inspiration mine, the sixth largest in Arizona, consists of two open-pit operations, the Thornton and the Live Oak pits. Mixed oxide-sulfide ore is treated by the dual process adopted in 1957. In this process the ore is leached with dilute sulfuric acid solutions that dissolve the soluble oxide copper content and about 35 percent of the sulfide content; the leached residue from this process is treated at the concentrator by flotation for recovery of the undissolved sulfide minerals, and the concentrate is smelted to blister copper. The electrolytic plant is divided into two sections. One section is devoted to electrowinning copper directly from leaching solutions; the other is employed for electrorefining anode copper resulting from the smelting of copper concentrate and precipitate. Cathodes are shipped to the International Smelting and Refining Co. refinery at Perth Amboy, N.J., for melting and casting into marketable shapes.

Copper is also recovered from leaching-in-place certain caved and mined-out underground areas and surface waste dumps. Copper is precipitated from this leach solution with scrap iron by the cementation process, and the precipitate is sent to the smelter.

Copper production in 1960 from ores—0.857 percent copper, 0.448 percent oxide, 0.409 percent sulfide—was almost 38,000 tons and from leaching in place operations was 2,500 tons. Production of molybdenum amounted to 433,681 pounds contained in sulfide concentrates.

Development work at the Christmas mine and construction of a 4,000-ton-per-day concentrator were completed in July 1962 and operations began in August. Concentrates are trucked to the Inspiration smelter at Miami, Ariz.

Kennecott Copper Corp.———161 East 42nd St., New York 5.—Incorporated in the State of New York, April 29, 1915. The company is an operating and holding concern and with its subsidiaries is engaged in these two kinds of business: (1) The chief activity is operation of its copper mines, concentrators, smelters, and refineries and sale of refined copper and other metals recovered as byproducts in the copper operations—including molybdenum, gold, silver, selenium, tellurium, rhenium, platinum, and palladium; and (2) the fabrication of copper and brass into mill products or finished items. Titanium and columbium are produced by Quebec Iron & Titanium Corp. and Tin & Associated Minerals, Ltd., subsidiaries. A list of the subsidiaries with the percent of voting control and business follows:

Companies 100 percent owned:

- Bear Creek Mining Co.
- Braden Copper Co., Chile.
- Chase Brass & Copper Co., Inc.
- Kennco Exploration, Ltd., Canada.
- Kennecott Sales Corp.
- Kennecott Refining Corp.
- Metal Sales Co., Ltd., England.
- Mines Products Corp.
- Nevada Northern Railway Co.
- Ozark Lead Co.
- Ridge Mining Corp.
- The Okonite Co.

Companies less than 100 percent owned:	*Percent*
Allied-Kennecott Titanium Corp	50. 0
Garfield Chemical & Manufacturing Corp.	50. 0
Kenbestos Mining Co., Ltd., Greece	95. 0
Quebec Columbium Ltd., Canada	45. 9
Quebec Iron & Titanium Corp., Canada	66. 67
The Superior Wire Cloth Co	68. 1
Tin Associated Minerals Ltd., Nigeria	76. 0

Through investment, the company has interests in Kaiser Aluminum & Chemical Corp.; Molybdenum Corporation of America; Compania de Acero del Pacifico; Western Phosphates, Inc.; and other companies.

Capitalization:

Authorized 12,000,000 shares; outstanding November 30, 1960, 11,053,051 shares; no par.

Assets and liabilities:

December 30, 1960, total current assets, $301,036,716; total current liabilities, $53,274,177.

Employees: December 31, 1960, 27,205.

Production:

	1959	*1960*
Copper, short tons:		
Domestic	235, 228	384, 088
Chilean	182, 017	187, 221
Total	417, 245	571, 309
Molybdenite, thousand pounds	20, 967	27, 426
Gold ounces	240, 179	396, 839
Silver do	2, 167, 469	3, 700, 784

Mines and plants:

Utah Copper Division.—In Bingham, Utah, the Utah Copper Division mine is the second largest copper producer in the world, ranking next to the Chile Exploration Co. Chuquicamata mine. Open-pit mining covers an area of 1,042 acres, and an average of 90,000 tons of ore is produced daily; in 1960 the ore averaged 0.81 percent copper. The ore is concentrated in company mills at Magna and Arthur, Utah. Both of these mills have molybdenite recovery units. The copper concentrate is shipped to the Utah smelter—annual capacity 1,225,000 tons of charge—and the blister copper is refined at the company electrolytic refinery, also at Garfield—capacity 204,000 tons of refined copper.

Chino Mines Division.—Comprised of the Chino mine at Santa Rita, N. Mex., and a concentrator and smelter at Hurley, N. Mex., 9 miles away. The Chino mine, an open-pit operation, was the sixth largest copper producer in the United States in 1960 with its output of 62,725 tons. Approximately 30 percent of this production was recovered from an enlarged and improved precipitation system handling dump-leach solutions. Most of the output of this division is marketed as fire-refined copper.

Ray Mines Division.—The Ray open-pit mine, Ray, Ariz., ranked eighth among United States copper producers in 1960. The ore is concentrated and smelted in company facilities at Hayden, Ariz. Sponge iron is produced from pyrite and is used as the precipitant in the complex leach-precipitation-flotation process employed at the mill for recovery of both oxide and sulfide values in the ore. Ore mined in 1960 averaged 0.9 percent copper; 58,799 tons of copper was produced. A substantial amount of copper was recovered from leaching abandoned underground block-caving areas. The blister copper is shipped to the refineries of Kennecott Refining Corp. and American Smelting and Refining Co. in Baltimore, Md.

Nevada Mines Division.—Mining has been concentrated in the Liberty Pit, Ruth, Nev., for more efficient mining and utilization of manpower. Previously ore was mined simultaneously from three pits. In 1960, the Liberty Pit ranked ninth among copper producers in the United States; 47,439 tons of copper was produced from ore averaging 0.79 percent copper. The ore is concentrated, then smelted in company plants at McGill, Nev. Blister copper produced is refined at the refineries of Kennecott Refining Corp. and American Smelting and Refining Co. in Baltimore, Md.

Kennecott Refining Corp.—A wholly owned subsidiary, operating the new electrolytic refinery completed in 1960—annual capacity, 198,000 tons—in Anne Arundel County, Md., where blister copper from the western divisions and Braden Copper Co. in Chile is refined.

El Teniente Mine.—In Sewell, Chile, see Braden Copper Co. under foreign producers.

Allard Lake Mines.—In eastern Quebec, Canada; iron-titanium properties are owned by the Quebec Iron & Titanium Corp. Ore treatment facilities are at Sorel, Quebec. One hundred million tons of ore, averaging 82 percent combined iron and titanium oxides, has been outlined and is being developed as an open-pit mine. In 1960, 863,726 tons of ore was treated for a production of 221,945 tons of iron and 345,213 tons of titanium slag.

Magma Copper Co.———300 Park Avenue, New York 22.—Incorporated in Maine, May 7, 1910. Magma Copper Co. is an operating and holding company engaged in mining and treating copper ore. Newmont Mining Corp. owns 82.5 percent of the company stock. The following subsidiaries are 100 percent owned:

- Magma Arizona Railroad Co.
- San Manuel Copper Corp.
- San Manuel Arizona Railroad Co.
- San Manuel Townsite Co.

Capitalization:

Authorized, 3,000,000 shares; outstanding December 31, 1960, 1,264,940 shares, par $10. The San Manuel Copper Corp. has an authorized capital of 1,500,000 shares of $1 par value; all outstanding shares are owned by Magma Copper Co.

Assets and liabilities:

December 30, 1960, total current assets, $32,426,182; total current liabilities, $8,411,694.

Employees: December 31, 1960, 1,100.

Mines and Plants:

Magma Copper Co.—The Magma mine, mill, and smelter are at Superior, Pinal County, Ariz. The property has been developed by eight shafts and has been in commercial production since 1915. In 1960, the Magma mine ranked 15th as a copper producer in the United States. The concentrator has capacity for treating 1,500 tons of ore per day, and the smelter has an annual capacity of 150,000 tons of charge. The blister copper produced is refined by Phelps Dodge Refining Corp.

Production, San Manuel Copper Corp.:		*1958*	*1959*	*1960*
Copper	short tons	74, 701	46, 170	81, 724
Molybdenite	pounds	1, 872, 450	1, 435, 613	2, 807, 671
Gold	ounces	16, 868	10, 232	18, 010
Silver	do	253, 858	158, 594	290, 617

Production, Magma Copper Co.:		*1958*	*1959*	*1960*
Copper	short tons	20, 658	13, 011	18, 917
Gold	ounces	12, 623	9, 302	14, 374
Silver	do	552, 009	368, 004	624, 141

In 1960 the mine produced 386,636 tons of ore—assaying 5.10 percent copper, 0.04 ounce gold, and 1.73 ounces silver.

San Manuel Copper Corp.—The San Manuel mine is one mile south of Tiger, Pinal County, Ariz., and 45 miles northeast of Tucson. The concentrator and smelter are approximately seven miles from the mine at the townsite of San Manuel, Ariz. In 1960, 12.3 million tons of 0.71 percent copper ore was mined for an average of 34,250 tons per operating day. In copper production the mine ranked fourth among the United States producers.

Newmont Mining Corp.———300 Park Avenue, New York 22.—Incorporated as Newmont Corp. in Delaware, May 2, 1921, as successor to Newmont Co. (Maine) Present title adopted June 2, 1925. Newmont is a holding company engaged in exploration, development, and financing of mining and petroleum properties and in investment of its capital in securities of existing mining and oil companies.

Exploration and development of nonferrous metal deposits has been conducted in North and South America, Africa, Europe, and the Philippine Islands. The company interest in mining and petroleum industries is indicated by the following partial list of its holdings:

Company:	*Percent owned*
Canadian Export Gas & Oil Ltd	16. 0
Cassiar Asbestos Corp., Ltd	16. 4
Continental Oil Co	4. 5
Creole Petroleum Corp	<1. 0
Cyprus Mines Corp	12. 2
Dawn Mining Co	51. 0
El Paso Natural Gas Co	<1. 0
Granduc Mines, Ltd	37. 6
Idarado Mining Co	74. 2
Lucky Friday Silver-Lead Mines Co	11. 0
Magma Copper Co	82. 5
Newmont Mining Corp. of Canada, Ltd	100. 0

Company—Continued	Percent owned
Newmont Oil Co	100. 0
O'okiep Copper Co., Ltd	56. 3
Palabora Mining Co., Ltd	26. 0
Phelps Dodge Corp	2. 9
St. Joseph Lead Co	3. 9
Sherritt Gordon Mines, Ltd	37. 4
Societe Algerienne du Zinc	31. 8
Societe Nord-Africaine du Plomb	31. 8
Southern Peru Copper Corp	10. 3
Tennessee Gas Transmission Co	<1. 0
Transcontinental Gas Pipe Line Corp	1. 6
Tsumeb Corp. Ltd	28. 5

Capitalization:

Authorized 6,000,000 shares; outstanding December 31, 1960, 2,824,518 shares; par $10.

Assets and liabilities:

December 31, 1960, total current assets, $11,675,088; total current liabilities, $1,754,247.

Phelps Dodge Corp.———300 Park Avenue, New York 22.—Incorporated in New York, August 10, 1885, as Copper Queen Consolidated Mining Co.; present name adopted in 1917. Through the years the company has acquired Detroit Mining Co., Burro Mountain Copper Co., Stag Canon Fuel Co., Montezuma Copper Co., Nicholas Copper Co., National Electric Products Corp., Calumet & Arizona Mining Co., United Verde Copper Co., and the Tucson, Cornelia and Gila Bend R.R. Co.

Phelps Dodge Corp., with its subsidiaries, is engaged in copper mining, milling, smelting, refining, fabricating, and selling. The company also does custom smelting and refining and operates railroads, electric utility companies, and general merchandise stores—all incidental to its various operations.

Copper is the principal metal produced. Molybdenite concentrates, gold, silver, platinum, palladium, selenium, and tellurium also are recovered from the ores. The company makes and markets copper sulfate and nickel sulfate. Over half of the copper produced is marketed in semifabricated and fabricated forms, such as rod, wire, tube, and extruded shapes.

The company is both a holding and operating concern, owning 100 percent of the stock of the following subsidiaries on December 31, 1960:

- Ajo Improvement Co.
- Anson Mines, Ltd., Canada.
- Ashfork Mines, Ltd., Canada.
- Cochise Publishing Co.
- Colfax Mines, Ltd., Canada.
- Mesa Mines Ltd., Canada.
- Moctezuma Copper Co.; inactive.
- Morenci Water & Electric Co.
- New Cornelia Cooperative Mercantile Co.
- Phelps Dodge Corp. of Canada, Ltd.
- Phelps Dodge Copper Products Corp.
- Phelps Dodge Copper Products International Corp.
- Phelps Dodge Copper Products, Puerto Rico.
- Phelps Dodge Exploration Corp.
- Phelps Dodge Mercantile Co.
- Phelps Dodge Refining Corp.
- Showlow Mines Corp.
- Stargo Mines, Ltd., Canada.
- Tempe Mines Corp.
- T.C. & G.B. Railroad Co.
- Tyrone Mines, Ltd., Canada.
- Warren Co.
- Yuma Mines, Ltd., Canada.

Other interests are: Phelps Dodge Copper Products of the Philippines—51-percent owned; United States Underseas Cable Corp.—formed in March 1960 jointly with Northrup Corp. and Felton & Guilleaume Carlswerk Aktiengesellschaft of Cologne, West Germany.

Capitalization:

Authorized, 12,000,000 shares; issued, 10,855,522 shares; in treasury, 713,002 shares; outstanding December 31, 1960, 10,142,520 shares; par $12.50

Assets and liabilities:

December 31, 1960, total current assets, $211,663,037; total current liabilities, $40,132,396.

Employees: December 31, 1960, 13,735.

Production:

	1959	1960
Copper, short tons:		
Smelter production	193, 557	234, 081
Refined production	315, 001	410, 857
Silver ounces	2, 289, 130	3, 281, 413
Gold do	88, 704	117, 414

Smelter production is derived from two sources, company ores and a very small amount of custom ores treated at its Arizona smelters. Refined production is from company smelter material and metals treated on toll for account of others and a very small amount of purchased custom material.

Mines and Plants:

Phelps Dodge Corp., Western General Offices, Douglas, Ariz.:

Morenci Branch, Morenci, Ariz.—This comprises open-pit mine, concentrator, and smelter. The Morenci open-pit mine is the second largest copper producer in the United States. It is the leading producer in Arizona, where it ranked second in molybdenum, third in silver, and sixth in gold in 1960. Copper production 1960, 105,640 tons.

New Cornelia Branch, Ajo, Ariz.—This open-pit mine, concentrator, and smelter operation ranked fifth as a copper producer in the United States and third in Arizona in 1960; copper production was 66,693 tons.

Copper Queen Branch, Bisbee, Ariz.—Included are underground mines, Lavender open-pit mine, concentrator, and precipitation plant. The branch ranked seventh as a copper producer in the United States in 1960 and fourth in Arizona, where it was also first in gold and second in silver output. Copper production: Copper Queen, underground, 25,575 tons; Lavender Pit, 33,248 tons.

Douglas Reduction Works, Douglas, Ariz.:

Smelts ore and concentrate from the Copper Queen mine, concentrate from the Lavender Pit mill, precipitate from leaching operations at the Lavender Pit, some scrap, and a small tonnage of custom material. Smelter capacity is 1,250,000 tons of charge; 800,410 tons of copper-bearing material was smelted in 1960.

Moctezuma Copper Co., Nacozari, Sonora, Mexico:

Leaching of mine workings was discontinued in December 1960, and operations were completely shut down.

Phelps Dodge Refining Corp.:

El Paso Refinery, El Paso, Tex.—The copper refinery has an annual capacity for 290,000 tons electrolytic and 25,000 tons fire refined. Also copper sulfate and nickel sulfate plants.

Laurel Hill Refinery, Laurel Hill, Long Island, N.Y.—A copper refinery that has an annual capacity of 175,000 tons electrolytic and a copper smelter, having annual charge capacity of 200,000 tons. Also copper sulfate and nickel sulfate plants.

Phelps Dodge Copper Products Corp.:

American Copper Products Division, Bayway, N.J.—Rod and wire mill.

Bayway Tube Division, Bayway, N.J.—Alloy rods and extruded shapes.

Mines and Plants—Continued

Phelps Dodge Copper Products Corp.—Continued

South Brunswick Tube Division, South Brunswick, N.J.—Tube mill.

Habirshaw Cable and Wire Division, Yonkers, N.Y.—Insulated wire and cable mills.

Inca Manufacturing Division, Fort Wayne, Ind.—Magnet wire mill.

Indiana Rod and Wire Division, Fort Wayne, Ind.—Rod and wire mill.

Los Angeles Tube Division, Los Angeles, Calif.—Tube mill.

Quincy Mining Co.———63 Wall St., New York 5.—Incorporated in Michigan June 1, 1932, as successor in reorganization to a company of the same name—originally incorporated in Michigan by special charter granted March 30, 1848, reincorporated March 6, 1878, and in 1908. The company is engaged in mining and smelting copper and in real estate and securities investments.

Capitalization:

Authorized, 250,000 shares; outstanding, 131,400 shares; par $25.

Assets and liabilities:

December 31, 1960, total current assets, $2,359,526; total current liabilities, $124,093.

Employees: December 31, 1960, 110.

Mines and Plants:

The company operates a tailing-reclamation plant for recovering copper in tailing deposited before 1910 in Torch Lake from the company mill, a mill with two gravity concentrators and flotation units of 5,500 tons daily capacity, and a smelter of 150 tons daily capacity. Copper production in 1960 was 1,722 tons.

Tennessee Corp.———61 Broadway, New York 6.—Incorporated October 14, 1916, in New York as Tennessee Copper & Chemical Corp., acquiring Tennessee Copper Co., which was incorporated April 24, 1899, in New Jersey to mine copper. Present name was adopted December 2, 1930. Tennessee Copper Co., a subsidiary, was dissolved December 31, 1956, and subsequently was operated as a division. Operating assets of Miami Copper Co. were acquired June 10, 1960; it is now operated as a division.

The company is engaged in producing copper, zinc concentrate, iron sinter, fertilizer, and chemicals. Its principal products are: (1) Commercial fertilizers; (2) super- and triple super-phosphate, used in company fertilizers and sold to others; (3) iron sinter, sold to operators of blast furnaces mainly in the Birmingham, Ala., district; (4) blister copper; (5) zinc concentrate; and (6) sulfuric acid, used by its own fertilizer plants and sold to other industries.

Tennessee Corp. is both a holding and an operating company. As of December 31, 1959, it owned 100 percent of the voting control of the following subsidiaries:

Adolph Lewisohn Selling Corp.
Capital Fertilizer Co.
Cleveland Agricultural Chemical Co.; inactive.
Copper Cities Transportation Co.
Number Twenty Copper Mining Co.; inactive.
Sand Mountain Fertilizer Co.; inactive.
Southern Agricultural Chemical Corp.; inactive.
Tencor Trading Corp.
Tennessee Copper Co.; inactive.
Tenn.—Tampa Co.; inactive.
The New Haven Copper Co., Seymour, Conn.
The North Carolina Exploration Co.; inactive.
U.S. Phosphoric Products Corp.; inactive.

It also owned 90 percent of Chester Cable Corp., a wire manufacturer. Holdings in Adolph Lewisohn and Chester Cable were acquired June 10, 1960, from Miami Copper Co.

Capitalization:

Authorized 5,000,000 shares; outstanding December 31, 1960, 3,935,529 shares; par $1.25.

Assets and liabilities:

December 31, 1960, total current assets, $56,196,000; total current liabilities, $13,498,000.

Mines and Plants, Operating Divisions:

Tennessee Copper Company Division, Copperhill, Tenn.—The principal mines are the Polk County, Burra-Burra, Boyd, Calloway, and Eureka. The company operates flotation, roasting, sintering, smelting, and sulfuric acid plants. It ranked 19th among United States copper producers in 1960. Products are: Blister and shot copper, 50-percent zinc concentrate, 68-percent iron sinter, sulfuric acid, copper sulfate, copper salts and fungicides, liquid sulfur dioxide, organic sulfonates, sodium hydrosulfite, zinc oxide, and ferric sulfate (Ferri-Floc).

Miami Copper Company Division, Miami, Ariz.—Ore is mined by open-pit methods and treated to recover a copper concentrate at the Copper Cities mine. Copper precipitate, cement copper, is recovered by leaching at the Miami and Castle Dome mines. Copper concentrate and precipitate are smelted by Inspiration Consolidated Copper Co. at Miami, Ariz., and Phelps Dodge Copper Corp. at Douglas, Ariz.; the blister copper produced is refined by International Smelting and Refining Co. at Perth Amboy, N.J., and Phelps Dodge Refining Corp. at El Paso, Tex. The selling agent is Adolph Lewisohn Selling Corp.

U. S. Phosphoric Products Division, East Tampa, Fla.—This division produces triple superphosphate, superphosphate, hydrofluosilicic acid, sodium fluosilicate, potassium fluosilicate, and phosphoric acid and uranium.

Subsidiary Companies:

Capital Fertilizer Company, Montgomery and Decatur, Ala.—The Montgomery plant produces superphosphate and complete fertilizers. The Decatur plant produces complete fertilizers from superphosphate furnished by the Montgomery plant.

The New Haven Copper Co., Seymour, Conn.—Fabricates plate, sheet, strip, and roll copper.

Tencor Trading Corp.—Operates facilities for warehousing triple superphosphate and DiMoN at Peoria, Ill., and St. Paul and Winona, Minn.

Chester Cable Corp., Chester, N.Y.—This is a wire and cable mill.

Primary Copper Mills and Primary Wire Mills

The primary copper mines—formerly referred to as primary brass mills—make up that part of the industry engaged in initial forming or alloying and forming refinery shapes and scrap into standard semifabricated forms of copper and copper alloys; such as, plate, sheet, strip tube, rod, and wire. Subsequent operations involve further rolling, drawing, and shaping so that the products will meet specification dimension and design.

The primary wire mills roll refined copper wirebars or extrude refined copper billets into rods that are drawn in stages to finished wire. Wire is also produced by redraw mills that obtain rod from the primary wire mills. There are other types of mills designed for singular operations such as insulation and stranding.

The company names, addresses and plant locations of the primary copper and wire mills are shown in tables 74 and 75.

Principal Associated Government and Industry Groups

A number of government agencies and national associations deal with minerals and metals and publish information regarding them. These organizations are shown in table 76. More information about government organizations is obtainable in "The United States Government Organization Manual", Federal Register Division, National Archives and Records Service, Washington, D.C. 20402, and the latest edition of the Official Congressional Directory, United States Government Printing Office.

TABLE 74.—*Primary copper mills*

Company	General Office	Location of fabricating plants	Type of products
American Smelting and Refining Company.	120 Broadway, New York, N.Y.	Perth Amboy, N.J.	Copper and brass mill products.
Ampco Metal, Inc.	1745 S. 38th St., Milwaukee 46, Wis.	Milwaukee, Wis.	Rods and shapes.
Anaconda American Brass Co.	414 Meadow St., Waterbury, Conn.	Los Angeles, Calif.; Ansonia Torrington, Waterbury, Conn.; Detroit, Mich; Buffalo, N.Y.; and Kenosha, Wis.	Plates, sheet, strip, tubes, rods, and shapes, wire, brass bars, print rolls, commutator.
Berryllium Corp.	P.O. Box 1462, Reading, Pa.	Reading, Pa.	Beryllium copper products, complete line, except tube.
Bohn Aluminum & Brass Corp.	1400 Lafayette Bldg., Detroit 26, Mich.	Adrian, Mich.	Rod, extruded shapes, wire.
Bridgeport Brass Co., Division of National Distillers and Chemical Corporation.	30 Grand St., Bridgeport 2, Conn.	Indianapolis, Ind.; Seymour, Conn. (Seymour Mfg. Co.).	Brass and copper mill products—sheet, strip, rod, wire, and tube.
Bridgeport Rolling Mills Co.	Bridgeport 1, Conn.	Bridgeport, Conn.	Alloy sheet and strip.
The Bristol Brass Corp.	580 Broad St., Bristol, Conn.	Bristol, Conn.	Copper and brass mill products.
Cerro Copper & Brass Co., Division of Cerro Corp.	1111 Chouteau Avenue, St. Louis 2, Mo.	Newark, Calif.; Monsanto, Ill.; Bellefonte, Pa.	Copper and brass tube, rod, shapes and electrolytic copper.
Chase Brass & Copper Co., Inc.	236 Grand St. Waterbury 20, Conn.	Waterbury, Conn.; Cleveland, Ohio.	Strip, tubes, rod, extruded shape, mechanical wire.
Chicago Extruded Metals Co.	1821 S. 54th Ave., Cicero 50, Ill.	Cicero, Ill.	Rod, shapes, wire.
Detroit Gasket & Mfg. Co.	Belding, Mich.	Belding, Mich.	Do.
Driver Harris Co.	P.O. Box 31, Harrison, N.J.	Harrison, N.J.	Alloy wire and rod.
Wilbur B. Driver Co.	1875 McCarter Highway, Newark 4, N.J.	Newark, N.J.	Alloy rod and wire.
Eastwood Nealley Corp.	28 Joralemon St., Belleville 9, N.J.	Belleville, N.J.	Alloy rod and wire.
The Electric Materials Co.	Clay & Washington Sts., North East, Pa.	North East, Pa.	Bus bar, commutators, rod.
Handy & Harman	82 Fulton St., New York 28, N.Y.	New York, N.Y.; Bridgeport 1, Conn.	Alloy sheet and strip.
Hoskins Mfg. Co.	4445 Lawton Ave., Detroit 8, Mich.	Detroit, Mich.	Cupronickel resistance wire rod.
Howe Sound Copper and Brass, Division of Howe Sound Company.	Rolling Place, Springdale, Conn.	Springdale, Conn.	Copper, brass and bronze strip.
C. G. Hussey & Co., Division of Copper Range Co.	2850 Second Ave., Pittsburgh 19, Pa.	Pittsburgh, Pa.	Rod, sheet, strip.
International Silver Co.	500 S. Broad St., Meriden, Conn.	Meriden, Conn.	Alloy sheet.
Miller Company	99 Center St., Meriden, Conn.	Meriden, Conn.	Sheet, strip, tube.
Mueller Brass Co.	Port Huron, Mich.	Port Huron, Mich.	Rod, shapes, tube.
New England Brass Co.	Taunton, Mass.	Taunton, Mass.	Sheet and strip.
The New Haven Copper Co.	79 Main St., Seymour, Conn.	Seymour, Conn.	Plate, sheet, strip.
Olin Mathieson Chemical Corp.	Shamrock St., East Alton, Ill.	New Haven, Conn., East Alton, Ill.	Sheet, strip, rod, bus bar, shapes.
Phelps Dodge Copper Products Corp.	300 Park Ave., New York 22, N.Y.	Los Angeles, Calif.; Bayway and South Brunswick, N.J.; Fort Wayne, Ind.	Rod, tube, wire, bus bar, strip and special shapes.
Plume & Atwood Mfg. Co.	235 E. Main St., Thomaston, Conn.	Thomaston, Conn.	Alloy sheet and strip.
H. K. Porter Company, Inc., Riverside-Alby Metal Division.	1 Pavilion Ave., Riverside, N.J.	Riverside, N.J.	Alloy strip, rod, wire.
Reading Tube Co., Division of Progress Mfg. Co.	Seventh & South Sts., Reading, Pa.	Reading, Pa.	Tube, pipe.
Revere Copper and Brass, Inc.	230 Park Ave., New York 17, N.Y.	Los Angeles, Calif.; Chicago & Clinton, Ill.; Baltimore, Md.; New Bedford, Mass.; Detroit, Mich.; and Rome, N.Y.	Plates, sheet, strip, tubes, rods and shapes, mechanical wire, bus bar, print rolls, commutators.
Scovill Mfg. Co.	99 Mill St., Waterbury 20, Conn.	Waterbury, Conn.; New Milford, Conn.	Alloy sheet, rod, wire and brass and copper tube.
Triangle Conduit & Cable Co., Inc.	P.O. Box 711, Jersey Ave., New Brunswick, N.J.	New Brunswick, N.J.	Tube.
U.S. Mint Service, Treasury Dept.	Washington 25, D.C.	Philadelphia, Pa.; Denver, Colo.	Alloy sheet.
Volco Brass & Copper Co.	801 Blvd., Kenilworth, N.J.	Kenilworth, N.J.	Sheet, strip, rod, wire.
Waterbury Rolling Mills, Inc.	P.O. Box 550, Waterbury 20, Conn.	Waterbury, Conn.	Sheet and strip.
Western Electric Co., Inc.	222 Broadway, New York 38, N.Y.	Chicago, Ill.	Rod, sheet, tube.
Westinghouse Electric Corp.	700 Braddock Ave., East Pittsburgh, Pa.	East Pittsburgh, Pa.	Do.
Wolverine Tube Division of Calumet & Hecla, Inc.	17200 Southfield Road, Allen Park, Mich.	Decatur, Ala.; Detroit, Mich; Inkster, Mich.	Tube.

TABLE 75.—*Primary wire mills*

Company	General office	Location of fabricating plants
Anaconda Wire & Cable Co	Hastings-on-Hudson 6, N.Y	Great Falls, Mont.; Hastings-on-Hudson, N.Y.
Circle Wire & Cable Corp	5500 Maspeth Ave., Maspeth, L.I., N.Y.	Maspeth, N.Y.
Copperweld Steel Co	322 Frick Bldg., Pittsburgh 19, Pa.	Glassport, Pa.
General Cable Corp	730 Third Ave., New York 17, N.Y.	Los Angeles, Calif.; St. Louis, Mo.; Perth Amboy, N.J.; Rome, N.Y.
General Motors Corp	3044 W. Grand Blvd., Detroit 2, Mich.	Warren, Ohio.
Hatfield Wire & Cable Division of Continental Copper & Steel Industries, Inc.	Hillside, N.J.	Hillside, N.J.
The Okonite Co.—subsidiary of Kennecott Wire & Cable Corp., Kennecott Wire & Cable Division.	200 Passaic St., Passaic, N.J.	Phillipsdale, R.I.
Phelps Dodge Copper Products Corp	300 Park Ave., New York 22, N.Y.	Fort Wayne, Ind.; Bayway, N.J.
Rods, Inc	23rd St., Marion, Ind.	Marion, Ind.
Rome Cable Corp	332–400 Ride St., Rome, N.Y.	Rome, N.Y.
Triangle Conduit & Cable Co., Inc	P.O. Box 711, Jersey Ave., New Brunswick, N.J.	New Brunswick, N.J.
Western Electric Co., Inc	222 Broadway, New York 38, N.Y	Chicago, Ill.; Baltimore, Md.

TABLE 76.—*Principal Government and industry groups concerned with the copper industry*

	Address
Government Agencies:	
Bureau of the Census	Department of Commerce
Business and Defense Services Administration.	Do.
Bureau of Mines	Department of the Interior.
Geological Survey	Do.
Office of Minerals Exploration.	Do.
Office of Minerals Mobilization.	Do.
Agency For International Development.	Department of State.
Bureau of the Budget	Executive Offices of the President.
Office of Emergency Planning.	Do.
Defense Materials Service.	General Services Administration.
Export-Import Bank	
Small Business Administration	
Tariff Commission	
National Associations:	
American Bureau of Metal Statistics.	50 Broadway, New York 4, N.Y., E. Boano, Director.
American Foundrymen's Society.	Golf and Wolf Roads, Des Plaines, Ill., W. W. Maloney, General Manager.
American Institute of Mining, Metallurgical and Petroleum Engineers, Inc.	The United Engineering Center, 345 East 47th St. New York, N.Y., Ernest Kirkendall, Secretary.
American Mining Congress.	1200 18th Street, N.W., Washington 6, D.C., Julian D. Conover, Secretary.
American Ordnance Association.	Mills Building, Washington 6, D.C., L. A. Codd, Executive Vice President.
American Society for Metals.	Metals Park, Novelty, Ohio, Allan Ray Putnam, Managing Director.
American Society for Testing Materials.	1916 Race St., Philadelphia 3, Pa., R. E. Hess, Acting Exective Secretary.
American Standards Association.	10 East 40th St., New York 16, N.Y., Roger Gay, Managing Director.
Brass and Bronze Ingot Institute.	300 West Washington St., Chicago 6, Ill.

TABLE 76.—*Principal Government and industry groups concerned with the copper industry*—Con.

	Address
Brookings Institution	1775 Massachusetts Ave., N.W., Washington 6, D.C., Robert D. Calkins, President.
Copper and Brass Research Association.	420 Lexington Ave., New York 17, N.Y., T. E. Velfort, Managing Director.
Copper Institute	50 Broadway, New York 4, N.Y., E. Boano, Secretary.
Electrochemical Society	1860 Broadway, New York 23, N.Y., Robert K. Shannor, Executive Secretary.
Engineers Council For Professional Development.	345 East 47th St., New York, N.Y., Elsie Murray, Executive, Secretary.
Engineers Joint Council	345 East 47th St., New York, N.Y., Leroy K. Wheelock, Secretary.
Industrial Research Institute.	100 Park Ave., New York 17, N.Y., C. G. Worthington, Secretary-Treasurer.
International Copper Research Association Inc.	1271 Avenue of the Americas, New York 20, N.Y., Charles H. Moore, Director.
Metal Powder Industries Federation.	60 East 42nd St., New York 17, N.Y., Kempton H. Roll, Executive Secretary.
Mineralogical Society of America.	U.S. National Museum, Washington 25, D.C., George Switzer, Secretary.
Mining and Metallurgical Society of America.	11 Broadway, New York 4, N.Y.
National Association of Manufacturers.	2 East 48th St., New York 17, N.Y., Charles P. Sligh, Jr., Executive Vice President.
National Association of Purchasing Agents.	11 Park Place, New York 7, N.Y., G. W. Howard Ahl, Executive Secretary-Treasurer.
National Association of Secondary Material Industries.	271 Madison Avenue, New York 16, N.Y., M. J. Mighdoll, Executive Vice President.
National Electrical Manufacturers Association.	155 East 44th St. New York 17, N.Y., Joseph F. Miller, Managing Director.

TABLE 76.—*Principal Government and industry groups concerned with the copper industry—Con.*

	Address
National Foreign Trade Council.	111 Broadway New York 6, N.Y., William S. Swingle, President.
National Industrial Conference Board.	460 Park Ave., New York 22, N.Y., John S. Sinclair, President.
Non-Ferrous Founders Society, Inc.	309 Terminal Tower, Cleveland, Ohio, Ben J. Imburgia, Secretary.
Pressed Metal Institute	3673 Lee Road, Cleveland 20, Ohio, H. A. Daschner, Managing Director.
Resources For The Future.	1775 Massachusetts Ave., N.W., Washington 6, D.C., John E. Herbert, Secretary.
Twentieth Century Fund.	41 East 70th St., New York 21, N.Y., August Heckscher, Director.
United Engineering Trustees.	345 East 47th St., New York, N.Y., Steven W. Marras, General Manager.
United States Copper Association.	50 Broadway, New York 4, N.Y., E. Boano, Secretary.
Wire Association	453 Main St., Stamford, Conn., Richard E. Brown, Executive Secretary.

Labor Organizations

Members of labor unions in copper mines, smelters, and refineries in the United States and Canada are represented largely in the International Union of Mine, Mill, and Smelter Workers, MMSW (I), an independent organization, and the United Steelworkers of America, which is an affiliate of the merged American Federation of Labor and Congress of Industrial Organizations (AFL–CIO), table 77. There are also a number of national, international, and local unions and associations connected with the various types of work at mines, mills, smelters, or refineries at particular locations. One large company in extending labor contracts relative to all its operations concluded agreements with 37 unions.

TABLE 77.—*Organization data of principal unions connected with the copper industry*

	Address
American Federation of Labor and Congress of Industrial Organizations: George Meany, President. Founded 1881—members 15,000,000; staff 600. Federation of national unions—135. Formed by merger of: The American Federation of Labor and the Congress of Industrial Organizations in 1955 (AFL–CIO).	815 16th Street, NW., Washington 6, D.C.
International Union of Mine, Mill and Smelter Workers, MMSW (I) John Clark, President. Founded 1893—members 100,000; locals 200. Independent.	941 East 17th Ave., Denver 18, Colo.
United Steelworkers of America: David J. McDonald, President. Founded 1936—members 960,000; locals 2,995. USA — affiliated with AFL–CIO.	1500 Commonwealth Bldg. Pittsburgh 22, Pa.
United Mine Workers of America: Thomas Kennedy, President. Founded 1890—members 600,000. UMWA—independent.	900 15th Street NW., Washington 5, D.C.
International Chemical Workers Union: Walter L. Mitchell, President. Founded 1944—members 81,144; locals 407. ICW — affiliated with AFL–CIO.	1659 West Market St. Akron 13, Ohio.
International Brotherhood of Electrical Workers: Gordon M. Freeman, President. Founded 1891—members 750,000; locals 1,754. IBEW — affiliated with AFL–CIO.	1200 15th Street, NW., Washington 5, D.C.

Source: Cohaney, Harry P., and Henry S. Rosenbloom. Directory of National and International Labor Unions in the United States, 1959. U.S. Department of Labor, Bull. 1267, December 1959.

Unions associated with the various operations of major copper producers in the United States and Canada are shown in table 78.

TABLE 78.—*Union affiliations at major copper mines, smelters, and refineries*

	Unions
United States:	
American Smelting & Refining Co.:	
Perth Amboy, N.J	International Union of Mine, Mill and Smelter Workers; United Auto Workers; International Union of Operating Engineers.
Baltimore, Md	International Union of Mine, Mill and Smelter Workers.
Hayden, Ariz., smelter	Do.
Silver Bell, Ariz	United Mine Workers, District 50.
Tacoma, Wash	International Union of Mine, Mill and Smelter Workers.
Mission, Ariz	Laborers District, Council; International Union of Operating Engineers; International Brotherhood of Teamsters, Chauffers, Warehousemen and Helpers of America; Laborers' Union.
The Anaconda Co.:	
Anaconda, Mont	United Steelworkers of America.
Butte, Mont	International Union of Mine, Mill and Smelter Workers.
Great Falls, Mont	Do.
Anaconda, Butte, Great Falls, Mont	International Brotherhood of Electrical Workers; various trade or craft unions.
Yerington, Nev	AFL–CIO Council.
Calumet & Hecla, Inc., Calumet, Mich	United Steelworkers of America.
International Smelting & Refining Co., Perth Amboy, N.J. (Raritan).	Do.
Cerro Corp.: Lewin Mathes Division, refinery St. Louis, Mo.	Do.
Inspiration Consolidated Copper Co.:	
Inspiration, Ariz	Trade and craft unions, AFL–CIO; Brotherhood of Railroad Trainmen AFL–CIO.
Miami, Ariz	International Union of Mine, Mill and Smelter Workers; International Association of Machinsts; Globe-Miami Metal Trades Council.
Kennecott Copper Corp.:	
Chino Mines Division	International Union of Mine, Mill and Smelter Workers.
Nevada Mines Division, Ruth & McGill, Nev	Do.
Ray Division, Ray, Ariz	United Steelworkers of America.
Utah Copper Division:	
Bingham, Utah	International Union of Mine, Mill and Smelter Workers.
Arthur & Magma mills	Do.
Garfield Smelter, Refinery	United Steelworkers of America.
Kennecott Refining Corp.: Anne Arundel County, Md	Do.
Magma Copper Co.:	
Magma Mine & Smelter, Superior, Ariz	International Union of Mine, Mill and Smelter Workers.
San Manuel Mine & Smelter, San Manuel, Ariz.	International Union of Mine, Mill and Smelter Workers; Brotherhood of Locomotive Firemen and Enginemen.
Nassau Smelting & Refining Co.: Staten Island, N.Y.	International Union of Mine, Mill and Smelter Workers.
Phelps Dodge Corp.:	
Ajo, Ariz	United Steelworkers of America.
Douglas, Ariz	International Union of Mine, Mill and Smelter Workers.
Morenci, Ariz	Do.
El Paso, Tex	Do.
Laurel Hill, Long Island City, N.Y	United Steelworkers of America.
All mine locations	AFL–CIO trade and craft unions; Railroad workers unions.
Tennessee Corporation:	
Tennessee Copper Division, Ducktown and Copperhill, Tenn.	International Chemical Workers Union.
Miami Copper Division, Miami, Ariz	International Union of Mine, Mill and Smelter Workers,
U.S. Metals Refining Co. (AMAX): Carteret, N.J	Do.
White Pine Copper Co., White Pine, Mich	United Steelworkers of America.
Canada:	
Hudson Bay Mining & Smelting Co., Flin Flon, Manitoba.	Canada Labor Congress, AFL–CIO.
Noranda Mines, Ltd., Noranda, Quebec	United Steelworkers of America.
Waite Amulet Mines, Ltd. (Noranda subsidiary)	Do.
Canadian Copper Refiners, Ltd. (Noranda) Montreal East.	Metal Refining Workers.
Gaspé Copper Mines, Ltd. (Noranda subsidiary)	Murdochville Workers Association.
International Nickel Co. of Canada, Ontario	International Union of Mine, Mill and Smelter Workers.

WORLD COPPER INDUSTRY

Growth of World Copper Industry

The cumulative world total of produced copper before 1800 has been estimated at less than 1 million tons, less than 1 percent of the total output from 1801 through 1960. Annual world production, about 18,000 tons in the first decade of the 19th century, increased steadily and reached about 545,000 tons in 1900. Accumulative world production from 1801 through 1900 totaled only 11.5 million tons. Since 1900 annual smelter production has increased nearly tenfold to almost 5 million tons in 1960.

Distribution of World Production

Copper was mined in 45 countries during 1960. Twenty-six of these countries produced more than 10,000 tons of copper, and eight—United States, Northern Rhodesia, Chile, U.S.S.R., Canada, Republic of the Congo, Peru, and Australia—exceeded 100,000 tons each; together they supplied 85 percent of the world total. Excluding the United States this major group produced 62 percent of the world output, and 13 companies in 5 of these countries accounted for 40 percent. Japan, China, Mexico, Republic of South Africa, and the Philippines are also important sources of copper.

Thirty countries had smelter production of copper in 1960. Twenty-three exceeded 10,000 tons, and nine—United States, Northern Rhodesia, Chile, U.S.S.R., Canada, West Germany, Republic of the Congo, Japan, and Peru—accounted for 89 percent of the world smelter output. Foreign countries supplied 64 percent.

Location of World Industry

Table 79 shows the 25 leading copper-producing companies in order of their 1960 output and their annual production from 1951 through 1963.

Table 80 lists smelting and refining plants outside the United States showing ownership, location, and capacity where available.

Important Foreign Copper Producing Companies

Following are descriptions of foreign copper-producing companies and their operations, compiled principally from these sources: Skinners' Mining Yearbook, 1961; Moody's Manual of Investments, Industrials, 1961; the World's Non-Ferrous Smelters and Refineries, 1960; and the latest available company reports.

NORTH AMERICA

Canada

Campbell Chibougamau Mines, Ltd.———55 Yonge St., Toronto, Ontario, Canada.—Incorporated March 10, 1950, in Province of Quebec. Owns control of Chibougamau Mining and Smelting Co., Inc.; Compania Minera Trans Rio, S.A. de C.V., to operate properties in Sonora, Mexico; and has management control of Chibougamau Venture, Ltd.

Capitalization:

Authorized 5,000,000 shares; outstanding June 30, 1961, 4,425,352.

Employees: June 30, 1961, 735; annual average.

Production, shipments:	*1959–60*	*1960–61*
Copper____tons__	16, 137	18, 744
Gold____ounces__	38, 377	34, 415
Silver____do____	310, 564	397, 726

Mines:

The company operates four mines and a 3,000-ton-per-day concentrator. The mines are the Main, Kokko Creek, Cedar Bay, and Henderson. Concentrate is shipped to Noranda Mines, Ltd., for smelting; blister is refined by Canadian Copper Refiners, Ltd.; and total production is sold by Noranda Mines, Ltd.

Canadian Copper Refiners, Ltd.———1700 Bank of Nova Scotia Bldg., 44 King St. West, Toronto 1, Ontario, Canada.—Incorporated February 6, 1929, in Canada, this is a subsidiary of Noranda Mines, Ltd. Owns an electrolytic copper refinery at Montreal East, Quebec, with an annual capacity of 240,000 tons. Production in 1960: 276,400 tons refined copper; 563,500 ounces gold, and 8,246,000 ounces silver. In addition selenium and tellurium are recovered, and copper sulfate is produced.

Capitalization:

20,000 shares, no par value; 18,455 shares held by Noranda Mines, Ltd.; balance, by Phelps Dodge Refining Corp.

The refinery receives most of its raw material from Noranda and its affiliates; has contract to refine blister produced by Hudson Bay Mining & Smelting Co., Ltd.

East Sullivan Mines, Ltd.———507 Place d'Armes, Montreal, Quebec, Canada.—Incorporated May 22, 1944, in Quebec, Canada. Affiliated with Sullivan Consolidated Mines, Ltd. Subsidiary is Sullico Mines, Ltd., formerly Quebec Copper Corp., Ltd.

Capitalization:

Authorized 4,500,000 shares; outstanding December 31, 1959, 4,250,000 shares. Sullivan Consolidated Mines, Ltd., owned 1,540,693 shares.

Production:	*1959*	*1960*
Copper____tons__	7, 182	3, 694
Zinc____do____	1, 756	4, 948
Gold____ounces__	4, 239	4, 125
Silver____do____	146, 822	155, 557

Mines: See chapter 4.

Noranda Mines, Ltd., handles smelting of the concentrate, and refining and marketing of the copper and precious metals.

Falconbridge Nickel Mines, Ltd.———44 King St. West, Toronto 1, Canada.—Incorporated August 28, 1928, in Ontario, Canada. Controlled by Ventures, Ltd.

Capitalization:

Authorized 5,000,000 shares; outstanding, 3,766,922 shares.

TABLE 79.—*Twenty-five leading copper producing companies in the world, in order of 1960 output, short tons*

Company	Country	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
Kennecott Copper Corp	United States	430, 187	444, 582	429, 052	338, 749	370, 487	402, 309	387, 291	318, 732	235, 228	384, 088
Union Minière du Haut-Katanga	Republic of the Congo	211, 596	226, 797	236, 020	246, 685	258, 680	272, 766	264, 860	259, 686	309, 088	331, 434
Chile Exploration Co	Chile	180, 237	175, 451	172, 858	205, 273	230, 741	266, 006	263, 422	234, 599	306, 497	254, 778
Phelps Dodge Corp.[1]	United States	250, 692	226, 584	223, 554	222, 137	257, 477	270, 181	246, 418	218, 574	193, 557	234, 081
Nchanga Consolidated Copper Mines, Ltd.	Northern Rhodesia	81, 924	102, 631	125, 540	129, 314	114, 897	122, 170	130, 191	149, 657	195, 784	209, 556
Braden Copper Co	Chile	171, 247	184, 813	140, 347	108, 330	156, 228	179, 896	172, 707	191, 578	182, 017	187, 221
International Nickel Co. of Canada, Ltd.	Canada	122, 168	117, 568	122, 337	129, 522	134, 156	141, 448	148, 028	92, 493	142, 082	154, 679
Southern Peru Copper Corp.[2]	Peru	-----	-----	-----	-----	-----	-----	-----	-----	-----	145, 115
The Anaconda Company	United States	54, 372	57, 802	74, 471	75, 669	124, 016	127, 951	117, 069	111. 956	90, 528	133, 695
The Rhokana Corp., Ltd.[3]	Northern Rhodesia	90, 299	80, 923	88, 805	91, 606	81, 490	93, 262	94, 878	84, 473	109, 796	121, 839
Mufulira Copper Mines, Ltd.[4]	do	93, 655	82, 498	91, 301	102, 264	97, 257	109, 856	108, 394	88, 215	116, 495	118, 563
Roan Antelope Copper Mines, Ltd	do	88, 352	86, 537	104, 353	98, 829	91, 361	97, 565	92, 881	77, 121	105, 786	100, 935
Andes Copper Mining Co	Chile	44, 945	51, 565	45, 059	42, 257	44, 616	43, 020	43, 277	35, 981	60, 314	86, 859
San Manuel Copper Corp	United States	-----	-----	-----	-----	-----	39, 076	59, 899	74, 701	46, 170	81, 724
Mount Isa Mines, Ltd	Australia	-----	-----	17, 470	22, 308	24, 020	32, 434	30, 936	43, 241	62, 518	79, 252
Bancroft Mines, Ltd	Northern Rhodesia	-----	-----	-----	-----	-----	-----	15, 467	6, 215	40, 492	60, 363
Boliden Mining Co.[5]	Sweden	29, 762	31, 967	33, 400	34, 502	35, 130	35, 483	36, 299	37, 710	44, 551	41, 334
Hudson Bay Mining & Smelting Co., Ltd.	Canada	39, 541	39, 724	39, 962	45, 010	46, 667	46, 341	44, 364	45, 456	43, 914	40, 870
Inspiration Consolidated Copper Co	United States	39, 125	42, 535	39, 703	34, 096	38, 114	37, 083	35, 728	41, 821	47, 012	40, 400
O'okiep Copper Co., Ltd	Union of South Africa	22, 560	24, 921	24, 379	28, 915	30, 900	32, 472	30, 553	36, 570	37, 785	40. 116
White Pine Copper Co	United States	-----	-----	-----	-----	31, 921	37, 758	34, 459	41, 027	34, 907	37, 463
Gaspé Copper Mines, Ltd	Canada	-----	-----	-----	-----	6, 692	27, 617	17, 693	35, 266	33, 412	34, 597
Cerro Corp	Peru	26, 798	22, 554	25, 384	29, 029	34, 671	34, 100	45, 345	41, 441	36, 883	33, 000
Tennessee Corp.—Miami Copper Division.[6]	United States	50, 834	50. 270	46, 621	29, 135	48, 337	49, 762	43, 690	33, 369	31, 536	28, 750
Noranda Mines, Ltd. (Horne mine)	Canada	25, 315	25, 380	15, 396	21, 882	27, 734	26, 308	27, 287	28, 803	27, 086	25, 779

[1] Includes production from Moctezuma, Mexico, and copper produced from purchased ores.
[2] Content of blister copper.
[3] Excludes Nchanga.
[4] Blister only; in addition small quantities were produced during 1951–52 from ore treated elsewhere.
[5] Includes secondary.
[6] Division of Tennessee Corp. since June 11, 1960; production for entire year. Previously Miami Copper Co. and subsidiaries.

Source: American Bureau of Metal Statistics Yearbooks.

TABLE 80.—*Foreign copper smelters and refineries*

Location	Company	Smelters: Location of plant	Smelters: Capacity, tons of charge	Refineries: Location of plant	Refineries: Capacity short tons
North America:					
Canada	Canadian Copper Refiners, Ltd			Montreal, East Quebec	284,400
	Falconbridge Nickel Mines, Ltd	Falconbridge, Ontario	770,000		
	Gaspé Copper Mines, Ltd	Murdochville, Quebec	260,000		
	Hudson Bay Mining & Smelting Co., Ltd.	Flin Flon, Manitoba	575,000		
	International Nickel Co. of Canada, Ltd.	Copper Cliff, Ontario Coniston, Ontario	5,600,000 1,000,000	Copper Cliff, Ontario	168,000
	Noranda Mines, Ltd	Noranda, Quebec	1,600,000		
Mexico	American Smelting and Refining Company.	San Luis Potosi	300,000		
	Cia. Minera de Santa Rosalía S.A.	Santa Rosalía, Baja California	120,000		
	Cobre de Mexico, S. A			Atzcapotzalco, District Federal.	43,000
	Compania Minera de Cananea, S.A. de C.V.	Cananea, Sonora	290,000		
	Mazapil Copper Co., Ltd	Concepcion del Oro, Zacatecas	200,000		
South America:					
Chile	Andes Copper Mining Co	Potrerillos		Potrerillos	
	Braden Copper Co	Caletones		Caletones	180,000
	Chile Exploration Co	Chuquicamata		Chuquicamata	
	Cia. Minera Disputada de las Condes, S.A.	Chagres			
	Paipote National Smelter	Paipote			
Peru	Cerro de Pasco Corp	Oroya		Oroya	40,000
	Southern Peru Copper Corp	Ilo			
Europe:[1]					
Austria	Montanwerke Brixlegg, G.M.B.H			Brixlegg, Tirol	11,000
Belgium	Soc. Generale Metallurgique de Hoboken, S.A.	Hoboken		Olen	193,000
Finland	Outokumpu Oy	Harjavalta		Pori	37,000
France	Campagnie Generale D'Electrolyse Du Palais.	Palais-sur-Vienne		Palais-sur-Vienne	33,000
East Germany	Kupferwerk Ilsenburg A.G	Ilsenburg, Harz		Ilsenburg, Harz	
	Mansfeldscher Kupferschieferbergbau A.G.	Eisleben		Hettstedt	
West Germany	Duisburger Kupferhutte	Duisburg			
	Huttenwerke Kayser Aktiengesellschaft.	Lünen		Lünen	35,000
	Metallhuttenwerke Lubeck G.M.B.H.			Lübeck (Herrenwyk)	14,000
	Norddeutsche Affinerie	Hamburg		Hamburg	165,000
	Stadtberger Kupferhutte	Niedermarsberg, Nordrhein-Westfalen.			
	Zinnwerke, Wilhelmsburg, G.M.B.H.			Hamburg	26,000
Norway	Falconbridge Nikkelverk A/S			Kristiansand	18,000
	A/S Sulitjelma Gruber	Sulitjelma			
Spain	Electrolisis de Cobre S.A	Barcelona and Palencia		Palencia	13,000
	Compania Espanola De Minas de Rio Tinto S.A.	Huelva			
	Industrias Reunidas Minero Metalurgicas S.A.			Asua, Vizcaya	15,000
	Soc. Espanola de Construcciones Electro-Mecanicas S.A.			Cordoba	40,000
	Soc. Industrial Asturiana			Santa Barbara (Oviedo)	8,000
Sweden	Bolidens Gruvaktiebolag	Rönnskär		Rönnskär	50,000
	Reymersholms Gamla Industri Aktiebolag.	Hälsingborg and Oskarshamn			
United Kingdom	Actid, Limited			High Blantyre, Scotland	
	Thomas Bolton & Sons, Ltd			Widnes, Lancaster and Froghall, Stafford, England.	22,000
	British Copper Refiners, Ltd			Prescot; Lancaster, England	112,000
	Elkington Copper Refiners, Ltd			Walsall, Stafford, England	26,000
	Enfield Rolling Mills, Ltd			Brimsdown, England	73,000
	Imperial Chemical Industries, Ltd			Birmingham, England	8,000
Yugoslavia	Rudnici Bakra I Topionice Bor	Bor		Bor	61,000
Asia:					
India	Indian Copper Corp	Moubhandar, Bihar		Moubhandar, Bihar	9,000
Japan	Dai Nippon Kogyo K.K	Hasse, Akita-ken			
	Dowa Mining Co., Ltd	Kosaka, Akita-ken		Kosaka, Akita-ken	20,000
	Do	Okayama, Okayama-ken		Okayama, Okayama-ken	6,000
	Furukawa Electric Co., Ltd			Nikko, Tochigi-ken	40,000
	Furukawa Mining Co., Ltd	Ashio, Tochigi-ken			
	Mitsubishi Metal Mining Co., Ltd	Osarizawakozen, Akita-ken; Naoshima-cho, Kegawa-ken.		Kita-ku, Osaka City	47,000
	Mitsui Mining & Smelting Co., Ltd	Hibi, Okayama-ken		Takehara, Hiroshima-ken	37,000
	Nippon Mining Co., Ltd	Ogoyamachi, Ishikawa-ken			
	Do	Hitachi, Motoyama, Ibaraki-ken.		Hitachi, Ibaragi-ken	46,000
	Do	Saganoseki, Oita-ken		Saganoseki, Oita-ken	46,000
	Sumitomo Metal Mining Co., Ltd	Setose, Hokkaido-cho			
	Do	Besshidozan, Ehime-ken		Besshi-Ehime-ken	46,000
Turkey	Ergani Bakir Isletmesi Muessesesi	Damar-Maden		Maden	7,000
	Murgul Bakir Isletmesi			Damar Istanbul	6,000 6,000
	Rabak Electrolitik Bakir Fabrikasi			Istanbul	6,000

[1] U.S.S.R. copper smelters listed separately.

TABLE 80.—*Foreign copper smelters and refineries*—Continued

Location	Company	Smelters: Location of plant	Smelters: Capacity, tons of charge	Refineries: Location of plant	Refineries: Capacity short tons
Africa:					
Republic of the Congo.	Union Minière du Haut-Katanga	Lubumbashi, Katanga			
		Jadotville, Katanga		Jadotville, Shituru	160,000
		Luilu, Katanga		Luilu	55,000
Northern Rhodesia.	Mufulira Copper Mines, Ltd	Mufulira		Mufulira	114,000
	Nchanga Consolidated Copper Mines, Ltd.			Chingola	76,500
	Ndola Copper Refineries, Ltd			Ndola	110,000
	Rhodesia Copper Refineries, Ltd			Nkana	160,000
	Rhokana Corporation, Ltd	Nkana			
	Roan Antelope Copper Mines, Ltd	Luanshya			
Southern Rhodesia.	Messina Rhodesia Smelting & Refining Co.	Alaska			
	Messina (Transvaal) Development Co., Ltd.	Messina, Transvaal, Republic of South Africa.		Messina, Transvaal, Republic of South Africa.	16,000
	O'okiep Copper Co., Ltd	Nababiep, Namaqualand			
	Tsumeb Corp., Ltd	Tsumeb			
Uganda	Kilembe Mines, Ltd	Jinja			
Oceania:					
Australia	Copper Refineries Pty., Ltd			Townsville, Queensland	80,000
	Electrolytic Refining & Smelting Co. of Australia Pty., Ltd.	Port Kembla, New South Wales.		Port Kembla, New South Wales.	35,000
	Mount Isa Mines, Ltd	Mount Isa, Queensland			
	Mount Morgan, Ltd	Mount Morgan, Queensland			
Tasmania	Mount Lyell Mining & Railway Co., Ltd.	Queenstown		Queenstown	15,000

Employees: December 31, 1960, 4,522.

Production, deliveries:	1959	1960
Nickel ... tons	29,207	32,501
Copper ... do	16,364	18,006
Cobalt ... pounds	732,000	827,000

Mines and plants:

Falconbridge owns properties in the Sudbury Basin, Ontario. The company mill, 6,500 tpd, and smelter are on the main property at Falconbridge. The matte is treated at the Kristiansand refining plant in Norway owned by the Norwegian subsidiary, Falconbridge Nikkelverk Aktieselskap.

Gaspé Copper Mines, Ltd.———Noranda, Quebec, Canada.—Incorporated in Quebec in 1947, this is controlled by Noranda Mines, Ltd.

Capitalization:

Authorized, 3,000,000 shares; issued, 2,650,000 shares; par $1. Noranda Mines, Ltd., owns 95.5 percent of stock.

Production:	1959	1960
Copper ... tons	45,039	83,497
Gold ... ounces	7,807	10,200
Silver ... do	462,610	579,800

Mines and plants:

Concentrator has capacity of 6,500 tons of ore daily. Concentrates smelted, refined, and marketed by Noranda Mines, Ltd.

Geco Mines Ltd.———44 King St. West, Toronto 1, Ontario, Canada.—Incorporated in Ontario, Canada, October 16, 1953.

Capitalization:

Authorized, 3,000,000 shares; outstanding, 3,000,000 shares; par $1. 795,400 shares owned by Mining Corp. of Canada, Ltd., and associates.

Production:	1959	1960
Copper ... tons	25,903	21,761
Zinc ... do	23,082	28,362
Silver ... ounces	1,363,525	1,391,177
Gold ... do	5,706	5,071

Mines and plants: See chapter 4.

Granby Mining Co., Ltd.———1111 West Georgia St., Vancouver, B.C.—Incorporated March 29, 1901, by special act of parliament of British Columbia as Granby Consolidated Mining, Smelting, and Power Co., Ltd.; present name adopted March 20, 1959.

A subsidiary, Phoenix Copper Co., Ltd., operates the Copper Mountain mine about 150 miles east of Vancouver, B.C. The concentrator is at Allenby, 8 miles north of the mine. Concentrate is shipped to the American Smelting & Refining Co. smelter at Tacoma, Wash. The company owns a power plant near Princeton, B.C.

Capitalization:

Authorized 2,000,000 shares, outstanding 454,261 shares par $5.

Production:	1959	1960
Copper ... tons	1,151	1,962
Gold ... ounces	4,447	5,742
Silver ... do	21,832	36,467

Howe Sound Co.———238 North 21st West, Salt Lake City, Utah.—Incorporated June 30, 1958, in Delaware and merged with Howe Sound Co. Incorporated in Maine in 1903 and Haile Mines, Inc. Incorporated in Delaware in 1934. The company operates directly and through subsidiaries gold, silver, and base metal mines in the United States, Canada, and Mexico.

Capitalization:

Authorized, 5,000,000 shares; outstanding, December 31, 1960, 3,011,797 shares; par $1.

Mines: The company and subsidiaries have four mines:

Britannia Mine.—Owned and operated by Britannia Mining & Smelting Co., Ltd., a wholly owned subsidiary. Property is 20 miles north of Vancouver, B.C., on Howe Sound; copper and zinc are produced. A concentrator built in 1922 has capacity of 6,000 tons of ore daily.

El Potosi Mine.—Operated by El Potosi Mining Co., 95⅓ percent owned. The El Potosi mine, in the Santa Eulalia Mining District, State of Chihuahua, Mexico, has been one of the great world's lead-silver mines.

Mill capacity is 1,700 tons of ore daily. 1958 production of ore averaged 14,000 tons per month.

Three Kids Mine.—Operated by Manganese, Inc., wholly owned subsidiary. Mine at Henderson, Nev., produces metallurgical-grade manganese.

Hamme Mine.—Operated by Tungsten Mining Corp., wholly owned subsidiary. Property near Henderson, N.C., produces tungsten concentrate. Mill capacity is 900 tons of ore daily.

Hudson Bay Mining and Smelting Co.———500 Royal Bank Bldg., Winnipeg, Manitoba, Canada.—Incorporated December 27, 1927, in the Dominion of Canada, this is essentially an operating company engaged in mining and processing copper-zinc ores and marketing the products—principally copper, zinc, gold, and silver. Cadmium, selenium, and tellurium are also recovered and sold. A wholly owned subsidiary produces electricity, most of which is used by company operations. Some is distributed to local users. Company subsidiaries are:

- Churchill River Power Co., Ltd.; 100 percent owned.
  - Northern Manitoba Power Co., Ltd.
  - Northern Power Co., Ltd.
- Flexar Mines, Ltd.; 80 percent owned; inactive.
- Hudson-Yukon Mining Co., Ltd.; 92.53 percent.
- Hudson Bay Exploration & Development Co., Ltd.
- Hudson Bay Air Transport, Ltd.; 71.27 percent.

Capitalization:

Authorized, 3,000,000 shares; outstanding, 2,757,973 shares; no par.

Employees: Average in 1960, 2,731.

Production:	1959	1960
Copper____________tons__	44, 124	39, 859
Zinc_______________do____	62, 582	68, 093
Cadmium________pounds__	322, 792	366, 636
Gold____________ounces__	101, 814	105, 530
Silver_____________do____	1, 553, 574	1, 645, 554
Selenium________pounds__	130, 588	88, 500
Ore mined___________tons__	1, 683, 690	1, 698, 256

Mines:

The Flin Flon mines include the Schist Lake; Birch Lake, closed April 1960; Coronation; Chisel Lake; Stall Lake; Ghost Lake; and Osborne Lake, inactive.

Plants:

The concentrator, 6,200 tons ore capacity, produces copper concentrate, zinc concentrate, and a tailing product for cyanidation. The company copper smelter has an annual charge capacity of 575,000 tons, and the electrolytic zinc plant capacity is estimated at 69,350 tons of slab zinc. The company also has a zinc fuming plant, a cadmium plant, and a cyaniding plant. The blister copper produced is refined by Canadian Copper Refiners, Ltd., a Noranda Mines, Ltd., subsidiary.

International Nickel Co. of Canada, Ltd.——— General office: Copper Cliff, Ontario. Toronto office: 55 Yonge St., Toronto 1, Ontario.—Incorporated July 25, 1916, in Canada. International Nickel is both an operating and holding company, owning 100 percent of the voting control of the following subsidiaries as of December 31, 1960:

- Alloy Metals Sales Ltd., Canada.
- Anglo-Canadian Mining & Refining Co., Ltd., Canada.
  - Geo. Gordon & Co., Ltd., Ontario.
  - The International Nickel Co., Inc., Del.
  - International Nickel Co. (Mond), Ltd., Great Britain.
  - Henry Wiggin & Co., Ltd., Great Britain.
  - Mond Nickel (Retirement System) Trustees, Ltd., Great Britain.
  - The Clydach Estates, Ltd., Great Britain.
- Canadian Nickel Products, Ltd., Canada.
- Canadian Nickel Co., Ltd., Canada.
  - The Huronian Co., Ltd., Ontario, Can.
  - Southern Mining & Development Co., Ltd., Canada.
  - The Upper Spanish Improvement Co., Ltd., Ontario.

Capitalization:

Authorized, 36,000,000 shares; outstanding Dec. 31, 1960, 29,196,118 shares; no par.

Employees: December 31, 1960, 30,447.

Production:	1959	1960
Ore mined_______tons__	15, 316, 000	16, 768, 000
Copper, refined___do___	126, 225	146, 270
Nickel deliveries all forms________tons__	158, 520	175, 940
Cobalt_______pounds__	2, 400, 000	2, 360, 000
Gold__________ounces__	36, 300	50, 100
Silver__________do____	1, 200, 000	1, 510, 000
Platinum metals_do____	384, 600	359, 300

Mines and plants:

The company owns approximately 130,000 acres of mineral lands near Sudbury, Ontario, Canada. The ores come from the Sudbury Nickel Range. Some of the mines are the Frood-Stobie, Creighton, Levack, Garson, and Murray—all in the district of Sudbury. The ores contain sulfides of copper, nickel, and iron. The plant at Copper Cliff includes a concentrator, roasting furnaces, 9 reverberatory furnaces, 23 basic converters, a sintering plant, and a copper-nickel separation plant. A copper refinery with a precious metals recovery plant is also at Copper Cliff. The nickel refinery with a cobalt producing plant is at Port Colburne; and there are a sintering plant, four blast furnaces and five basic converters at Coniston. A 6,000-ton-per-day mill began operating in June 1959 at Levack.

There is also a new nickel refinery at Thompson, Manitoba, having an annual capacity of 75,000,000 pounds of nickel, that began operations in 1961; a nickel refinery at Clydash, Wales; and a precious metals refinery at Acton, England, that produces platinum metals, gold, and silver from byproduct materials obtained from other plants.

International Nickel produces nickel, nickel oxide, and nickel salts; copper and various alloys of nickel and copper; cobalt, gold, silver, selenium, and tellurium; and platinum, palladium, rhodium, ruthenium, and iridium. This company is the foremost producer of nickel in the world.

Manitou-Barvue Mines, Ltd.———25 Adelaide St. W., Toronto, Ontario, Canada. Incorporated in Ontario November 10, 1910, as Barvue Mines, Ltd.; adopted present name December 31, 1958, on acquisition of Golden Manitou Mines, Ltd.

Capitalization:

Authorized, 8,500,000 shares; outstanding February 1, 1960, 1,554,491 shares; par $1.

Production:	1958	1959
Zinc________________tons__	11, 154	10, 193
Copper_____________do____	2, 984	2, 584
Lead_______________do____	1, 054	1, 106
Silver_____________ounces__	654, 819	751, 659
Gold_______________do____	13, 667	10, 583

Mines and plants:

The Golden Manitou mine is in Bourlamaque Township, Quebec, Canada. Daily mill capacity is 550 tons of zinc ore and 850 tons of copper ore. The Barvue zinc-lead-silver properties are in Barraute Township, Quebec, about 35 miles north of the Golden Manitou mine. Rated capacity of this mill is 6,000 tons of ore per day.

Maritimes Mining Corp., Ltd.———Head office: Bathhurst, New Brunswick, Canada.—Incorporated in New Brunswick, Canada, December 8, 1952, and merged with Bathhurst Mining Corp., Ltd., December 30, 1955.

Capitalization:

Authorized and outstanding, 10,000,000 shares. Falconbridge Nickel Mines, Ltd., owns a substantial interest.

Employees: December 31, 1960, 328.

Production:	1958	1959	1960
Copper tons	12,562	12,189	12,004
Gold ounces	4,074	4,819	5,244

Mines and mill:

All production is from the Tilt Cove mine. Exploration and development work are being conducted at the Gullbridge mine and two properties in New Brunswick. The Tilt Cove mill has a daily capacity of 2,000 tons of ore, and the concentrate produced is shipped to the Gaspé Copper Mines smelter at Murdochville, Quebec.

Noranda Mines, Ltd.———Bank of Nova Scotia Bldg., 44 King St. West, Toronto 1, Ontario, Canada.—Incorporated May 1, 1922, in Ontario, Canada. The company is both an operating and holding company and with its affiliates is engaged in mining, milling, smelting, refining, and marketing. Subsidiaries and affiliates are:

- Amulet Dufault Mines, Ltd.
- Anglo Porcupine Gold Mines, Ltd.
- Arbutus Porcupine Mines, Ltd.; 100 percent owned.
- Aunor Gold Mines, Ltd.; 55 percent owned.
- Canada Wire and Cable Co., Ltd.; 70 percent owned.
- Canadian Copper Refiners, Ltd.; 92.27 percent owned.
- Cia. Minera Las Cuevas, S.A.; Mexico.
- Empresa Minera de El Sethentrion; 60 percent owned.
- Gaspé Copper Mines, Ltd.; 100 percent owned.
- Hallnor Mines, Ltd.; 94 percent owned.
- Noranda Copper & Brass Co., Ltd.; 60 percent owned.
- Noranda Exploration Co., Ltd.; 100 percent owned.
- Noranda Hotel Co., Ltd.; 100 percent owned.
- Orchan Uranium Mines; 40 percent owned.
- Pamour Porcupine Mines, Ltd.; 46 percent owned.
- Quebec Iron Foundries, Ltd.
- Quebec Smelters, Ltd.; 100 percent owned.
- Waite Amulet Mines, Ltd.; 67.5 percent owned.
- West Mac Donald Mines, Ltd.; 51 percent owned.

Capitalization:

Authorized, 6,000,000 shares; outstanding December 31, 1960, 4,479,894 shares; no par.

Production, Horne mine:	1959	1960
Copper tons	26,480	[1] N.A.
Gold ounces	186,639	209,860
Silver do	987,000	N.A.

[1] Not available.

Mines and plants:

The company operates the Horne Mine in Rouyn Township, Temiscamingue County, Province of Quebec. The mine has been developed to about 6,000 feet by various shafts. The company concentrator, capacity 3,500 tons ore daily, and smelter, capacity 3,500 tons charge daily, are in the town of Noranda and treat custom ore and concentrate as well as the company ore. There is also a 500-ton-per-day cyaniding plant to treat the pyrite tailing from the flotation plant for further recovery of gold. Blister copper produced is refined by Canadian Copper Refiners, Ltd., a wholly owned subsidiary at Montreal East, Quebec.

Normetal Mining Corp.———44 King St. West, Toronto 1, Ontario, Canada.—Incorporated September 8, 1931, in Canada. Controlled by Mining Corp. of Canada, which owns 1,812,888 shares.

Capitalization:

Authorized, 4,000,000 shares; outstanding December 31, 1960, 3,757,012 shares; no par.

Production:	1959	1960
Copper tons	11,257	10,736
Zinc do	9,442	10,313
Gold ounces	6,833	6,361
Silver do	582,577	515,798

Opemiska Copper Mines (Quebec), Ltd.———25 King St. West, Toronto 1, Ontario, Canada.—Incorporated August 21, 1937, in Canada. Ventures, Ltd., has a 35-percent stock interest.

Capitalization:

Authorized, 6,000,000 shares; outstanding, 5,515,000 shares; par $1.

Production:	1959	1960
Ore tons	443,444	751,453
Copper do	14,272	20,569
Gold ounces	13,080	17,813
Silver do	169,300	242,646

Mine and mill:

The property consists of 58 mining claims containing copper and gold deposits in the Chibougamau District, Quebec. Three shafts have been sunk at the Springer and Perry mines. The mill has a capacity of 2,000 tons of ore per day; concentrates are shipped to the Noranda smelter.

Quemont Mining Corp., Ltd.———44 King St. West, Toronto 1, Ontario, Canada.—Incorporated June 8, 1928, in Canada as Mining Corp. (Quebec), Ltd.; present name adopted March 6, 1929. The company is controlled by Mining Corp. of Canada, Ltd. It owns 103,000 shares of Geco Mines, Ltd., and share interests in other companies.

Capitalization:

Authorized, 2,500,000 shares; outstanding, 2,102,168 shares; no par.

Production:	1959	1960
Ore treated tons	850,099	856,862
Copper do	10,373	10,209
Zinc do	16,035	16,591
Gold ounces	121,867	103,222
Silver do	395,276	392,754

Mine and mill:

In 1928, Mining Corp. of Canada, Ltd., acquired an interest in the Murray copper-gold property and Quemont Mining Corp., Ltd., was formed to develop it. The main five-compartment shaft has been deepened to 4,150 feet for developing lower levels. The concentrator has a daily capacity of 2,300 tons of ore, and there is a cyaniding plant for removing gold from the pyrite tailing.

Sherritt Gordon Mines, Ltd.———25 King St. West, Toronto 1, Ontario, Canada.—Incorporated July 5, 1927, in Ontario. Wholly owned subsidiaries are: Sherritt Gordon Airtransport, Ltd.; Michipicoten Holdings, Ltd.; Lauri River Power Co., Ltd.; and Sherlynn Mines, Ltd. (83 percent). Through Michipicoten Holdings, Ltd., Sherritt Gordon has an 82.7 percent interest in the Ruth and Lucy iron property in the Michipicoten District.

Capitalization:

Authorized, 12,000,000 shares; outstanding, 11,333,318 shares; par $1.

Employees: December 31, 1960, 1,181.

Production:	1959	1960
Nickel tons	12,406	11,629
Copper do	5,171	5,495
Cobalt pounds	314,343	310,410
Ammonium sulfate tons	113,890	123,841

Mines and plants:

The company has 405 claims at Lynn Lake, Granville Lake district, Northern Manitoba. The property is developed by three shafts, the deepest being 2,350 feet. The concentrator at Lynn Lake has a daily capacity of 3,400 tons of ore. Nickel concentrate is shipped to the company nickel refinery at Fort Saskatchewan, Alberta; copper concentrate is smelted by Hudson Bay Mining & Smelting Co., Ltd.

Waite Amulet Mines, Ltd.———Head office: Noranda, Quebec, Canada.—Incorporated June 23, 1927, in Canada as Waite-Ackerman-Montgomery Mines, Ltd.; name changed August 1933. Controlling interest, 67.5 percent, held by Noranda Mines, Ltd. The company has substantial share interests in Amulet Dufalt Mines, Ltd.; Geco Mines, Ltd.; and Mining Corp. of Canada, Ltd.

Capitalization:

Authorized, 3,500,000 shares; outstanding, 3,300,000 shares; no par.

Production:

	1959	*1960*
Copper ______ tons	12, 830	13, 153
Zinc ______ do	8, 546	7, 350
Gold ______ ounces	7, 132	8, 345
Silver ______ do	198, 956	193, 877
Sulfur ______ tons	25, 728	26, 329

Mine and mill:

The Waite Amulet mine is 9 miles north of Noranda, Quebec, in Duprat and Dufresnay townships. The property is held under patented mining claims covering 2,679 acres. The mill has a daily capacity of 2,000 tons of ore and produces copper, zinc, and pyrite concentrates. Copper concentrate is shipped to the Noranda smelter; zinc and pyrite concentrates are sold for export.

Haiti

Consolidated Haliwell Ltd.———Head office: 1374 Sherbrooke St. West, Montreal, Quebec, Canada.—Incorporated in 1933 in Quebec, Canada. A wholly owned Haitian subsidiary, Sedren, S.A., is exploring and developing a concession about 100 square miles in area in the Terre Neuve district, Republic of Haiti. A 500-ton-per-day mill was scheduled for production in 1960.

Capitalization: Authorized, 10,000,000 shares; issued, 9,655,000 shares; par $1.

Mexico

Cobre de Mexico, S.A.———Poniente 44, No. 3310, Mexico 16, D.F.—Established in 1943.

Capital: Authorized, Mexico $20,000,000; all is issued.

Plant:

An electrolytic copper refinery in Mexico City refines blister copper from the smelter at Cananea, Sonora. Produces cathodes and wirebars, makes copper sulfate from scrap copper, and recovers commercial grade selenium from electrolytic tank slimes.

Compagnie Minera Santa Rosalía, S.A.——Articulo 123, No. 37, 50 Piso, Mexico, D.F.—This is a semi-official agency of the Mexican Government, conducting studies to develop low-cost methods to concentrate and smelt complex low-grade copper ores from numerous but small occurrences in the Santa Rosalía district. Production from 1909 until 1954 averaged 12,000 tons a year from the Boleo mine. Copper smelter is at Santa Rosalía, Baja California, Mexico.

Greene Cananea Copper Co.———25 Broadway, New York 4, N.Y.—Incorporated December 26, 1906, in Minnesota.

Capitalization:

Authorized, 600,000 shares; outstanding, 500,000 shares of which 99.41 percent is owned by The Anaconda Company; par $100.

Mines and plant:

The mines, concentrator, and smelter of the operating subsidiary, Cia. Minera de Cananea, S.A. de C.V., formerly The Cananea Consolidated Copper Co., S.A., are at Cananea, Sonora, Mexico. The concentrator handles 16,000 tons of ore daily, and the smelter has an annual charge capacity of 290,000 tons. Production in 1959 was 32,182 tons copper, 433,771 ounces silver, and 9,030 ounces gold.

In 1952 Cananea Consolidated Copper Co., S.A., acquired a 25-percent stock interest in Cobre de Mexico, S.A., and in 1953 purchased a 12-percent stock interest in the Conductores Electricos, S.A., wire mill in Mexico City. See chapter 3.

Mazapil Copper Company, Ltd.———8 Great Winchester St., London, England.—Registered April 21, 1896, as a reconstruction of a company of the same name.

Capitalization:

£1,000,000; issued, £600,000 ordinary stock transferable in units and multiples of £1; unissued, 400,000 ordinary shares of £1.

Mines and plants:

The company has copper, lead, and zinc mines in the State of Zacatecas, Mexico, with a concentrator and copper and lead smelters at Concepcion del Oro. The company operates the copper mines and leases the lead-zinc ores in the La Leona and Salaverna mines to Compania Minera de Penoles.

The copper ores are smelted and sold in matte form. In 1959 copper production consisted of 6,267 tons of copper matte averaging 39.8 percent copper and 5,257 tons of concentrate containing 20.3 percent copper. See chapter 3.

SOUTH AMERICA

Chile

Andes Copper Mining Co.———25 Broadway, New York.—Incorporated in Delaware in 1916 under perpetual charter to acquire copper properties in Chile, this is primarily an operating company and is controlled by The Anaconda Company, which as of December 31, 1960, owned 99.446 percent of the outstanding stock.

Capital:

Authorized, 3,600,000 shares at $14 each; outstanding December 31, 1958, 3,582,379 shares.

Mines and plants:

Owns the El Salvador and Potrerillos mines in the Province of Atacama and a concentrator and smelter. The Potrerillos mine closed in 1959. Sulfide ores are smelted, and the blister copper is shipped to the United States for refining. A molybdenum recovery plant completed in 1959 operated satisfactorily in 1960. Copper production was 86,859 tons in 1960, compared with 60,314 tons in 1959.

Braden Copper Co.———161 East 42nd St., New York, 17.—Incorporated June 23, 1904, in Maine. The company is a wholly owned subsidiary of Kennecott Copper Corp.

Capitalization:

$2,332,030, in shares of $10 each; all shares are issued and fully paid.

Production of copper:

1958, 191,578 tons; 1959, 182,017 tons; 1960, 187,221 tons. Virtually all of the Braden copper in 1960 went to the European market; 41 percent was fire refined, 40 percent was electrolytic, and 19 percent was sold as blister.

Mines and plants:

The El Teniente mine near Sewell, Province of O'Higgins, is the largest underground producer of copper in the world. Facilities include a concentrator, molybdenum recovery plant, smelter, fire refinery, and hydroelectric power plant.

Chile Exploration Co.———25 Broadway, New York 4.—Incorporated January 11, 1912, in New Jersey. Chile Exploration is wholly owned by Chile Copper Co. which in turn is 99.756 percent owned by The Anaconda Company. The company mines, mills, smelts, and refines copper at Chuquicamata, Province of Antofagasta, Chile.

Capitalization:

$1,000,000 in 10,000 shares of $100 each; all shares are issued and fully paid, and held by Chile Copper Co.

Production:

1958, 234,599 tons; 1959, 306,497 tons; 1960, 254,778 tons.

Mine and plants:

The Chuqicamata mine is an open-pit operation and the largest copper mine in the world. The ore is oxide and sulfide. The oxide ore is leached for recovery of the copper as refined copper by electrowinning. The sulfide ore is concentrated and smelted, and the blister copper is electrolytically refined. Facilities include crushing plants, leaching vats, concentrator, tailing disposal system, dechloridizing plant, smelter, tank house for producing electrolytic copper by electrowinning and by electrodeposition, and melting plant for casting copper into marketable shapes.

Empresa Minera de Mantos Blancos.———Augustinas 1360, Casilla 153-D, Santiago, Chile.—A subsidiary of the Mauricio Hochschild organization, established in 1955 to develop the Mantos Blancos deposit 28 miles from the port of Antofagasta. The deposit consists of a series of ore bodies; five have been explored. The largest, Quinta Tercera, is being mined by open-pit methods. The ore is leached with sulfuric acid, and copper is precipitated with sulfur dioxide as cuprous chloride. The precipitate is mixed with lime and coke for reduction to copper, which is fire refined. Production began in December 1960 and by September 1961 capacity production of 1,650 tons of copper a month was achieved.

Empresa Nacional Mineria.———No. 1010, Fifth Floor, Union Central, Santiago, Chile.—This is the Government organization that controls operation of the copper smelter at Paipote on the outskirts of Copiapo in Northern Chile. Under Ministry of Finance Decree with Force of Law No. 153, February 29, 1960, the Empresa Nacional De Fundiciones (ENAF) and the Caja de Credito Y Fomento Minero (CACREMI) were joined to form the Empresa Nacional Mineria (National Mining Enterprise). By this decree the ore buying and concentrating operations of CACREMI and the copper smelting operations of ENAF have been combined in one organization as they were before the new copper law became effective in 1955 and gave autonomy to ENAF.

The smelter treats a mixture of copper ores and concentrates from medium and small producers in Chile, producing blister copper assaying 99.30 percent copper. The smelter has one reverberatory furnace, 110 by 30 feet, and three Pierce Smith converters—two 10 by 13 feet and one 10 by 20 feet—and handles about 160,000 to 170,000 tons of charge annually.

Cia Minera Disputada de las Condes.———Casilla 25 D, Santiago, Chile.—This company has taken over the copper mine and smelter formerly belonging to the Compagnie Miniere du M'Zaita. The smelter, 40 miles southwest of Santiago at Chagres, was reopened in 1960 after being inactive since 1945. Annual output is expected to reach 30,000 tons in 1962 and about 45,000 tons in 1965. The blister copper is shipped to the United States for refining.

Santiago Mining Co.——— 25 Broadway, New York 4.—A 96.673-percent-owned subsidiary of The Anaconda Company, this organization operates the La Africana mine and a 400-ton-per-day concentrator about 15 miles west of Santiago, Chile. Production began in September 1957, and the 1960 output was 21,023 tons of concentrate, averaging 28.1 percent copper.

Peru

Cerro de Pasco Corp., Incorporated in Delaware.——— 300 Park Ave., New York 22.—Incorporated in 1956 as Cerro de Pasco Corp. in Delaware; name was changed April 18, 1957.

Capitalization:

Authorized, 150,000 shares 6¼-percent-cumulative-convertible preferred stock, par value $100 per share; all shares issued. 900,000 shares common stock, par value $5 per share; 500,000 shares issued.

Wholly owned by Cerro Corp., this subsidiary operates copper-lead-zinc-silver mines and mills in the Departments of Pasco, Junin, and Lima, Peru, and smelting and refining works at La Oroya, Peru. The mines and mills are at Cerro de Pasco, Morococha, Casapalca, Yauricocha, and San Cristobál. Daily capacities of the selective flotation mills are Cerro de Pasco (Paragsha mill), 2,200 tons lead-zinc ore and 1,700 tons copper ore; Morococha, 1,000 tons copper, lead, zinc ore; Casapalca, 1,000 tons copper-lead-zinc and silver ores; San Cristobál (Mahr mill), 650 tons copper-lead-zinc ores. The copper smelter and refinery are at La Oroya; other facilities there include a lead smelter and refinery, an electrolytic zinc plant, a sulfuric acid plant, and several byproduct plants.

Compagnie Des Mines de Huaron.———Casilla Pastale No. 368, Lima, Peru.—Incorporated May 10, 1912, in Paris, France.

Capital:

Authorized, 360,000 shares of 25 new francs each; all shares issued and fully paid.

Operated lead-zinc-copper mines and mill at Huaron, Province of Cerro de Pasco, Peru.

Production, tons of concentrate:	*1958*	*1959*
Copper	14, 678	16, 353
Lead	13, 885	12, 789
Zinc	17, 045	13, 296

Northern Peru Mining Co.———120 Broadway, New York 5.—Wholly owned by American Smelting and Refining Company.

Operates the Quiruvilca mine and concentrator at Trujillo, Peru, which produces 5,000 to 6,000 tons of copper annually as concentrate. The concentrate is shipped to the American Smelting and Refining Company smelter at Tacoma, Wash.

Southern Peru Copper Corp.———120 Broadway, New York 5.—Incorporated December 12, 1952, in Delaware. The capital stock of Southern Peru Copper Corp. is owned 51½ percent by American Smelting and Refining Co., 22¼ percent by Cerro Corp., 16 percent by Phelps Dodge Corp., and 10¼ percent by Newmont Mining Corp.

Mine and plants:

Open-pit mine and concentrator at Toquepala and a smelter and powerplant at Ilo.

Production:

Operations at Toquepala began January 1, 1960, and scheduled production was achieved in March. Mine production of ore and waste averaged 166,897 tons per day in 1960. Ore milled averaged 26,052 tons per day, containing 1.73 percent copper, which is substantially higher than the average of the ore body. 145,115 tons of blister copper was produced during the year.

EUROPE

Belgium

Societe Generale Metallurgique de Hoboken.———14, Rue Adolph Greiner, Hoboken near Antwerpen, Belgium.—Established in 1908, this concern is controlled by Union Minière du Haut Katanga.

Capitalization: Authorized, 550 million Belgian francs; all is issued.

Plants:

The plants are at Hoboken near Antwerp, Olen near Herentals, and Reppel near Bree.

Hoboken.—Plant comprises lead and copper smelters, copper converters, a lead refinery, a tin smelting and refining plant, a precious metals refinery, a selenium refinery, an antimony refinery, and a sulfuric acid plant.

Olen.—Electrolytic copper refinery and chemical products division, including: Cobalt refinery, metal, powder, oxides, and salts; radium plant; nuclear-grade uranium refinery, oxides, metal, and salts; germanium extraction and electronic-grade refining plant, dioxide, polycrystalline metal, intrinsic and doped single crystals; electronic-grade silicon plant; and nickel salts and sodium sulfate plants.

Reppel.—Producing arsenical products and insecticides.

Products and brands:

Electrolytic copper (UMK); HER Lead (Hoboken extra raffine); HER Lead (Star); tin (U.M.H.K.); S.G.M.H. antimony.

La Metallo-Chimique S.A.———8 rue d'Egmont, Brussels, Belgium.—Established in 1919.

Capitalization: Authorized, 35 million Belgian francs.

Plant:

The plant at Beerse, Province of Antwerpen, consists of: (1) A pyrometallurgical plant—including water jacket, reverberatory, converter, and rotary furnaces with up-to-date filtering installations; (2) a chemical plant—including leaching, filtering, crystallizing, and precipitating facilities; and (3) an electrorefining copper plant.

Refined copper, copper ingots and alloys, copper sulfate, and other copper salts are produced from low-grade complex ores and concentrates, residues, ashes, slags, drosses, and copper-bearing scrap.

Bulgaria

Georgi Damyanov Copper Plant.—The first copper-producing plant in Bulgaria began operations at Pirdop in 1958 with an initial capacity of 8,000 metric tons of electrolytic copper annually. It was planned to increase the capacity to 25,000 tons in 1959. The plant was built by Soviet engineers, construction beginning in 1956. It uses Bulgarian ore and in addition to copper produces copper sulfate and sulfuric acid.

Czechoslovakia

Krompachy Copper Works (Slovakia).—This is a State copper-mining undertaking. Some difficulty has been experienced in smelting because of the high-arsenic content of the ores. In recent years an electrolytic copper refinery has been added.

Finland

Outokumpu Oy.———Töölönkatu 4, Kuparitalo, Helsinki, Finland.—Established in 1932.

Capitalization: Authorized, Fmk3,200 million; all is issued.

Plants:

Mines and concentrators at Outokumpu, Ylöjärvi, Vihanti, Kotalahti, and Aijala-Metsamonttu; a copper smelter at Harjavalta; and the electrolytic refinery and metal works at Pori.

The flash-smelting process is used at the Harjavalta smelter. All the copper produced is oxygen-free high-conductivity copper—brand HCOKOF. Annual refined copper capacity is 36,000 tons.

France

Compagnie Generale d'Electrolyse du Palais.———66 Avenue Marceau, Paris, France.—Established in 1950.

Capitalization: Authorized, Fr400 million; all is issued.

Plant:

The plant consists of a primary and a secondary copper smelter, an electrolytic copper refinery, electric-arc cathode-melting furnaces and gas-fired reverberatory furnaces for making fire-refined copper. The products are wirebars, billets, and slabs. Annual capacity is 33,000 tons. Nickel sulfate is a byproduct.

East Germany

Ilsenburg Copper Plant.———East Germany.—Electrolytic and refined copper are produced. Most of the rolling facilities are used for producing steel sheets. This concern is affiliated with VVB Vesta (Leipzig) which is the central planning authority for the iron and steel industry.

Huttenwerk Kayser.—This is now a publicly-owned concern, situated at Berlin in the Niederschöneweide section, and affiliated to VVB Alu, Potsdam in the Babelsberg section. It produces copper wirebars, brass, bronze, soft and hard lead, type metals, bearing metals, and remelted aluminum alloys.

Kombinat Wilhelm Pieck.—Formerly styled Mansfelder Kupferschiefbergbau, A. G., and subsequently Mansfelder Kupferbergbau und Huttenwerk, this is now a publicly-owned concern belonging to VVB Mansfeld (Eisleben).

This concern produces electrolytic and fire-refined copper, soft lead, red lead, zinc oxide for paints, zinc sulfate, selenium, cadmium, silver, gold, platinum, palladium, sulfuric acid, and vanadium salts, utilizing ores obtained from large-scale copper-mining operations in the Eisleben-Hettstedt area. The combine produces about 22,000 tons of copper a year from local ore, and this is expected to be increased to 31,000 tons by 1965.

West Germany

Duisburger Kupferhutte.———Werthauser Strasse 220, Duisburg, Germany.—Established in 1876.

Capitalization: Authorized, DM42,000,000.

Products:

The smelter and electrolytic and chemical plants at Duisburg produce copper cathodes and wirebars, lead, zinc, zinc oxide, cadmium, thallium, cobalt, gold, silver, and special pig iron and low-phosphoric-purple ore with 60 to 62 percent Fe. Byproducts include sodium sulfate, copper oxychloride, and thallium sulfate.

Kupferhutte Ertel, Bieber & Co.———Ballindam 11, Hamburg 1, Germany.—Established in 1881. The plant is in the free port area of Hamburg at Stillhornerdamm; it uses the Henderson process of chloridizing roasting in treating about 250,000 tons of cupreous pyrites annually.

The products are iron agglomerate, sinter, and purple ore having an annual capacity of 220,000 tons; copper, 3,300 tons; zinc oxide, 3,500 tons; lead, 1,000 tons; sodium sulfate, 12,000 tons; and minor quantities of gold and silver.

Metallhutte Kall, G.M.B.H.———Kall (Eifel), West Germany.—

Capitalization: Authorized and issued capital amounts to DM500,000.

Plant:

The plant is at Kall and consists of several converters for producing blister copper and other melting furnaces to produce copper alloy ingot from scrap metal.

Huttenwerke Kayser Aktiengesellschaft.———Kupferstrasse, Lünen Nordhein-Westfalen, West Germany.—Established in 1911.

Capitalization: DM4,200,000.

Plant:

A smelter at Lünen with copper blast furnaces and converters, an electrolytic plant with wirebar-casting facilities; and Mischzinn alloying-tin smelter.

Electrolytic copper production in 1958 was 31,600 tons. Raw materials used are scrap and residues.

Metallhuttenwerke Lubeck G.M.B.H.———24a Lübeck (Herrenwyk), West Germany.—Established in 1905.

Capitalization: Authorized, DM24,000,000; all is issued.

Plant:

The plant at Lübeck in Herrenwyk, a former section of Lübeck, consists of blast furnaces, coke ovens, refining furnaces, and an electrolytic copper refinery. In 1958 electrolytic copper production was 13,500 tons from copper-bearing pyrites, residues and blister, cement, and scrap copper.

Metallgesellschaft, A.G.———14, Reuterweg, Frankfurt (Main), West Germany.—Established in 1881.

Capitalization: Authorized, DM56,000,000; all is issued.

This concern mines and smelts ores and refines and fabricates metals. The company engages in trade, especially in ores, metals, and other products; banking and financing; and other commercial and industrial activities. These activities are carried on partly by departments and partly through subsidiaries. Affiliations with a number of enterprises are maintained through shareholding.

Norddeutsche Affinerie.———Alsterterrasse, 2, Hamburg 36, West Germany.—Established in 1886.

Capitalization: DM42,000,000; fully paid.

Plant:

The plant, at Hovestrasse 50, Hamburg, consists of copper and lead smelters, copper converters, a lead refinery, an electrolytic copper refinery, plants for recovering various metals, a precious metals refinery, a sulfuric acid plant, and plants for producing various chemicals. Annual capacity for electrolytic copper is 165,000 tons and for fire-refined copper is 33,000 tons; refined lead capacity is 40,000 tons.

Products:

Blister copper and electrolytic copper in all customary shapes and sizes, refined lead, antimony, arsenic, bismuth, selenium, gold, silver, platinum, palladium, nickel, tin, antimonial lead, cobalt oxide, metal powders, metal salts, sulfuric acid, insecticides, and fungicides.

Zinnwerke Wilhelmsburg G.M.B.H.——— Neuhoferstrasse 26, Hamburg (Wilhelmsburg), West Germany.—Established in 1903.

Capitalization: DM3,000,000.

Plant:

An electrolytic copper plant having an annual refined copper capacity of 27,000 tons and a secondary smelter that processes scrap and residues.

Hungary

Csepel Iron & Steel Works.—This plant near Budapest has been producing copper as part of its activities and is now embarking on electrolytic refining. There is a rolling mill at the plant.

"Metallochemia" Works.—This concern produces fire-refined copper. Capacity is being expanded. The company also produces lead from domestic lead concentrates.

Italy

Societa Metallurgica Italiana.———99 Borgo Pinti, Florence, Italy.—

Plant:

Fire refining of copper; electrolytic copper refinery, having an annual capacity of 66,000 tons; high-frequency electric foundry for nickel and nickel alloys; Ajax-type electric foundry for brass and copper alloys; and semicontinuous four-high rolling equipment for manufacturing sheet and strip of copper and copper alloys, aluminum and aluminum alloys, and nickel and nickel alloys. The plants are at Fornaci di Barga, Provincia di Lucca; Campo Tizzoro, Provincia di Pistoia; and Limestre Provincia di Pistoia.

The raw materials used are fire refined, blister, cathode, and wirebar copper purchased on foreign markets. Copper and copper alloy scrap but not residues are purchased to be processed at the water-jacket furnace.

Montecatini Societa Generale per l'Industria Mineraria e chimica.———Via F. Turati 18/20, Milan, Italy.—Established in 1888.

Capitalization:

Authorized, Lit100 billion; all is issued.

Plants:

Alumina and blister copper plants are at Marghera, Provincia di Venezia. Copper is extracted from cupriferous pyrites cinders by chlorinating roasting, solubilization, cementation, and refining until reaching 98 to 99 percent blister copper. Aluminum reduction plants are at Bolzano and Mori, Provincia di Trento. There is also a selenium recovery plant at Vicenza; beryllium, boron, and lithium plants at Merano; and plants producing silicon, titanium, and zirconium at Novara. Annual capacity for blister-copper production is 6,600 tons.

Norway

Falconbridge Nikkelverk, Aktieselskap.——— Kristiansand, Norway.—The metallurgical operations of Falconbridge Nickel Mines, Ltd., in Canada are limited to concentrating and blast furnace smelting. The matte produced is upgraded in basic-lined converters to about 80 percent copper plus nickel. This high-grade matte is shipped to Kristiansand, Norway, where it is processed in the company electrolytic refinery.

Orkla Grube-Aktiebolag.———Løkken Verk, Norway.—Incorporated October 1904 in Norway.

Capitalization:

NKr19,999,800 in 111,110 shares of NKr180 each; all issued and fully paid.

The smelting and refining subsidiary, Orkla Metal-Aktieselskap, is capitalized for NKr2,000,000, all held by the parent company.

Mines and plants:

Cupriferous iron pyrites mines are at Medalen, Norway. Ores are smelted and refined at Thamshamn in Orkedalsfjorden by Orkla Metal-Aktieselskap.

Production:

In 1959, 245,616 tons of ore was smelted, yielding 3,800 tons of copper and 78,349 tons of sulfur.

A/S Sulitjelma Gruber.———Fr. Nansens Plass 6, Oslo, Norway.—Established in 1891.

Capitalization: Authorized NKr5,500,000; all is issued.

Mine and plant:

The mine, concentrator, and smelter are at Sulitjelma about 60 miles east of Bodø. The concentrates are smelted in Westly electric furnaces and Bessemer converters. About 4,200 tons of blister copper was produced in 1958.

Poland

Legnickie Zaklady Metalurgiczne.—The first stage of this copper plant at Legnica was being constructed in mid-1954. Ore was to be supplied by a mine in the Bolesławiec region.

Zaklady Hutnicze Szopienice.—Located at Szopienice, Upper Silesia, this operation was formerly the biggest electrolytic zinc producer in Poland and belonged to Anaconda-Giesche. Estimated annual zinc capacity is 35,000 tons g.o.b. and 40,000 tons electrolytic. The plant also produces electrolytic copper and lead, with estimated annual capacities of 11,000 and 28,000 tons, respectively.

Spain

Electrolisis del Cobre, S.A.———Batista 3, Barcelona, Spain.—Established in 1941.

Capitalization: Authorized, Pts48,000,000; all is issued.

Mines and plants:

The company mines, the Concepcion and Ponderosa at Zalamea la Real, Huelva, have an annual output of about 110,000 tons of cupreous pyrites. The processing plants at Barcelona and Palencia have mechanical and flotation, ore-dressing installations; roasting furnaces and shaft furnaces; an electrolytic copper refinery; a copper sulfate plant; and a plant for recovering other metals in the ore. Annual capacities are as follows: Fire-refined copper, 16,500 tons; electrolytic copper, 11,000 tons; and brass, 550 tons.

Sociedad Espanola de Construcciones Electro-Mecanicas, S.A.———Calle de Alcola 16, 4° piso, Madrid, Spain.—Established in 1917.

Capitalization: Pts 302,596,500, fully paid.

The company refines copper and manufactures semifabricated copper, brass, and aluminum products. At Cordoba there are an electrolytic copper refinery, having an annual capacity of 35,000 tons; brass and light alloys foundries; hot and cold rolling mills; a rodmill, and a wire and cable mill. Items produced are electrolytic copper wirebars, ingot bars, slabs, cakes, and other refinery shapes, and brass mill and wire mill products such as sheet, strip, rod, wire, cable, profiles, tubes, coin blanks, and cups for making military cartridges. Aluminum and aluminum alloy are processed into sheet, strip, profiles, and other shapes. Annual production is about 45,000 tons.

There is a redraw mill at Bilbao that draws copper and brass wire from rod produced at the Cordoba plant.

Industrias Reunidas Minero-Metalurgicas, S.A.——— Ibanez de Bilbao 2, Bilbao, Spain.—This concern operates a smelter and refinery at Asua, Vizcaya. There are subsidiary plants at San Adrian de Besos, Barcelona, and Almuradiel, Cuidad Real. Installations include electrolytic refining equipment; water-jacket, reverberatory, and rotary furnaces and converters; and a sintering plant. Scrap materials and ores are used to produce copper refinery shapes, wirebars, ingots, etc.; brasses; bronzes; soft and hard lead; virgin tin, phosphor copper, 15 percent copper; and nonferrous metals and alloys.

Compania Espanola de Minas de Rio Tinto, S.A.——— Alcala, 95,3°, Madrid, Spain.—This company was formed in 1954 to take over the entire assets of The Rio Tinto Co., Ltd., in Spain. The Rio Tinto Co. retains a third of the share capital in the new company and through subsidiaries provides certain technical and commercial services.

Capitalization: Authorized Pts 1 billion, in 666,667 A shares and 333,333 B shares, of Pts1,000 each.

Mines and plants:

The company massive pyrite mines in the Province of Huelva comprise about 32,000 acres. The processing plants near the mines include a flotation concentrator, a concentrate briquetting plant, a smelter with four blast furnaces, four Great Falls-type converters, and a small precipitate-smelting furnace. Blister copper is produced. Annual capacity is 7,700 tons; 1958 production was about 6,200 tons.

Sweden

Bolidens Gruvaktiebolag.———Sturegatan 22, Stockholm 0, Sweden.—Incorporated September 7, 1925, in Stockholm, Sweden.

Capitalization:

SKr100,800,000 in 1,008,000 shares of SKr100 each; all shares are issued and fully paid.

Mines and plants:

The company operates seven mines in the Norrland District and five in the Bergslagen District. The most important mines are the Laisvall, Kristineberg, Rudtjebacken, Ravliden, Renström, Boliden, Långsele, Garpenberg, and Vassbo. In addition, the company operates the publicly owned mines of Adakgruven. There are four concentrators in the Norrland area and three in the Bergslagen area. Most of the concentrates are treated in the copper and lead smelting plants at Rönnskär, near Skellefteå, where there is also an electrolytic copper refinery. Pyrite and zinc concentrates are exported.

Products:

White arsenic, annual capacity, 16,500 tons; electrolytic copper, annual capacity, 50,000 tons; refined lead, 45,000 tons; gold, silver, selenium, bismuth-lead alloy, pyrites, zinc concentrate, iron concentrate, lead concentrate, red lead, nickel sulfate, cesium salts, metallic arsenic, and sulfuric acid.

Reymersholms Gamla Industri Aktiebolag.——— Hälsingborg, Sweden.—Capitalization: Authorized, SKr 30,000,000; issued SKr14,000,000.

Plants:

Located at Hälsingborg and Oskarshamn, the plants are copper extracting facilities, equipped with chloridizing, roasting, and smelting furnaces. Cupreous pyrites are treated by the wet process to produce cement copper which is refined in Sweden.

United Kingdom

Actid, Ltd.———High Blantyre, near Glasgow, Scotland.

Capitalization: Authorized, £10,000; all is issued.

Plant:

This is an electrolytic copper refinery at the Scottish Industrial Estate, High Blantyre. Refined copper is produced from scrap.

Thomas Bolton & Sons, Ltd.———Mersey Copper Works, Widnes, Lancaster, England.—Established in 1783.

Capitalization:

Authorized and issued, £500,000 in ordinary stock; £300,000 of 5 percent cumulative preferred stock, £600,000 in 4½ percent cumulative redeemable preferred stock.

Plants:

The company has two plants in Lancaster—Mersey Copper Works at Widnes, and Sutton Rolling Mills at St. Helens—and two in Stafford at Froghall and Oakamoor.

The Widnes works smelts and refines brass and copper residues and other copper-bearing scrap for the manufacture of Musey brand copper sulfate. It also refines blister copper and processes scrap.

The refinery of the Froghall works deals with electrolytic cathode copper and processes scrap from other works. High-conductivity copper is produced in all forms for manufacturing wire, strip, sheet, bars, rods, machined components, and similar products.

British Copper Refiners, Ltd.———Norfolk House, Norfolk St., London W.C. 2, England.—Established in 1932.

Capitalization: Authorized, 120,000 ordinary shares of £1 each, all are issued.

Plant:

The plant is at Prescot, Lancaster. Annual combined capacity for fire-refined and electrolytic copper is 100,000 tons—output of fire-refined in 1959 was 80,000 tons and of electrolytic was 7,000 tons. Other products include brass, bronze, and cadmium copper.

Elkington Copper Refiners, Ltd.———P.O. Box No. 24, Goscote Works, Walsall, Stafford, England.—Established in 1955, formerly Elkington and Company, Ltd.

Capitalization: Authorized, £600,000; all is issued.

Plant:

Copper fire-refining and electrolytic refining plant at Walsall, Stafford. Annual fire-refining capacity is 15,000 tons, electrolytic refining capacity, 10,000 tons.

Enfield Rolling Mills, Ltd.———Brimsdown, Enfield, Middlesex, England.—Established in 1924. Subsidiary companies are Enfield Copper Refining Company, Ltd.; Enfield Rolling Mills, Ltd., aluminum; London Zinc Mills, Ltd., The Aston Chain and Hook Company Ltd., and Barker and Allen, Ltd.

Capital: Authorized, £6,983,333; issued, £6,529,883.

Plant:

At Brimsdown, Enfield, Middlesex, the plant consists of a copper refinery, copper and brass sheet and strip mills, copper rodmill, and copper drawing mill. Copper and copper-base alloys produced are cast and fabricated into refinery and mill shapes.

McKechnie Brothers, Ltd.———80 Hagley Road, Birmingham, England.—Established in 1894.

Capital: Authorized, £3,000,000; issued, £2,536,038.

Plants:

At Widnes, Lancaster, are copper smelting and refining, copper sulfate, copper powder, and lithopone plants. The company has copper and copper-base alloy fabricating plants at Aldridge, Stafford; Ratton Village, Birmingham; Stratford, London; Germiston, South Africa; New Plymouth, New Zealand; and Chatham, Ontario, Canada. Copper, copper-base alloys, and aluminum and aluminum alloys are cast in refinery shapes or fabricated into mill products.

Capper Pass and Son, Ltd.———Melton Works, North Ferriby, Yorkshire, England.—Established in 1830. Present company formed in 1912.

Capitalization: Authorized, £2,000,000; issued £1,735,630.

Plants:

The plants are at Bristol and North Ferriby, Yorkshire, and produce electrolytic copper, tin, lead, antimony, silver, tin-base alloys, antimonial lead, solder in all forms, and bismuth alloys from low-grade and complex ores and residues containing copper, lead, tin, antimony, bismuth, silver, and gold.

The Wolverhampton Metal Co., Ltd.———Well Lane, Wednesfield, Wolverhampton, Stafford, England.

Capitalization: Authorized, £1,000,000; issued, £591,000.

Plant:

The plant at Wednesfield has electric and reverberatory furnaces for producing high-grade, fire-refined copper and copper-base and aluminum-base alloys. The James Bridge Copper Works, Ltd., at Darlaston Road, Walsall, has smelting and electrolytic refining facilities and produces anodes, rough cakes and cathodes. Nickel-sulfate is produced as a byproduct.

U.S.S.R.

The U.S.S.R. is the fourth largest copper-producing country in the world, having an annual output of more than 500,000 tons which is approximately twice the quantity produced in 1950. Emphasizing prospecting and exploration and mine and plant expansions made known additional reserves and raised the output of copper ore and copper. The present seven year plan (1958–65) calls for an annual production of 1 million tons of copper by 1965.

The four principal copper areas in the U.S.S.R. are: Kazakhstan, the Urals, Uzbekistan, and Armenia. Other significant producing areas are the Kola Peninsula and Noril'sk. The principal copper smelters in the U.S.S.R. processing the ores from the mines in these regions are:

Smelter	Capacity, short tons
Karsakpay, Kazakhstan	220, 000
Balkhash, Kazakhstan	165, 000
Almalyk, Uzbekistan	165, 000
Pyshma, Ural	110, 000
Revda, Ural	55, 000
Blyava, Ural	55, 000
Minusinsk, Siberia	55, 000
Krasnoural'sk, Ural	44, 000
Karabash, Ural	33, 000
Kirovograd, Ural	28, 000
Allaverdy, Armenia	11, 000
Baymak, Ural	11, 000
Zangezur, Armenia	11, 000
Pechenga, Kola	6, 600
Kadjaran, Armenia	(1)
Monchegorsk, Kola	(1)
Total	969, 000

[1] No data.

Yugoslavia

Rudnici Bakra I Topionice Bor.———Bor, Yugoslavia.—The Government holds the majority interest in this concern, which was formerly Cie. Francaise des

Mines de Bor, a French-controlled company. The annual capacity of the smelting and refining plant at Bor was increased to 60,000 tons in 1960. Leaching, smelting, and electrolytic refining processes are used.

On June 25, 1961, the Majdanpek open-pit mine was officially placed in production, and the planned mining capacity rate, 12,000 tons of ore per day, was programed for 1962. Official statistics for production of blister and electrolytic copper are reported as follows:

Year:	*Blister copper, short tons*	*Electrolytic copper, short tons*
1939	45, 903	13, 738
1946	23, 953	14, 247
1956	32, 390	27, 655
1957	37, 186	33, 210
1958	37, 117	32, 964
1959	38, 857	34, 796
1960	39, 384	38, 639

Fabrika Kablova Svetozarevo.———Svetozarevo, Yugoslavia.—This is a wire and cable plant, equipped for producing oxygen-free, high-conductivity copper. The new refining unit was built by Ajax Engineering Corp., now Ajax Magnethermic Corp., Trenton, N.J., and began operating in 1955. Half the electrolytic copper production of Yugoslavia is converted to oxygen-free, high-conductivity copper and is vertically cast into wirebars at this plant.

ASIA

China

There are virtually no data available on the structure of the copper industry in China. Increasing estimates of production and other occasional news items indicate significant activity in mining, smelting, and refining, but specific information either on size, expansion, and production of established plants or construction of new concentrators, smelters, and refineries has not been found. The known plants are the Chunking copper refinery, Szechwan Province; Szechwan copper and zinc refinery, Tungchuan copper plant, Yunnan Province; and the Kunming electrolytic copper refinery, Yunnan Province. It is reported that a great number of small copper smelters, blast furnaces, were set up throughout China in 1958.

Cyprus

Cyprus Mines Corp.—For data on this company see Arizona.

Cyprus Sulphur and Copper Co., Ltd.———Limni, Polis, Cyprus.—Incorporated August 3, 1940, in Cyprus.

Capitalization:

£200,000, in shares of £1 each. 196,196 shares are issued and fully paid; 196,009 of the shares are held by Esperanza Copper and Sulphur Co., Ltd., a holding company.

Property:

The company holds lease on 30 square miles of the Limni concession in Cyprus, containing pyrites, copper, and gold. The Limni concentrator was rehabilitated in 1958. During the year ending March 3, 1960, 107,650 tons of cupreous pyrites, 1,990 tons of copper concentrates, and 467 tons of copper precipitates were produced during the year ending March 31, 1960.

India

Indian Copper Corp., Ltd.———Gillander House, Netaji, Subhas Road, Calcutta 1, India.—Registered London in 1924 as a reconstruction of Cordoba Copper Co., Ltd.

Capitalization:

Authorized, £2,000,000 in units of stock of 2s. each, issued, £1,371,300.

Production:	*1958*	*1959*
Ore milled------short tons	442, 088	434, 282
Refined copper--------do--	8, 630	8, 310

Mines and plants:

Mining operations consist of the Mosaboni and Badia copper mines and kyanite deposits at Kharsāwān. Power, concentrating, smelting, and refining plants; a rod mill; and a brass foundry have been erected at Moubhander. An electrolytic copper plant under construction was scheduled for production by the end of 1962. Most of the copper produced is made into rolled brass products.

Israel

Israel Mining Industries.———Tel Aviv, Israel.—This Government-owned company was designed and set up in 1951 to explore and develop mineral resources of Israel. One of the prime ventures of this company was development of the Timna ore deposit and associated processing facilities for leaching and precipitating copper by the cementation process.

Israel Mining has a capital of £1,000,000. The plant was designed to process 1,500 tons of ore daily or 500,000 tons a year. In 1959, 495,000 tons of ore was treated, yielding 4,930 tons of copper. The copper cement is shipped abroad for smelting and refining; however, the company plans are projected to produce blister or refined copper at Timna.

Japan

Dai Nippon Kogyo K.K.———Tokyo, Japan.—This company owns the Hassei smelter, which has eight stamping machines, one-Voleeze-type briquetting machine, two round Dwight-Lloyd sintering machines, one shaft furnace, and two converters. Annual capacity is about 6,000 tons; 5,900 tons was produced in 1958. Raw materials processed are concentrated fines, unconcentrated fines, unconcentrated lump, siliceous ore, and copper scrap.

The Dowa Mining Co., Ltd.———Tokyo, Japan.—Established in 1937, this company is capitalized for ¥3,045 million and is engaged in mining, smelting, chemical, and transportation industries. The company is noted for the copper, pyrite ore, and decopperized, pyrite cinder it produces. Other products are zinc-gypsum, sulfuric acid, gold, silver, lead, and copper sulfate.

Mines and plants:	*Location*
Kosaka mine and smelter.	Kosaka, Kazuno-gun, Akita-ken.
Hanaoka mine	Hanaya-machi, Kita-akita-gun, Akita-ken.
Yanahara mine	Yanahara, Kume-gun, Okayama-ken.
Akagane mine	Ezashika, Iwate-ken.
Nissho mine	Mamurogawa-machi, Mogami-gun, Yamagata-ken.
Okayama plant	3 Kaigan-dori 3 chome, Okayama.
Amagashi plant	5 Ogimachi, Amagasaki.

Production for the 6 months, from October 1958 to March 1959, was as follows:

Electrolytic copper---------short tons--	7, 577
Cement copper, copper content---do----	539
Electrolytic zinc----------------do----	4, 058
Electrolytic gold--------------ounces--	6, 366
Electrolytic silver---------------do----	108, 782
Electrolytic cadmium----------pounds--	17, 637

The Furukawa Electric Co., Ltd.———No. 14, 2-chome, Marunouchi, Chiyoda-ku, Tokyo, Japan.—The company owns the following plants: Nikko Copper Works, Yokohama Cable Works, Osaka Copper Works, Kyushy Cable Works, and the Oyama plant.

The Nikko Copper Works produces electrolytic copper and refines byproduct gold and silver. It also produces copper and copper-alloy wire and fabricates copper and copper-alloy strip, sections, and forgings. In addition, it produces aluminum and aluminum-alloy wire sheet, strip, rods, pipe, sections, and forgings.

The annual electrolytic-copper refining capacity is 32,000 tons. Blister copper produced at the following mines is sent to this plant for refining. Ashio copper mine, owned by the Furukawa Mining Co., Ltd.; Osaruzawa copper mine, owned by Mitsubishi Metal Mining Co., Ltd.; and Tsubaki copper mine and Hasseia copper mine, owned by the Dai Nippon Mining Co., Ltd.

The Furukawa Mining Co., Ltd.———No. 8, Marunouchi 2-chome, Chiyoda-ku, Tokyo, Japan.—Formally established in 1918; originated in 1875. Capital: Authorized, ¥5,000,000,000; issued, ¥3,307,500,000.

Properties and plants:

This company has the following operating divisions: metal, electric power, machinery, chemical, and coal. The principal mines in the Metals Division are the Ashio, Nagamatsu, Ani, Kune, Iimori, and Daira. There are two plants in the Chemical Division, the Ashio smelter and the Osaka plant, producing sulfuric acid, cement copper, cupreous oxide, ferric oxide, and titanium dioxide. The Ashio smelter, built in 1956, uses the flash-smelting process developed by Outokumpu Oy in Finland.

Mitsubishi Metal Mining Co., Ltd.———No. 6, 1-chome Ohte-machi, Chiyoda-ku, Tokyo, Japan.—Established in 1950.

Capitalization: Authorized, ¥10,000,000,000; issued, ¥2,730,000,000.

Properties and plants:

This company mines, smelts, refines, and fabricates copper, lead, and zinc. The more important mines are the Shimokawa, Osarizawa, Washiaimori, Hosokura, Akenobe, Ikuno, Myoho, and Makimine. The company also operates the Naoshima smelter and two refineries, the Akita and Osaka. Annual copper-smelting and electrolytic-refining capacities are 53,000 tons and 40,000 tons, respectively.

Mitsui Mining & Smelting Co., Ltd.———1,2-chome, Nihonbashi-Muromachi, Chuo-ku, Toko, Japan.

Capitalization:

Authorized, ¥9,600,000,000, 192,000,000 shares; issued, ¥4,800,000,000, 96,000,000 shares.

Mines and plants:

This company is one of the larger producers in Japan of refined zinc, copper, and lead and byproduct bismuth, cadmium, gold, silver, palladium, platinum, selenium, tellurium, and tin. It operates mines, smelters, and refineries and has the largest zinc-lead mine, Kamioka mine, and the largest zinc smelter, Miike smelter, in Japan. Blister copper is produced at the Hibi smelter and refined at the Takehara electrolytic refinery.

Copper production increased from 13,513 tons in 1958 to 25,438 in 1959.

Nihon Kogyo Kabushiki Kaisha, Nippon Mining Co., Ltd.———3, Akasaka Aoi-cho, Minato-ku, Tokyo, Japan.—Established in 1929.

Capitalization: Authorized and issued, ¥5,670,000,000.

Properties and plants:

The company owns 18 mines scattered throughout the country, smelters and refineries at Hitachi-shi and Saganoseki, and a smelter at Ogoya.

The Hitachi mine, smelter, and electrolytic refinery are at Miyatacho, Hitachi-shi, Ibaraki-ken. Mine production in 1958 was 5,500 tons of copper. The technique of autogeneous smelting in converters using oxygen-enriched air was introduced at this smelter near the end of 1958. The smelter is equipped with one blast furnace, four converters, and an oxygen plant. The smelter treats other domestic and imported ores and concentrates. Smelter capacity is 41,000 tons of product, and there is 48,000 tons of refining capacity for electrolytic copper with equal wirebar casting facilities. The refinery also has a gold and silver parting plant. There are two Lurgi-type contact sulfuric acid plants, having capacities of 150 and 220 tons per day, respectively, that use the sulfur dioxide in the converter gases.

The Saganoseki smelter and refinery are at Seki-machi, Saganoseki-machi, Kita-amabe-gun, Oita-ken. There is no mine at this plant site but the smelter operates on ores from other company mines, domestic custom ores, and imported material. The smelter has two blast furnaces and four converters. The refinery has a capacity of 43,000 tons of electrolytic copper a year, and there is a silver and gold parting plant.

There is also a lead smelting and refining plant, capacity 10,800 tons per year; a Lurgi-type contact sulfuric acid plant, having a capacity of 5,000 tons a month; and a ferronickel plant with three furnaces, having a capacity of 4,800 tons a year of nickel-content.

The Ogoya mine and smelter are at Ogoyamachi, Kamatsu-shi, Ishikawa-ken. Ore containing 2,650 tons of copper was mined and concentrated in 1958. The smelter has an annual capacity of 6,000 tons of blister copper that is sent to the Saganoseki electrolytic refinery.

Production and capacity:	*1958*	*Annual capacity, nominal*
Electrolytic copper short tons	40, 400	83, 200
Lead do	6, 800	11, 100
Gold ounces	76, 012	694, 500
Silver do	1, 579, 790	6, 109, 000
Selenium pounds	37, 383	47, 600

Sumitomo Metal Mining Co., Ltd.———No. 12, 5-chome Shimbashi, Shiba, Minato-ku, Tokyo, Japan.—Established in 1950.

Capitalization:

Authorized, ¥5,200,000,000; issued, ¥3,217,500,000.

Plants:	*Operations or products*
Shisakajima smelter	Copper and nickel smelting, sulfuric acid.
Niihama refinery	Copper, nickel, gold, and silver electrolysis.
Kunitomi smelter	Copper smelting and lead electrolysis.
Kohnomai cyanidation plant	Gold and silver cyanidation.

Antimony oxide, nickel sulfate, and copper sulfate also are produced.

North Korea

Virtually all of the metal producing works are in North Korea—north of the 38th parallel of latitude. Since this area is Communist-controlled, up-to-date information is lacking.

Republic of Korea

The only metal producer of any significance is the Changhŭng copper refinery, having an estimated capacity of 1,000 tons of copper a year.

Philippines

Atlas Consolidated Mining and Development Corp.——Soriano Building, Manila, Philippines.—Incorporated in the Philippines as Masbate Consolidated Mining Co. on March 1, 1935; name was changed in the 1953 merger with Antamok Goldfields Mining Co., Inc., and IXL Mining Co.

Capital:

₱25,000,000 in shares of ₱1 each; ₱17,240,481 shares, issued and fully paid.

Property:

The company owns the Toledo mine and a 15,000-ton-per-day concentrator on the island of Cebu, holds 35 percent of the capital of Phelps Dodge Copper Products Corp. of the Philippines, and a 40-percent interest in Atlas Fertilizer Corp. It operates an iron property of Philippine Iron Mines, Inc., for 10 percent of royalty, at Mati, Davao, on the Island of Mindanao. The iron ore is shipped to Japanese steel mills and the copper concentrate is sent to Mitsubishi Metal Mining Co. in Japan.

Production, short tons:	*1958*	*1959*
Ore	3, 487, 322	3, 931, 543
Copper	20, 755	21, 288

Lepanto Consolidated Mining Co.——Dimsco Bldg., 422 Arzobispo St., Manila, Philippines.—Incorporated in the Philippines September 21, 1936.

Capitalization:

₱20,000,000 in 200,000,000 shares of 10 centavos each; 138,633,334 shares are issued and fully paid.

Property:

The Lepanto mine and the 1,250-ton-per-day concentrator are at Mountain, Luzon, Philippines. The mine is the largest vein copper mine and the second largest producer in the country.

Production:		*1959*	*1960*
Copper	short tons	14, 439	15, 279
Gold	ounces	47, 230	49, 085
Silver	do	196, 901	218, 094

Marinduque Iron Mines Agents, Inc.——Ledesma Bldg., Anda & Sta. Lucia St., Intramuros, Manila, Philippines.

Capitalization:

Authorized, ₱20,000,000 in 200,000,000 shares at 10 centavos per share.

Property:

The company owns two copper operations, the Bagaycay mine and mill on Samar Island and the Sipalay mine and mill in Negros Occidental Province. It also has a number of petroleum exploration concessions in various parts of the archipelago.

Production:

During the first 2 months of 1960, mine and mill operations at Bagaycay were adversely affected because of damage caused by Typhoon Gilda, which hit during December 1959. However, during 1960 the mine produced 4,275 tons of shipping-grade ore, averaging 12.33 percent copper and 150 tons of milling grade ore containing 3.19 percent copper and 2.19 percent zinc. Approximately 25,500 tons of concentrate, averaging 14.13 percent copper, 7.80 percent zinc, 0.023 ounce per ton gold, and 3.66 ounces per ton silver, was shipped in 1960.

733-740 O—65——20

The Sipalay operations were halted in April and May of 1960 by a labor strike. About 1,300,000 tons of ore was mined and milled to produce 33,200 tons of concentrate, containing 8,385 tons of copper.

The company obtained a $13-million loan from the Export-Import Bank to finance purchase of equipment and machinery for an integrated copper-zinc smelting plant.

Philex Mining Corp.——Equitable Bank Bldg., Juan Luna St., Manila, Philippines.—Incorporated in the Philippines in 1955.

Capitalization:

Authorized, 90,000,000 shares at 10 centavos per share.

Property:

The company owns and operates the Santo Tomas II mine and mill in Pacdal, Tuba, Mountain, Philippines. Mining is by open-pit and block-caving methods.

Production:

Of the 605,677 tons of ore mined and milled in 1960, 345,309 tons came from the open pit and 260,368 from underground; 14,106 tons of concentrate—containing 3,678 tons of copper, 12,532 ounces of gold, and 15,034 ounces of silver—was produced.

Turkey

Ergani Bakir Isletmesi Muessesesi, Ergani Copper Mining Co., Ltd.——Maden, Turkey.—Established in 1925. Owned, controlled, and operated by Eti Bank, a Government agency.

Capitalization:

Authorized, TL15,000,000 issued, TL10,000,000.

Mines and plants:

The company operations are at the town of Maden near Elâziğ and Kiyarbakır in southeastern Turkey. There are two open-pit mines, a 450-ton-per-day mill, and a smelter equipped with two blast furnaces, four converters, and two refining furnaces.

Production in 1958:	*Short tons*
Blister copper	16, 650
Fire-refined copper	3, 300

Murgul Bakir Isletmesi.——Damar, Hopa, Turkey.—There was some mining of the Damar deposit before 1916. The Government (Eti Bank) took over and began developing the property in 1938; production was resumed in 1951.

Capitalization: Authorized, TL20,000,000; all is issued.

Mine and plants:

This property consists of an open-pit mine, a 2,000-ton-per-day concentrator, and a smelter with one fire-refining furnace. A calculated annual production capacity of 10,000 tons of blister copper was based on the assumption of 3-percent copper ore—now estimated in the reserve at 2 percent copper. Production is about 7,500 tons of blister copper per year.

AFRICA

Republic of the Congo

Union Miniere du Haut Katanga.——Registered office: Elizabethville, Republic of the Congo; Administrative office: 6 rue Montagne du Parc; Brussels, Belgium.—Incorporated in 1906, in the former Belgian Congo; reincorporated in Belgium during 1960. The company was formed to acquire the interests of the Katanga (Belgian) Special Committee and Tanganyika Concessions, Ltd., in the mineral concessions made by the latter company, under a concession granted by the former (extending until March 11, 1960) and situated in Katanga Province. This concession comprises a copper area of about 7,700 square miles, containing also cobalt, zinc, uranium, radium, cadmium, germanium, silver, gold, iron ore and limestone deposits, and a tin area of about 5,400 square miles.

The company is one of the largest copper producers in the world and holds important interests in many enterprises, one of the chief ones being Société Générale Metallurgique de Hoboken.

Capitalization:

Congolese francs 8,000,000,000 in 1,242,000 shares; all shares are issued.

Production:

		1957	1958	1959	1960
Copper	short tons	264, 861	259, 686	309, 088	331, 466
Cobalt	do	8, 945	7, 166	9, 293	9, 083
Zinc	do	207, 431	220, 479	195, 965	211, 642
Germanium	pounds	19, 987	35, 838	30, 077	57, 540
Cadmium	do	258, 489	308, 364	217, 905	53, 792
Radium deliveries	grams	89. 3	69. 8	101. 6	----------

Mines and plants:

The active mines are the Mine Prince Leopold (Kipushi), Musonoi, Kolwezi, Ruwe, Kamoto, Kambove, Lukuni, and Shinkolobwe.

Most of the ores are concentrated before smelting, and the company has concentrating plants at Kipushi and Kolwezi and a washing plant at Ruwe. Uranium ores are treated at the Shinkolobwe concentrator. Sulfide concentrates are sent to the Lubumbashi smelter which is equipped with four water-jacketed blast furnaces and two converters. The blister copper produced is refined at the Olen works of the Société Générale Metallurgique de Hoboken or in France at the copper refinery of Cia. Générale d' Electrolyse du Palais.

The oxide concentrates, which usually contain a little cobalt, are treated by leaching and electrolysis at the Jadotville-Shituru works. The company also owns an electric smelter at Jadotville-Panda, where certain ores are treated to produce cobaltiferous alloy and crude copper. The alloy is sent to Belgium for refining, and the crude copper is cast into anodes.

Northern Rhodesia

The modern history of the Copperbelt began in 1923 when the British South Africa Co. was granted exclusive prospecting rights over large areas of the Territory of Northern Rhodesia. The finding of copper ores containing from 3 to 5 percent copper in 1925 resulted in the development of mines at Luanshya (Roan Antelope), Kitwe (Nkana), Mufulira, and Chingola (Nchanga).

These mines and Chibuluma and Bancroft are controlled by two groups as follows:

Anglo American Corp. Group:
- Bancroft Mines, Ltd.
- Nchanga Consolidated Copper Mines, Ltd.
- Rhokana Corporation, Ltd.
- Rhodesia Copper Refineries, Ltd.

Rhodesian Selection Trust Group:
- Chibuluma Mines, Ltd.
- Mufulira Copper Mines, Ltd.
- Roan Antelope Copper Mines, Ltd.
- Ndola Copper Refineries, Ltd.

Anglo American Corporation of South Africa, Ltd.———44, Main Street, Box 4587, Johannesburg, Transvaal, Republic of South Africa.—Incorporated in the Republic of South Africa, September 25, 1917, the corporation was formed mainly as a finance and holding company, and to manage and perform technical and secretarial services for mining, investment, and industrial companies. The corporation has considerable interests in South Africa—mainly in gold, gold-uranium, diamond, and coal mines—and in the Federation of Rhodesia and Nyasaland, where its investments are principally in copper mines. Through affiliated companies it has substantial interests, direct and indirect, in many companies for whom it acts as secretary or technical advisor.

Capitalization:

£9,000,000 in £2,379,375 of 6 percent cumulative preferred stock, transferable in units of 10s., 1,241,250 6 percent preference shares of 10s. each, and 12,000,000 ordinary shares of 10s. each; £2,379,375 preferred stock and 10,587,002 ordinary shares were issued and fully paid December 31, 1960.

Bancroft Mines, Ltd.———70 Jameson Avenue Central, Salisbury, Southern Rhodesia.—Incorporated in Northern Rhodesia, May 21, 1953. The company holds special grants of mining rights over 63,000 acres and leasehold surface rights over 57,600 acres in the Bancroft area, Northern Rhodesia. Exclusive prospecting rights over the Kawiri area adjacent to the special grants are also held by the company.

Capitalization:

Authorized, £13,750,000 in 22,000,000 stock units of 5s. each, 3,000,000 ordinary shares of 5s. each, and 7,500,000 6½-percent redeemable participating preference shares at £1 each; all the stock units and preference shares are issued and fully paid.

Mine and plant:

The Kirila Bomwe South and Kondola ore bodies are being worked through two shafts, 1,500 and 1,400 feet deep, respectively. The Kirila North ore body is being explored north of the No. 1 shaft on the 1,150 level by a third shaft. The concentrator has the capacity for treating 170,000 tons of ore per month. The concentrate is sent to the Rhokana smelter at Nkana.

Production:

For the year ended June 30, 1960, 1,655,700 tons was milled for 58,424 short tons of recoverable copper-in-concentrate; blister copper production was 57,256 tons.

Nchanga Consolidated Copper Mines, Ltd.———70 Jameson Avenue Central, Salisbury, C. 4, Southern Rhodesia.—Registered in London March 8, 1937; management and control transferred to Northern Rhodesia, January 1, 1951. Reincorporated in Northern Rhodesia May 11, 1954, under Rhoanglo Group Act, 1953.

The Company holds special grants of mining rights over 36,100 acres and leasehold surface rights over 29,800 acres in the Chingola area, Northern Rhodesia. It also holds mining rights covering 564 acres and prospecting rights covering 2,200 acres in the King Edward mine area west of Lusaka, Northern Rhodesia.

The Company participated with Rhokana Corp., Ltd., in forming Rhodesia Copper Refineries, Ltd., and in acquiring the 500,000 shares of ordinary stock issued.

Capitalization:

£28,000,000 in stock units of £1 each, all issued and fully paid.

Mines and plant:

The copper ore is obtained by underground mining of the Nchanga West ore body and by open-pit mining of the Nchanga and Chingola ore bodies. The concentrating and leaching plants have a combined capacity for treating 360,000 tons of ore per month.

The sulfide copper concentrates are sent to the Rhokana Corp. smelter at Nkana. The oxide concentrates are treated in the leach plant, and copper cathodes produced by electrowinning are sent to the Rhodesia Copper Refineries plant at Nkana for melting and casting into finished shapes.

Production:	Ore milled	Copper content of concentrates
1957–58 short tons	3, 544, 500	148, 861
1958–59 do	3, 648, 500	162, 596
1959–60 do	4, 357, 100	207, 336

Rhokana Corporation, Ltd.——70 Jameson Avenue Central, Salisbury, C. 4, Southern Rhodesia.—Registered in London February 16, 1923, as Rhodesian Congo Border Concessions, Ltd.; name changed March 1931; control transferred to Northern Rhodesia as of January 1, 1951; reincorporated May 11, 1954, in Northern Rhodesia under the Rhoanglo Group Act, 1953.

The Corporation holds mineral rights covering 52 square miles in the Nkana area and 54 square miles in the Bwana Mkubwa area near Ndola. The freehold and leasehold surface rights in the Nkana and Bwana Mkubwa areas total approximately 100 square miles.

Capitalization:

Authorized, £26, 500, 342 in 24,950, 342 ordinary shares of £1 each, 50,000 A shares of £1 each, and 1,500,000 of 5½-percent redeemable cumulative preference shares of £1 each. Issued, 24,950,342 ordinary stock units of £1 each, 49,678 A stock units of £1 each, and 767,955 of 5½-percent redeemable cumulative preference shares of £1 each, including a bonus issue of 9 shares for every ordinary and A share held from 1959 to 1960.

Principal shareholdings:

Company:	Percent of shares issued
Rhodesia Copper Refineries, Ltd	50. 0
Bancroft Mines, Ltd	43. 38
Nchanga Consolidated Copper Mines, Ltd	33. 6
Mufulira Copper Mines, Ltd	26. 56
Chibuluma Mines, Ltd	26. 68
Chambishi Mines, Ltd	26. 68
Chisangwa Mines, Ltd	30. 0
Rhodesia Congo Bondu Power Corp., Ltd	25. 0
Baluba Mines, Ltd	26. 68

Mines and plants:

The mines and surface plants are at Nkana, Northern Rhodesia. Ore production is from the Nkana North and Mindola sections and the Nkana South ore body. A concentrator and smelter treat about 16,000 tons of ore per day. There is a sulfuric acid plant, an electrolytic-copper refinery, and an electrolytic-cobalt refinery. A recovery plant for treating uranium-bearing ore from the Mindola section operated from May 1957 to July 1959.

The ores are concentrated to produce sulfide copper concentrate and cobalt concentrate. The former is smelted with copper concentrates from Nchanga and Bancroft. The copper produced is cast as blister cakes for market or anodes for electrolytic refining in the adjacent plant of Rhodesia Copper Refiners, Ltd. The cobalt concentrate is roasted and leached with sulfuric acid, and the cobalt is recovered by electrowinning from the sulfate solution.

Production:	1958	1959	1960
Blister copper, short tons	28, 172	29, 264	30, 374
Electrolytic copper short tons	67, 390	56, 956	86, 084
Electrolytic cobalt short tons	1, 269	1, 092	1, 307

Rhodesia Copper Refineries, Ltd.——70 Jameson Avenue Central, Salisbury, C. 4, Southern Rhodesia.—Registered in London, January 1, 1947; head office transferred to Nkana, Northern Rhodesia, January 1, 1951; reincorporated in Northern Rhodesia May 11, 1954, under the Rhoanglo Group Act, 1953; head office moved to Salisbury, Southern Rhodesia, August 5, 1957.

Capitalization:

Authorized, 500,000 shares of £1 each; 1,300,000 shares of 5-percent redeemable cumulative preference shares of £1 each; 700,000 shares of £1 each. Issued, 500,000 ordinary shares converted into stock units of £1 each and 1,024,127 of 5-percent redeemable cumulative preference shares converted into stock units of £1 each. The ordinary stock is held equally by Rhokana Corporation, Ltd., and Nchanga Consolidated Copper Mines, Ltd. The preference stock is quoted on the London and Rhodesian Stock Exchange.

Operations:

The company operates an electrolytic copper refinery adjacent to the Rhokana Corp. smelter at Nkana. The plant is equipped with facilities for casting horizontal and vertical wirebars and shapes.

Rhodesian Selection Trust, Ltd.——Livingston House, 48 Jameson Central Avenue, Salisbury, C. 4, Southern Rhodesia.—Registered in London May 22, 1928; control transferred to Northern Rhodesia July 1, 1953; reincorporated in Northern Rhodesia July 1, 1954, under the Rhodesian Selection Trust, Ltd., and Associated Companies Act, 1954.

This concern is a holding company 50.60 percent controlled by American Metal Climax, Inc. Its principal asset is the 64.67-percent ownership of Mufulira Copper Mines, Ltd. In addition, a 64.98-percent interest is held in Chibuluma Mines, Ltd.; Baluba Mines, Ltd.; and Chambishi Mines, Ltd., as well as a controlling interest in Rhodesian Selection Trust Exploration, Ltd. A wholly owned subsidiary, Rhodesian Selection Trust Investments, Ltd., was formed in 1957 and acquired certain investments from the company.

Capitalization:

£12,000,000 in 48,000,000 shares of 5s. each; 45,239,116 shares are issued and fully paid.

Chibuluma Mines, Ltd.——48 Jameson Avenue Central, Salisbury, C. 4, Southern Rhodesia.—Incorporated July 2, 1951, in Northern Rhodesia, the company acquired from Mufulira Copper Mines, Ltd., a special mining grant covering the Nkana South Limb area seven miles west of Kitwe and about 34 miles southwest of the Mufulira mine.

Capitalization:

Authorized and issued £1,000,000 in £1 shares; Rhodesian Selection Trust, Ltd., holds 64.29 percent.

Of the cost of equipping and developing the property, £5,000,000 was loaned by the General Services Administration of the U.S. Government under an agreement providing for repayment in copper and cobalt. As of June 30, 1961, the balance was £406,488 which was repaid in the following fiscal year.

Mine and plant:

The mine started hoisting ore in October 1955, and the mill, having a capacity of 40,000 tons per month, began full operation in April 1956. The main ore body is mined by the cut-and-fill method, and the deepest haulage level is 945 feet below the surface. The ore body west of the mine is being developed through the Norrie shaft, which was sunk to a vertical depth of 1,185 feet. This new development is expected to increase annual production 4,500 tons beginning in 1963. The copper concentrates are sent to the Mufulira smelter. The mixed copper/cobalt concentrate is roasted and smelted at the cobalt treatment plant managed by Ndola Refineries, Ltd.

Production: Year:	Copper, short tons	Cobalt, sales, thousand pounds
1957	16, 233	---------
1958	30, 443	---------
1959	21, 544	1, 660
1960	24, 700	1, 600

Mufulira Copper Mines, Ltd.———48 Jameson Avenue Central, Salisbury, C. 4, Southern Rhodesia.—Registered in London February 3, 1930. Control transferred to Northern Rhodesia as from July 1, 1953; reincorporated in Northern Rhodesia July 1, 1954, under Rhodesian Selection Trust, Ltd. and Associated Companies Act, 1954. The company has special grants of mining rights covering a total area of 76,816 acres in the Luangwa District of Northern Rhodesia.

Mufulira is 64.67 percent controlled by Rhodesian Selection Trust, Ltd., which in turn is 50.60 percent controlled by American Metal Climax, Inc.

Capitalization:

Authorized, 18,000,000 shares of £1 each; issued, 15,866,622 shares of £1 each, fully paid.

Mine and plants:

The Mufulira mine is equipped with a concentrator-smelter, and electrolytic refinery. The annual produc, tion capacity will be increased approximately 50 percent to about 170,000 tons when development of the western area of the mine is completed and plant extensions installed.

Production:	Ore mined	Blister copper produced
1958.......short tons..	4, 352, 832	104, 153
1959............do....	4, 123, 493	98, 623
1960............do....	4. 894. 015	116, 154

Roan Antelope Copper Mines, Ltd.———48 Jameson Avenue Central, Salisbury, C. 4, Southern Rhodesia.—Registered in London June 3, 1927. Control transferred to Northern Rhodesia as from July 1, 1953; reincorporated in Northern Rhodesia July 1, 1954, under Rhodesian Selection Trust, Ltd., and Associated Companies Act, 1954. The company holds three special grants of mining rights for the entire 10,803 acres located 24 miles southwest of Ndola.

Capitalization:

Authorized, £18,000,000 in ordinary units of stock and shares of 5s. each. Issued, £16,177,838 15s. 0d. in 64,711,355 shares and units of stock of 5s. each, fully paid.

Mine and plants:

The property is equipped with a concentrator and smelter to produce copper at a rate of about 100,000 tons per year. Production is refined at the plant of Ndola Copper Refineries, Ltd.

Production:	Tons mined	Blister copper production
1958.. short tons..	5, 707, 900	89, 523
1959.. ...do......	5, 549, 800	90, 644
1960.. ...do......	6, 661, 800	102, 028

Ndola Copper Refineries, Ltd.———48 Jameson Avenue Central, Salisbury, C. 4, Southern Rhodesia.—Incorporated March 30, 1954, in Northern Rhodesia. The company operates an electrolytic-copper refinery at Ndola, Northern Rhodesia, and supervises and operates the cobalt plant of Chibuluma Mines, Ltd., at Ndola.

Capitalization:

Authorized, 4,500,000 shares of £1 each. Issued, 4,500,000 shares of £1 each, fully paid.

Roan Antelope Copper Mines, Ltd., holds two-thirds of the capital and British Insulated Callenders' Cables, Ltd., one-third.

Operations:

The first stage of the tankhouse and refined-copper-casting operations started up in the latter part of 1958 with an initial annual electrolytic-copper capacity of 60,000 tons. An extension to the refinery is under construction which will increase its production to 110,000 tons per year.

Republic of South Africa

Messina (Transvaal) Development Co., Ltd. (M.T.D.)———Messina, Northern Transvaal, Republic of South Africa.—Incorporated January 27, 1950, in the Republic of South Africa. The company was formed to acquire a company of the same name registered in London January 30, 1905. The mining property in Northern Transvaal consists of an area of 17,990 morgen (37,779 acres) in the Zoutpansberg District. The company also has the Umkondo claims, the Alaska copper property, and the Alaska smelter in Southern Rhodesia; it owns approximately 62 percent of the issued capital of M.T.D. Mangula, Ltd. Other subsidiaries are M.T.D. (Sanyati), Ltd.; M.T.D. Copper (Sales), Ltd.; The Messina (Rhodesia) Development Co., Ltd.; and Messina Rhodesia Smelting & Refining Co., Ltd.

Capitalization:

Authorized, £2,500,000; £2,462,500 in 9,850,000 stock units of 5s. each is issued; 150,000 shares are unissued.

Operations:

At Messina, Transvaal, the working plant consists of five producing shafts; a crushing, sorting, milling, and concentrating plant; and a smelter with reverberatory, converter, and refining furnaces. Fire-refined copper, averaging 99.91 percent and conforming to British Standard 1037 is produced.

A smelting and refining plant was erected near Alaska, 13 miles west of Sinoia, Southern Rhodesia to handle concentrates from the Mangula and Alaska mines. The plant will be operated by Messina Rhodesia Smelting & Refining Co., Ltd., whose capital of £750,000 is 80-percent held by Messina (Transvaal) Development Co., Ltd., and 20-percent held by M.T.D. (Mangula), Ltd. Production at the Alaska smelter began in December 1960.

Production:

During the year ending September 30, 1960, the Messina and Umkondo concentrating plants handled 1,136,761 tons of ore for 40,820 tons of concentrates; the smelter produced 15,389 tons of copper. Production from the Mangula and Alaska mines for the same period amounted to 1,141,300 tons of ore, yielding 25,923 tons of concentrates containing about 13,250 tons of copper.

O'okiep Copper Co., Ltd.———Nababiep, Cape Province, Republic of South Africa.—Incorporated in the Republic of South Africa in May 1937. Ore was found at the site of the present mines by Governor van der Stet in 1686, but there were no actual mining operations until 1852. The Cape Copper Mining Co., Ltd., mined in the area from 1863 to 1888, when it was succeeded by the Cape Copper Co., Ltd. Most of the production came from the Nababiep South, the old O'okiep, the Spektakel, and the Narrap mines.

The company has mineral holdings covering approximately 256,106 acres and a half share in mineral rights over an additional 52,093 acres at O'okiep, Namaqualand. In addition, 90,000 acres consisting of 32 base mineral claims are owned outright, and optional rights are held on 38 base metal claims and on mineral rights of 13 farms. The principal mines are the Nababiep, East O'okiep-Narrap, Wheal Julia, and Nababiep West.

Capitalization:

Authorized, £1,600,000 in 3,200,000 shares of 10s. each; 1,021,056 shares are issued and fully paid, Newmont Mining Corp. holds 56.3 percent.

Mines and plants:

The Nababiep, O'okiep, Wheal Julia, and Nababiep West are underground mines; the Carolusberg West is an open-pit mine. There are concentrators at Nababiep and Okiep, and a smelter, a 40-ton-per-day sulfuric acid plant and three leaching plants at Nababiep. A new mill, having a capacity of 100,000 tons per month, will be erected at Carolusberg for production anticipated in 1963.

Production:

In the year ended June 30, 1960, 1,775,600 short tons of ore was milled. The smelter treated 132,724 tons of concentrate and produced 39,457 tons of blister copper.

Tsumeb Corporation, Ltd.———Tsumeb, South-West Africa.—Incorporated January 4, 1947, in South-West Africa. This company was formed by Newmont Mining Corp.; American Metal Co., Ltd., now American Metal Climax, Inc.; O'okiep Copper Co., Ltd.; and four British and South African companies to purchase all the assets, except cash, debts, and investments, of Otavi Minen und Eisenbahn Gesellschaft (Otavi Mines and Railway Co.) from the Custodian of Enemy Property in the former Union of South Africa for £1,010,000. The properties comprise 1,788 hectares of mining rights and almost 60,000 acres of grazing and horticultural land in the Grootfontein District, South-West Africa.

The Tsumeb copper-lead-zinc mine was operated by a German-controlled company from 1908 to 1940. It had been developed to a depth of 1,900 feet.

Capitalization:

Authorized, SA £1,050,000 in 4,200,000 shares of 5s. each; 4,000,000 shares are issued and fully paid. Stock ownership is as follows:

Company:	*Percent of stock held*
American Metal Climax, Inc	28. 5
Newmont Mining Corp	28. 5
Selection Trust, Ltd	14. 25
O'okiep Copper Co., Ltd	9. 50
South West Africa Co., Ltd	2. 37
Union Corp., Ltd., and others	16. 88

Mines and plants:

The De Wet shaft was sunk to a depth of 3,301 feet and ore hoisting through the shaft began early in 1955; this shaft will be deepened to 4,150 feet.

The first 300-ton unit of a 2,000-ton flotation mill began operating in March 1948, and a pilot plant for producting germanium-enriched concentrate was placed in operation in 1954. A copper smelter is being constructed at Tsumeb which will have an annual output capacity of 20,000 tons of blister copper. A lead smelter and refinery with an annual capacity of 80,000 to 90,000 tons of refined lead will be built beside the copper smelter and is scheduled for operation by mid-1963.

Production:

The following shows the refined metals accounted for by smelters:

		1956	*1957*	*1958*	*1959*
Copper	short tons	25, 767	27, 792	28, 939	28, 991
Lead	do	90, 206	87, 436	72, 539	79, 623
Zinc	do	4, 177	13, 172	22, 636	21, 609
Cadmium	pounds	122, 935	403, 203	675, 831	349, 724
Silver	ounces	1, 404, 812	1, 701, 536	1, 708, 027	1, 701, 934
Tons ore milled	short tons	624, 857	638, 481	666, 062	625, 534

OCEANIA

Australia

Mount Isa Mines, Ltd.———363 Adelaide St., Brisbane, Queensland, Australia.—Incorporated in Queensland December 11, 1931, to acquire operations of company of the same name registered January 15, 1924, in New South Wales. Controlling interest of 53.8 percent is held by American Smelting and Refining Co. Wholly owned subsidiaries are Copper Refineries Pty., Ltd., Stuart, Townsville, Queensland, and Brittania Lead Company, Ltd., Northfleet, Kent, England. Products are blister and refined copper, refined lead, lead alloys, refined silver, and zinc concentrate.

Capitalization:

Authorized, A£10,000,000; issued, A£9,524,565 in 38,098,261 shares of 5s. each.

Mines and plants:

The Mt. Isa mine is the largest copper producer in Australia. Mill capacity is 8,100 tons of combined sulfide ore daily, and the smelter has been enlarged to a capacity of 70,000 tons of blister copper a year. Capacity of the Townsville electrolytic plant of Copper Refineries Pty., Ltd., is 80,000 tons annually.

Production:

For the year ending June 30, 1960, Mt. Isa Mines, Ltd., produced 3 million tons of ore from which were extracted 45,332 short tons of blister copper; 97,040 tons of copper concentrate, containing 24,063 tons of copper, for treatment overseas; 56,582 tons of lead bullion, containing 4,282,970 ounces of silver; and 37,698 tons of zinc concentrate, containing 19,604 tons of zinc. Copper Refineries Pty., Ltd., produced 31,185 tons of refined copper from Mount Isa blister.

Mount Morgan, Ltd.———11 Castlereagh St., Sydney, Australia.—Incorporated July 18, 1929, in New South Wales. The company acquired the Queensland assets of Mount Morgan Gold Mining Co., Ltd., July 1, 1929; the assets included freehold property, mining leases, and plant and equipment at Mount Morgan and a coal mine at Baralaba.

Capitalization: Authorized A£2,444,876; issued, A£2,081,-625.

Mine and plant:

The company has an open-pit mine operated with electric shovels and diesel trucks, two flotation plants with combined capacity of 6,000 tons of sulfide ore daily, and a smelter. The smelter is equipped with roasters, a reverberatory furnace fired with pulverized coal, and a converter. Blister copper is shipped to Port Kembla, New South Wales, for refining and sale.

Production:

	1959	1960
Copper .... short tons..	7, 857	8, 112
Gold .... ounces..	67, 085	69, 020
Silver .... do....	20, 285	25, 195

Peko Mines N.L.———82 Elizabeth St., G.P.O. Box 3351, Sydney, New South Wales, Australia.—Incorporated in New South Wales, Australia, in 1950.

Capitalization: Authorized, A£2,000,000; issued A£787,-500.

Mine and plant:

The mine is a copper-gold property at Tennant Creek, Northern Territory. A shaft has been sunk to a depth of 1,130 feet and a 400-ton-per-day mill is in operation. The concentrate is transported by road and rail to Port Augusta, South Australia, for shipment abroad.

Production:

For the year ending June 28, 1960, 139,000 tons of ore was milled, yielding 28,606 tons of concentrate containing 7,509 tons copper, 12,720 ounces gold, and 42,909 ounces silver.

The Electrolytic Refining and Smelting Co. of Australia Proprietary, Ltd.———360 Collins St., Melbourne, Australia.—The company plant at Port Kembla, New South Wales, treats various copper, silver, and gold bearing materials—including blister copper, cathode copper, and copper scrap. The plant consists of a smelter, casting department, and refinery department. The smelter is equipped with a blast furnace and converters. Anodes, wirebars, ingot bars, cakes, and billets are cast in the casting department. The refinery has an electrolytic tankhouse, a silver mill for recovery of silver, gold, and platinum-group metals, a selenium plant, and a copper sulfate plant.

Tasmania

Mount Lyell Mining and Railway Co., Ltd.———381 Little Collins St., Melbourne, Australia.—Incorporated in Melbourne, Australia, August 11, 1903, to take over a company of the same name and the North Mount Lyell Copper Co., Ltd., owning copper mining leases and reduction works at Mount Lyell, about 18 miles from Macquarie Harbour on the West Coast of Tasmania. The property now covers 4,864 acres. The company holds large interests in fertilizer and chemical industries, in Metal Manufacturers, Ltd., manufacturers of copper wire, sheets, tubes, cables, etc., with works at Port Kembla, near Sydney, and in Renison, Ltd., (Tasmania).

Capital: Authorized, A£5,000,000; issued and fully paid, A£4,059,777.

Mine and plant:

Except for some underground exploration ore in the Crown Lyell No. 2 mine, the entire output is mined from the West Lyell open pit. The reduction works consist of a flotation mill, smelter with blast furnace and converters, and a sintering plant. The blister copper is refined at the company electrolytic refinery at Queenstown, which has an annual capacity of 13,000 tons of refined copper.

Production:

	1959	1960
Cathode copper ... short tons..	10, 094	11, 260
Silver .... ounces..	31, 369	38, 372
Gold .... do....	6, 125	6, 994

CHAPTER 8.—EMPLOYMENT AND PRODUCTIVITY

EMPLOYMENT

The working force of the copper industry engaged in mining and beneficiating ores, smelting concentrates, and refining copper has remained relatively steady since World War II, averaging approximately 33,000 men annually and ranging from a low of 29,000 in 1946 to a high of 37,000 in 1956. The average number of men employed daily in 1960 was 32,900. About half were engaged in mining, one-sixth in milling, and a third in smelting and refining. This distribution has been fairly uniform throughout the postwar years with increases and decreases of employment in all operations following the accelerated or relaxed industrial activity of the country.

The years of highest employment at copper mines were 1916 and 1917; slightly more than 61,000 men mined a little more than 1 million tons of recoverable copper in 1916 and just under 1 million tons in 1917. In 1929 it took 37,000 men to mine 1 million tons; in 1942 and 1943, 23,500; in 1956 and 1957, 18,000; and in 1960, 15,600. This decrease in employment is due to adoption of mass mining and milling methods which require fewer production workers.

Widespread mechanization and large-scale operations have changed the number of men and the types of skills needed. Men now are trained for specific tasks and less dependence is placed on the mining skills of the workers. Mining is directed and supervised by experienced foremen in accordance with plans prepared by technically trained mine superintendents and engineers. Mechanization has increased the demand for mechanics, enginemen, technicians, and operators of many kinds of machines, eliminating a large number of unskilled laborers. A resultant rise in productivity is due to the greater portion of copper ore mined by the open-pit method (table 81), plus technological advances in the mining processes and equipment.

Safety

In table 81 employment and injury statistics are given by underground and open-pit mining methods. The notable reductions in injuries and their frequency are due largely to the increasing proportion of workers being exposed to less hazardous conditions in open-pit mines. Also, substantial progress has been made in preventing accidents at surface and underground mines through technologic advances, proper education, discipline, good management, and intelligent administration.

Employment Statistics

The statistics of mine employment from different sources vary according to method of reporting. The Bureau of Mines reports the average number of men working daily at mines, at concentrators, and at smelters and refineries (combined). The Bureau of Labor Statistics shows monthly payroll figures and averages these figures annually for total employment at mines and concentrators. The Bureau of the Census reports the average mid-month employment in March, May, August, and November of the census years. Statistics from all these sources are shown in the following tables. However, Bureau of Mines data are used in evaluating productivity changes because of the separate and more complete coverage of mines, mills, and smelters and refineries.

PRODUCTIVITY

Definitions of the term "productivity" tend to vary according to the purpose for which the term is used. Usually productivity is considered to be the relation of output to input, but one concept refers to it as the relation of input to output. Input consists of capital equipment, raw materials, and labor-time; output consists of goods and services produced.

Productivitv is expressed, frequentlv, in units of output per man-hour of labor, reflecting the ratio of output to a specific measure of input. In some instances it is advantageous to show the inverse ratio. Thus, productivity can be measured in tons of ore produced per man-hour or in man-hours required to produce a ton of ore. The second concept is used as a measure of production efficiency and also shows the labor cost per unit of output. For example, both concepts were used in comparing the efficiencies of block caving and other underground methods of mining at Butte, Mont. (table 82).

Productivity, however, results from a composite of many input factors. Although most productivity measurements appear as units of

TABLE 81.—*Employee and injury data at underground and open-pit mines*

Year	Employees		Injuries		Frequency rate, per million man-hours	
	Underground	Open pit	Underground	Open pit	Underground	Open pit
1939	15, 268	3, 168	2, 307	212	67. 39	26. 95
1940	16, 351	3, 147	2, 447	176	60. 84	20. 82
1941	16, 466	5, 110	2, 812	211	69. 01	14. 67
1942	17, 615	5, 607	2, 752	283	62. 27	17. 48
1943	18, 652	5, 048	3, 322	254	71. 36	17. 97
1944	14, 459	4, 367	2, 381	209	66. 79	17. 64
1945	10, 355	4, 187	1, 393	161	56. 54	14. 86
1946	8, 911	4, 058	1, 344	136	65. 51	16. 78
1947	10, 723	4, 931	1, 506	181	59. 18	14. 12
1948	10, 935	5, 345	1, 344	259	51. 03	19. 40
1949	10, 645	5, 382	1, 016	187	45. 95	14. 82
1950	9, 870	5, 513	1, 012	181	44. 74	12. 29
1951	10, 282	5, 992	1, 024	299	42. 94	18. 89
1952	8, 712	6, 198	911	280	44. 25	16. 78
1953	8, 983	6, 911	961	276	45. 16	15. 16
1954	9, 447	6, 628	920	227	44. 93	14. 49
1955	9, 711	7, 289	1, 116	292	64. 90	15. 88
1956	10, 822	7, 325	1, 269	222	55. 50	11. 03
1957	10, 603	7, 061	1, 120	175	57. 18	16. 79
1958	8, 397	6, 575	788	143	55. 11	10. 12
1959	7, 744	6, 457	625	105	52. 11	8. 20
1960	7, 387	8, 261	683	127	54. 13	5. 40

output per man-hour, which is labor productivity, such measures indicate the effect of some change or series of changes that cannot be attributed solely to labor. The input factors also include planning, engineering, research, and managerial competence. Some or all the factors are affected by geography, weather, size and grade of deposit, and by local, national, and international political and economic changes.

TABLE 82.—*Comparison of mine efficiency by block caving with other mining methods in Butte district.*

	1952	1953	1954	1955 [1]
Labor output, average:				
Tons of ore per man-shift:				
Block caving	9. 37	15. 20	15. 65	16. 24
Other methods	2. 36	2. 58	2. 43	2. 65
Labor requirement, average:				
Man-hours per ton of ore:				
Block caving	. 86	. 53	. 51	. 49
Other methods	3. 39	3. 10	3. 29	3. 02

[1] First 6 months.

Production efficiency may be expressed as labor measurement in comparing productivity differences due to factors unrelated to labor input. For instance, a spokesman for The Anaconda Company referred to the increasing importance of open-pit and block-caving methods of mining in their Montana operations, stating that in the first six months of 1959 open-pit mining accounted for 63 percent of total production; block-caving, 27 percent; and stope mining, 10 percent. In emphasizing the advantage of the open-pit and block-caving methods of mining, production was expressed in tons per man-shift, as follows: Stope mines accounted for an average of 3.4 tons per man-shift; block-caving, 26.3 tons per man-shift; and open-pit operations, 86.9 tons per man-shift. The productivity reference here is to the mining method, with all input factors considered, not just labor.

Besides measuring productivity in terms of labor input, it can, of course, be expressed in terms of any one element of input or in terms of all elements of input. Thus, it could be measured by production per dollar of capital investment, production per unit of energy consumed, or production per unit of raw material consumed. But, because 40 to 60 percent or more of the total cost of most productive operations is labor cost, expressing productivity in units of labor shows this measurement in terms of the major element of input. Such expression does not mean that workers create or are the sole cause of production because the importance of other elements of input are well recognized.

Mine Productivity

Over the last fifty years the annual recoverable copper content of copper ores produced in the United States has almost doubled; the bulk of ore mined has increased almost fivefold. In 1911 it required 110 million man-hours to produce 30 million tons of ore containing 557,000 tons of copper; whereas in 1960, 35 million man-hours produced 135 million tons of ore yielding 1.08 million tons of copper. Converting this information into productivity terms, 0.27 ton of ore and 10.1 pounds of metal were produced per man-hour in 1911, compared with 3.88 tons of ore and 62.0 pounds of copper per man-hour in 1960 (table 83). These increases in production and productivity, and the decreases in the number of men and man-hours required are due principally to the greater use of large-scale mining methods—open-pit and block-caving—and the high degree of mechanization of most all operations.

From 1939 to 1960 the quantity of ore mined per man-hour increased 196 percent while the recoverable copper rose only 79 percent. Also in the same period, the cost of wages per ton of ore increased 32 percent, while that for recovering 1 pound of copper-in-concentrate rose 115 percent. The explanation for this anomaly is that while large scale mining methods have helped to keep down labor costs in ore production, the average recoverable metal content of ore has been decreasing steadily since 1939, causing the average wage cost per ton of metal to accelerate more rapidly than per ton of ore. Cost elements contributing to the increasing labor cost per ton of ore and per pound of metal are higher wage rates and more fringe benefits.

TABLE 83.—*U.S. copper mine productivity—wages and labor cost, 1911–60*

Year	Mined copper, recoverable content, thousand pounds	Man-hours worked, thousand	Output per man-hour in pounds, copper	Recoverable copper in ore, percent	Total ore mined, thousand tons	Ore per man-hour, tons	Average wage per man-hour	Average wage per pound metal	Average wage per ton ore
1911	1, 114, 762	110, 195	10. 1	1. 82	29, 998	0. 27	----------	----------	----------
1912	1, 249, 092	126, 650	9. 9	1. 71	35, 656	. 28	----------	----------	----------
1913	1, 235, 570	138, 954	8. 9	1. 67	36, 337	. 26	----------	----------	----------
1914	1, 148, 416	102, 760	11. 2	1. 60	35, 176	. 34	----------	----------	----------
1915	1, 488, 074	113, 691	13. 1	1. 66	43, 404	. 38	----------	----------	----------
1916	2, 005, 878	151, 457	13. 2	1. 70	57, 863	. 38	----------	----------	----------
1917	1, 895, 434	152, 685	12. 4	1. 60	58, 483	. 38	----------	----------	----------
1918	1, 910, 024	152, 833	12. 5	1. 51	62. 289	. 41	----------	----------	----------
1919	1, 212, 330	94, 852	12. 8	1. 65	36, 122	. 38	----------	----------	----------
1920	1, 224, 552	89, 457	13. 7	1. 63	36, 765	. 41	----------	----------	----------
1921	466, 194	35, 690	13. 1	1. 70	13, 396	. 37	----------	----------	----------
1922	964, 586	60, 040	16. 1	1. 74	26, 893	. 45	----------	----------	----------
1923	1, 477, 740	82, 452	17. 9	1. 58	45, 519	. 55	----------	----------	----------
1924	1, 606, 164	81, 121	19. 8	1. 59	49, 178	. 61	----------	----------	----------
1925	1, 678, 118	83, 366	20. 1	1. 54	53, 103	. 64	----------	----------	----------
1926	1, 725, 274	84, 096	20. 5	1. 46	57, 182	. 68	----------	----------	----------
1927	1, 649, 950	77, 023	21. 4	1. 41	56, 725	. 74	----------	----------	----------
1928	1, 809, 784	79, 205	22. 8	1. 41	62, 097	. 78	----------	----------	----------
1929	1, 995, 104	95, 870	20. 8	1. 41	68, 298	. 71	----------	----------	----------
1930	1, 410, 144	66, 002	21. 4	1. 43	47, 752	. 72	----------	----------	----------
1931	1, 057, 750	41, 019	25. 8	1. 50	33, 989	. 83	----------	----------	----------
1932	476, 222	18, 605	25. 6	1. 83	12, 261	. 66	----------	----------	----------
1933	381, 286	13, 472	28. 3	2. 11	8, 348	. 62	----------	----------	----------
1934	473, 896	14, 727	32. 2	1. 92	11, 659	. 79	----------	----------	----------
1935	760, 982	22, 293	34. 1	1. 89	19, 009	. 85	----------	----------	----------
1936	1, 229, 032	34, 900	35. 2	1. 54	38, 505	1. 10	----------	----------	----------
1937	1, 683, 996	51, 982	32. 4	1. 29	61, 501	1. 23	----------	----------	----------
1938	1, 115, 526	34, 600	32. 2	1. 34	37, 962	1. 09	----------	----------	----------
1939	1, 456, 640	42, 098	34. 6	1. 25	55, 221	1. 31	$0. 68	$0. 020	$0. 518
1940	1, 756, 172	48, 700	36. 1	1. 20	69, 278	1. 42	. 73	. 020	. 512
1941	1, 916, 298	55, 100	34. 8	1. 15	78, 453	1. 42	. 79	. 023	. 558
1942	2, 160, 122	60, 400	35. 8	1. 09	92, 286	1. 53	. 90	. 025	. 591
1943	2, 181, 636	60, 689	35. 9	1. 04	98, 120	1. 67	1. 01	. 027	. 603
1944	1, 945, 098	47, 496	40. 2	. 99	91, 064	1. 92	1. 02	. 026	. 533
1945	1, 545, 788	35, 474	43. 6	. 93	77, 473	2. 18	1. 04	. 029	. 479
1946	1, 217, 474	28, 622	42. 5	. 91	62, 232	2. 17	1. 16	. 027	. 533
1947	1, 695, 126	38, 264	44. 3	. 90	87, 865	2. 30	1. 32	. 030	. 575
1948	1, 669, 626	39, 684	42. 1	. 92	84, 729	2. 14	1. 46	. 035	. 680
1949	1, 505, 500	34, 730	43. 3	. 91	76, 033	2. 20	1. 51	. 035	. 687
1950	1, 818, 686	37, 345	48. 7	. 89	94, 586	2. 53	1. 60	. 033	. 633
1951	1, 856, 660	39, 677	46. 8	. 90	95, 494	2. 41	1. 70	. 036	. 704
1952	1, 850, 718	37, 280	49. 6	. 85	99, 947	2. 68	1. 88	. 038	. 701
1953	1, 852, 896	39, 488	46. 9	. 85	101, 065	2. 56	2. 00	. 043	. 781
1954	1, 670, 944	36, 143	46. 2	. 83	93, 654	2. 59	2. 05	. 044	. 792
1955	1, 997, 140	40, 500	49. 3	. 83	112, 550	2. 78	2. 17	. 044	. 781
1956	2, 208, 312	45, 981	48. 0	. 78	131, 776	2. 87	2. 30	. 048	. 801
1957	2, 173, 718	41, 452	52. 4	. 77	129, 716	3. 13	2. 39	. 046	. 764
1958	1, 958, 658	31, 295	62. 6	. 79	114, 824	3. 67	2. 42	. 039	. 659
1959	1, 649, 692	26, 382	62. 5	. 74	103, 716	3. 93	2. 51	. 042	. 639
1960	2, 160, 338	34, 824	62. 0	. 73	134, 994	3. 88	2. 65	. 043	. 683

Source: Output: United States Bureau of Mines. Man-hours worked: 1911–36–WPA—"Copper Mining" 1940; 1936–60—Bureau of Mines. Hourly wages: Bureau of Labor Statistics, Bulletin Copper Mining (102), and Monthly Labor Reviews.

The average wage per man-hour for copper mining has almost quadrupled since 1939. In addition, the effective wage rate has been increased by fringe benefits, some such as paid vacations, holiday pay allowances and premiums, sick leave, compensation for unemployment, industrial injury, and occupational disease are entirely paid for by the companies. Other common advantages provided by employers, in which employees share some of the cost, are Social Security, hospital-medical-surgical plans covering employees and dependents, and life insurance. The cost of fringe benefits can amount to 20 percent or more of the average straight time wage rate.

The largest increases in production and productivity rates have occurred in open-pit mines. Because these mines have contributed most of domestic production, 80 percent in 1960, they tend to lift the productivity average of the whole industry.

Concentrator Productivity

Productivity in ore concentration plants may be measured by man-hours of labor per ton of ore milled. Employment, production, productivity, and labor-cost data covering the period from 1943 to 1960 inclusive are shown in table 84.

Most of the ore-dressing processes are mechanical and plants usually require a fixed number of men for various operations; as a consequence the productivity and labor-cost per ton varies with the tonnage treated. However, significant portions of the increased efficiencies at the new and enlarged concentrators are due to technological advances made in new equipment and automation, accounting for the treatment of greater tonnages with less men.

Smelters and Refineries

Data are not readily available on productivity at smelters and refineries, principally because the number of workers and man-hours are not reported separately for smelters and refineries. However, some idea of the productivity and productivity changes at these plants may be had from tables 85 and 86.

The man-hours worked at smelters and refineries are matched with smelter output from domestic ores to derive a productivity expression of pounds of copper per man-hour. Refined production from domestic ores is very close to the smelter output, being only 142,413 tons (0.7 percent) less for the 21-year period from 1939 through 1960.

Although the number of employees and man-hours are relatively steady so that the changes in indicated productivity appear to be caused by varying production quantities, considerable credit must be given to the following improvements in smelting and refining processes and equipment:

1. Elimination of roasting at some smelters.
2. Larger reverberatory furnaces.
3. Gas-deoxidation of converter copper.
4. Improved casting equipment at smelters for anodes and at refineries for wirebars, cakes, and billets.
5. Continuous casting at refineries.

TABLE 84.—*Productivity data of copper concentrators in the United States 1943–60*

Year	Employment		Production		Productivity		Labor cost	
	Average men working daily	Man-hours worked, thousands	Tons of ore milled, thousands	Recoverable copper content, thousand pounds	Tons ore milled per man-hour	Pounds of recoverable copper per man-hour	Man-hour per ton of ore milled	Man-hour per pound recoverable copper
1943	7, 095	19, 797	92, 247	1, 794, 992	4. 66	90. 67	0. 215	0. 01102
1944	6, 558	18, 104	86, 393	1, 628, 392	4. 77	89. 95	. 210	. 01111
1945	5, 891	15, 439	73, 959	1, 327, 538	4. 79	85. 99	. 209	. 01162
1946	5, 579	12, 436	58, 521	1, 030, 280	4. 71	82. 85	. 212	. 01207
1947	5, 846	15, 100	83, 283	1, 454, 598	5. 52	96. 33	. 181	. 01038
1948	6, 308	15, 998	80, 098	1, 420, 094	5. 01	88. 77	. 200	. 01126
1949	6, 582	15, 526	72, 019	1, 287, 342	4. 64	82. 92	. 216	. 01206
1950	5, 828	15, 731	90, 206	1, 583, 886	5. 73	100. 69	. 175	. 00993
1951	6, 033	16, 205	91, 021	1, 590, 528	5. 62	98. 15	. 178	. 01018
1952	6, 141	16, 969	95, 307	1, 571, 652	5. 62	92. 62	. 178	. 01079
1953	6, 243	17, 254	96, 595	1, 587, 658	5. 60	92. 02	. 179	. 01086
1954	7, 096	16, 699	89, 620	1, 421, 714	5. 37	85. 14	. 186	. 01174
1955	6, 222	15, 854	108, 061	1, 745, 040	6. 82	110. 07	. 147	. 00908
1956	6, 683	18, 400	127, 251	1, 915, 828	6. 92	104. 12	. 145	. 00960
1957	7, 083	18, 095	124, 640	1, 899, 106	6. 89	104. 95	. 145	. 00952
1958	6, 468	14, 618	114, 028	1, 758, 916	7. 80	120. 33	. 128	. 00831
1959	5, 588	11, 156	103, 239	1, 496, 508	9. 25	134. 14	. 108	. 00745
1960	5, 230	13, 129	134, 306	1, 926, 408	10. 23	146. 73	. 098	. 00681

TABLE 85.—*Productivity data of smelters and refineries, combined* [1]

Year	Average men working daily	Man-hours worked, thousands	Smelter production of copper, thousand pounds	Pounds copper per man-hour
1939	9, 234	21, 643	1, 424, 350	65. 8
1940	10, 743	25, 092	1, 818, 168	72. 5
1941	10, 927	27, 848	1, 932, 144	69. 4
1942	10, 286	27, 911	2, 175, 982	78. 0
1943	10, 153	28, 533	2, 185, 878	76. 6
1944	7, 728	21, 733	2, 006, 758	92. 3
1945	10, 420	28, 947	1, 565, 452	54. 1
1946	10, 187	23, 573	1, 199, 312	50. 9
1947	12, 393	31, 938	1, 725, 744	54. 0
1948	12, 419	32, 496	1, 684, 954	51. 9
1949	11, 626	28, 395	1, 515, 862	53. 4
1950	11, 756	30, 402	1, 822, 704	60. 0
1951	11, 928	31, 198	1, 861, 548	59. 7
1952	10, 629	27, 508	1, 854, 730	67. 4
1953	11, 177	28, 943	1, 886, 782	65. 2
1954	11, 244	27, 316	1, 668, 762	61. 1
1955	11, 691	29, 661	2, 014, 622	67. 9
1956	12, 194	31, 497	2, 235, 160	71. 0
1957	11, 826	30, 583	2, 162, 110	70. 7
1958	10, 801	26, 966	1, 985, 836	73. 6
1959	11, 204	23, 516	1, 598, 658	68. 0
1960	12, 009	29, 445	2, 285, 696	77. 6

[1] Approximate: Employment for smelters and refineries not separable, and some refinery man-hours chargeable to refined production derived from foreign ores.

TABLE 86.—*Copper industry employment data*

Year	Mining		Ore-dressing		Smelting-refining		Total	
	Employment [1]	Man-hours worked, thousands	Employment [1]	Man-hours worked, thousands	Employment [1]	Man-hours worked, thousands	Employment [1]	Man-hours worked, thousands
1943	23, 700	60, 689	7, 095	19, 797	10, 153	28, 533	40, 948	109, 019
1944	18, 826	47, 496	6, 558	18, 104	7, 728	21, 733	41, 268	87, 333
1945	14, 542	35, 474	5, 891	15, 439	10, 420	28, 947	30, 853	79, 860
1946	12, 969	28, 622	5, 579	12, 436	10, 187	23, 573	28, 735	64, 631
1947	15, 654	38, 264	5, 846	15, 100	12, 393	31, 938	33, 893	85, 302
1948	16, 280	39, 684	6, 309	15, 998	12, 419	32, 496	35, 007	88, 178
1949	16, 027	34, 730	6, 582	15, 526	11, 626	28, 395	34, 235	78, 651
1950	15, 383	37, 345	5, 828	15, 731	11, 756	30, 402	32, 967	83, 478
1951	16, 274	39, 677	6, 033	16, 205	11, 928	31, 198	34, 235	87, 080
1952	14, 910	37, 280	6, 141	16, 969	10, 629	27, 508	31, 680	81, 757
1953	15, 894	39, 488	6, 243	17, 254	11, 177	28, 943	33, 314	85, 685
1954	16, 075	36, 143	7, 096	16, 699	11, 244	27, 316	34, 415	80, 158
1955	17, 000	40, 500	6, 222	15, 854	11, 691	29, 661	34, 913	86, 015
1956	18, 147	45, 981	6, 683	18, 400	12, 194	31, 497	37, 024	95, 878
1957	17, 664	41, 452	7, 083	18, 095	11, 826	30, 583	36, 573	90, 130
1958	14, 972	31, 295	6, 468	14, 618	10, 801	26, 966	32, 241	72, 879
1959	14, 201	26, 382	5, 588	11, 156	11, 204	23, 516	30, 993	61, 054
1960	15, 648	34, 824	5, 230	13, 129	12, 009	29, 445	32, 887	77, 328

[1] Average number men working daily.

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CHAPTER 9.—RESEARCH AND DEVELOPMENT

Research and development departments have long been an integral part of many copper producing and fabricating firms. Some companies that do not have their own or adequate scientific facilities and personnel contract their research projects to outside organizations, such as commercial laboratories, engineering service firms, research institutes, and colleges and universities. Many of the copper and copper-base-alloy fabricating companies have erected new facilities or expanded their existing scientific laboratories to study properties and methods of manufacturing copper and copper-alloy products for traditional as well as new fields of use. The emphasis given science and technology by the industry, the Federal Government, educational institutions, and other organizations, points up the value of basic and applied research in development of future growth for the copper industry. Studies in solid-state physics will be emphasized in the coming years to obtain fundamental knowledge and to discover new scientific facts pertaining to the metals industry. Continuing applied research will be directed toward improving the technology of recovery and processing of copper, recovering byproduct metals, and developing new applications.

INDUSTRY RESEARCH

The knowledge gained through numerous studies of science and techniques has resulted in the development of improved equipment, processes, and products, as well as more effective planning and management to meet the worldwide growing demand for copper. The advantages realized by the major copper producers from efforts expended in research have encouraged them to emphasize their research activities for the future. A brief résumé of some of the research and development programs through 1961 follow.

U.S. COMPANIES

The Anaconda Company

The Anaconda Company has made large investments in new research facilities in recent years. Geological research laboratories at Butte, Mont., and El Salvador, Chile, contribute to the basic knowledge of ore formation and a variety of different problems. Mining engineers are continuously investigating mining methods, techniques, and equipment to find means of mining and handling lower grade ore economically, and new underground mining methods to extract high-grade ore from the deep mines. A new company unit, the Extractive Metallurgical Research Division, established in 1962 at Anaconda, Mont., undertakes projects for the various operations. This division may also contract for projects to be completed by other research organizations in the Western Hemisphere. The Anaconda Wire and Cable Company, a subsidiary, inaugurated an extra-high-voltage research laboratory at Hastings-on-the-Hudson, N.Y., in 1959 and has other research centers at Marion, Ind., and Muskegon, Mich. The Anaconda American Brass Company, another subsidiary, dedicated a new Research and Technical Center at Waterbury, Conn., in 1961 for studies in basic and applied research.

American Smelting and Refining Company

At the American Smelting and Refining Company, Central Research Laboratories, South Plainfield, N.J., research is being done in the detection, determination, and control of impurities in both high-purity elements and commercial metals. A continuing study of the basic chemistry of electrolytic refining of copper has yielded knowledge that permits refining of anodes much higher in silver and certain other impurities than was thought possible a few years ago. This research department developed equipment for the semicontinuous casting of cakes and large billets. At New Haven, Conn., the company works on problems of surface cleaning, treating, and finishing of metals.

American Metal Climax, Inc.

American Metal Climax, Inc., conducts research and development activities concerning its copper, lead, and zinc operations through Amco Research & Development, Inc., a wholly owned subsidiary located at Carteret, N.J. The research program includes investigations of a wide range of nonferrous alloys, improvement of plant operations to increase the value of raw materials processed and byproducts recovered, and pilot plant studies for modernizing copper refining and casting.

Cerro Corp.

Cerro Corp. explores for new ore deposits, carries on metallurgical and process research, and participates in programs for new product development. Studies by the research department of Cerro de Pasco Corp. in Peru include: Economic recovery of metals from zinc plant leach residue, improved recovery of copper from mine waters, leaching-in-place of low grade copper ores, and smelting high-grade lead concentrates without sintering.

Copper Range Company

The Copper Range Company has research facilities at the White Pine Copper Company, a wholly owned subsidiary at White Pine, Mich. These are equipped for investigation and improvement of recovery processes. The laboratories of nearby Michigan College of Mining and Technology are used for additional studies of recovery techniques through pilot plant stages. Recovery has been increased to 85 percent at White Pine from the original 82 or 83 percent, and a continuing research program is being emphasized for greater efficiency. Each 1 percent of additional recovery means production of an additional 1 million pounds of copper annually. Copper Range maintains modern facilities at Alloyd Electronics Corp. in Cambridge, Mass., for metallurgical research and testing of the company products. The research equipment here includes that needed for investigation of properties of metals and for experimentation in development of new products. Specialized work is conducted in electron beam techniques, vapor deposition, heat treating, and protective coatings.

Inspiration Consolidated Copper Co.

The Inspiration Consolidated Copper Co. revised its concentrator treatment in 1961, as a result of process research, and produced a copper concentrate averaging 35 percent copper, compared with the 23-percent concentrate of 1960. The amount of waste material treated by the smelter was reduced about 40 percent, and the improved concentrate could be smelted easier and quicker.

Kennecott Copper Corp.

Kennecott Copper Corp. research and development activities are carried on at the Western Research Center in Salt Lake City, Utah; the laboratories of Chase Brass & Copper Co. in Waterbury, Conn.; and the laboratories of Okonite Co. in Passaic and Paterson, N.J. The Western Research Center laboratories contain modern scientific equipment and pilot plants designed for investigating mining, milling, smelting, and refining operations. Studies here resulted in development of the leach-precipitation-flotation process for concentrating the mixed oxide-sulfide ores of the Ray Division of the company, recovery of byproduct rhenium, development of an electrolyte-purification system, and new reclamation techniques for re-use of water at the various concentrating mills. Research at the Chase and Okonite laboratories is planned for improvement of fabricated products, development of new products, and discovery of new uses for copper and copper base alloys. Research achievements at Chase include new alloys, improved coatings for copper and brass, continuous casting of copper, improved methods of joining copper, and methods of processing columbium, titanium, zircaloy, and rhenium. In Salt Lake City and Denver, Bear Creek Mining Co., the exploration subsidiary of the corporation, is undertaking comprehensive chemical and mineralogical studies at its own and the Kennecott laboratories to develop new geochemical prospecting techniques for use in exploration. Kennecott is presently building a basic research laboratory at Lexington, Mass.

Newmont Mining Corp.

Newmont Mining Corp., through the geophysical department of Newmont Exploration, Ltd., at Danbury, Conn., has developed two novel devices for geophysical surveying. One is an electromagnetic drill-hole apparatus and the other an improved overvoltage or induced polarization device used in electromagnetic field surveys. The Newmont metallurgical department participated in developing a slag-fuming process for recovering germanium from slag at the Tsumeb Corporation, Ltd., operation in Southwest Africa.

Phelps Dodge Corp.

Phelps Dodge Corp. conducts research at all its divisions and fabricating plants to improve operating processes and to develop better and new products. A new process developed at the Douglas, Ariz., smelter removes oxygen from blister copper with reformed natural gas instead of wood poles. A method of manufacturing sponge iron from iron oxides produced in the smelting process was also developed at Douglas. The sponge iron is expected to provide a more economical precipitant for copper in leaching operations. Different processes for recovering the small amount of copper present in the ore in oxide form at Morenci are constantly being investigated. At the fabricating plants, the metallurgical laboratory at Bayway, N.J., perfected a new cupronickel alloy having high strength and corrosion-resisting properties and the ability to resist high temperatures. In the condenser-tube field important developments were the perfection of a welding process joining tubes to condenser sheets and a condenser tube with a tapered-end design to prolong the life of the tube by increasing its resistance to water turbulence. A new laboratory for research in pipe, tube, and other extrusion products began operation in 1961. At the Habirshaw Cable and Wire Division, Yonkers, N.Y., laboratory-developed products included a self-supporting, aerial-telephone cable with built-in messenger wire; a helical-membrane, air-dielectric coaxial cable; improved power cables for use in underground mines; and a combined conduit and cable assembly that can be installed in a single operation.

FOREIGN COMPANIES

The ever increasing interest in research implied by the efforts of the above companies is manifested also by similar research activities of copper producers and fabricators in foreign countries.

FEDERAL BUREAU OF MINES

The research program of the Bureau of Mines related to copper is concerned principally with extraction and beneficiation of ores. Some projects in basic research have been initiated for a better understanding of the problems associated with mining and metallurgical procedures.

Two areas of research related to mining are essential parts of the Bureau program. These are (1) Development of engineering principles and mathematical techniques applicable to exploration, development, and operational problems in mining, and (2) study of rock mechanics and geologic structure affecting ground control. The first area includes three categories: Methods research of ore sampling, mine-systems analysis, and statistical evaluation of mineral exploration problems. The second area involves studies in two main categories: Laboratory investigations of how rock behaves under loads imposed by mining operations and field examinations to evaluate stress-strength relationships in full scale operating mines.

Mining research is conducted at five Bureau locations—Denver, Colo.; Minneapolis, Minn.; Reno, Nev.; Spokane, Wash.; and College Park, Md. Each unit is assigned a special field of investigation and has laboratory space and equipment for its particular research activity. The Denver Mining Research Center engages in rock mechanics research with respect to ground control and development of engineering principles and mathematical techniques applicable to exploration, development, and operational problems of mining. At the Minneapolis Mining Research Center research involves rock penetration, fragmentation, and supporting operational problems. The Reno Office of Mining Research specializes in studies of open-pit slope design. The Spokane Office of Mining Research has primary responsibility for research on artificial ground stabilization, and the Applied Physics Research Laboratory at College Park investigates applications of physics to all phases of mining.

The Bureau metallurgical research program respecting copper involves studies in mineral-dressing, hydrometallurgy, and pyrometallurgy—emphasizing investigations of fundamental actions and reactions in concentrating and leaching ores, smelting concentrate, and recovering byproducts. Each project is directed toward improving the efficiency of a process by solving problems and analyzing procedures, or it is aimed at discovering new knowledge about why certain basic chemical or metallurgical reactions follow the same pattern under similar or all conditions.

The Bureau of Mines metallurgical research units include seven centers and five associated laboratories. The centers are at Albany, Oreg., and Reno, Nev., with associated laboratories at Boulder, Nev., and Berkeley, Calif.; Salt Lake City, Utah, with a laboratory at Tucson, Ariz.; Rolla, Mo., and Minneapolis, Minn., with a laboratory at Bruceton, Pa.; College Park, Md., with a laboratory at Norris, Tenn.; and Tuscaloosa, Ala. Most of the research on copper is carried on at Salt Lake City, Tucson, Minneapolis, and College Park.

OTHER GOVERNMENT AGENCIES

Other Government agencies perform or contract for research directly or indirectly involving copper. The Geological Survey conducts fundamental research in geochemistry and geophysics, developing information to aid exploration. The research and development branches of the Army, Navy, and Air Force, investigating properties of metals for specific end-item applications, test copper and copper-base alloys for particular qualities.

RESEARCH AND DEVELOPMENT ASSOCIATIONS

There are three outstanding cooperative associations in the United States whose members are research-conscious producers and/or fabricators of copper and wrought- or casting-copper-base alloys. These groups are: International Copper Research Association, Copper & Brass Research Association, and Brass and Bronze Ingot Inst.

Foremost among these and world cooperatives of copper companies concerned with technical research is the International Copper Research Association (INCRA), which was the Copper Products Development Association (CPDA) before June 1, 1962. Founded in 1960, this research organization has a membership of 35 copper-producing companies representing mining operations in North America, South America, Africa, and Australia. These companies, which account for approximately 95 percent of the free world copper production, formed this association to promote new and improved uses for copper and its alloys through research in certain fields where new or larger outlets might be found for the larger quantities of copper being mined. The costs of research are prorated to the members on the basis of tonnage of production. The technical director of INCRA works with one committee of technical experts, and one committee of marketing specialists. Committee personnel are employees of the member companies. Engineering and literature surveys are made first to determine potential areas of development; then specific research projects are designed and assigned to laboratories of member companies and commercial non-profit research laboratories or university foundations in the United States and foreign countries.

INCRA is pursuing applied and fundamental research under 10 broad research programs. The projects scheduled, and the organizations carrying out the work under these programs were outlined by INCRA in August 1962 as follows:

- Protective Coating Program:
  - Organic protective coatings:
    - One project—British Non-Ferrous Metals Research Association, London, England.
    - One project—Chase Brass & Copper Co., Inc., Waterbury, Conn.
- Corrosion Program:
  - Electrochemical study of pitting:
    - One project—Cebelcor, Brussels, Belgium.
  - Copper surfaces (structure):
    - One project—British Non-Ferrous Metals Research Association, London, England.
- Electroforming Program:
  - Automobile radiators by electroforming:
    - One project—University of Michigan, Ann Arbor, Mich.
  - Physical properties of copper electrodeposits (joint project with American Electroplaters Society):
    - One project—National Bureau of Standards, Washington, D.C.
- Copper in Iron and Steel Program:
  - Grinding balls:
    - One project—University of Ghent, Belgium.
    - One project—The Anaconda Company, Anaconda, Mont.
    - One project—National Casting Co.
    - One project—Quebec Iron Foundries, Ltd., of Noranda Mines Ltd., Mont Joli, Quebec, Canada.
  - Properties of cast iron containing copper:
    - One project—Battelle Memorial Institute, Columbus, Ohio.
- Improved Copper Alloys Program:
  - Copper-rare-earth alloys:
    - One project—Denver Research Institute, Denver, Colo.
  - Dispersion strengthening by electroplating:
    - One project—American Metal Climax, Inc., Carteret, N.J.
  - Cooperative project with Cast Bronze Bearing Institute:
    - Cast Bronze Design Manual expansion, Franklin Institute, Philadelphia, Pa.

Copper Compound Program—Smog Control—Fungicides:
  - Copper compounds in mufflers:
    - One project—Franklin Institute, Philadelphia, Pa.

Copper Alloys for Molds Program:
  - Castable alloys for glass molds and plungers:
    - One project—Philadelphia Bronze & Brass Co., Philadelphia, Pa.

Stainless Copper Alloys Program:
  - Beta brass alloys:
    - One project—Anaconda American Brass Co., Waterbury, Conn.
  - Related oxide studies:
    - One project—University of Stockholm, Sweden.
  - Metal-oxide relation studies:
    - One project—University of Florence, Italy.

Fundamental Research Program:
  - Mechanics of surface reactions of copper:
    - University of Arizona, Tucson, Arizona.
  - Effect of surface dislocations on the physical properties of copper:
    - University of Ghent, Belgium.

The Copper & Brass Research Association (CABRA) is an organization maintained by 43 copper and brass mills that produce copper and copper-base-alloy sheet, wire, pipe, tube, and shaped products. CABRA has a staff of 35 qualified technicains that compiles standards for brass mill products, publicizes the merits of copper and its alloys, and publishes general and technical information and a variety of specialists reports concerning copper. The association also encourages research through sponsorship of an annual contest to honor outstanding achievement in the use or application of copper metal. Prizes have been awarded for such developments as a revolutionary molded-circuit (printed circuit) process; a copper current-conductor system for electrified fixed-track, materials-handling equipment—such as ore bridges, overhead cranes, and other industrial facilities; and an all bronze, uniquely designed, church spire.

Membership of the Brass and Bronze Ingot Institute (BBII), founded in 1928, consists of 14 manufacturers of brass and bronze ingot. The BBII initiated its metal research program in 1930 to help foundries by supplying them with accurate detailed physical and chemical specifications for brass and bronze casting alloys. The program was started at the National Bureau of Standards and later transferred to the Battelle Memorial Institute in Columbus, Ohio. The first Battelle project was designed to furnish foundries with badly needed information about mechanical properties of sand-cast copper alloys. From 1944 to 1954, many factors were evaluated, including metal composition, mold materials, method of charging, and rate of pouring. The latest project, begun in 1955 and still aggressively pursued, develops authoritative data about the properties of standard brass and bronze casting alloys. The new information is valued by foundrymen, metallurgists, design engineers, and architects because it allows foundries to produce castings of greater precision and variety than heretofore considered possible.

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CHAPTER 10.—LEGISLATION AND GOVERNMENT PROGRAMS

INTRODUCTION

The direct interest of the Government in the copper industry is manifested in the forms of regulation, taxation, aid, and participation. Its policy respecting the entire mining industry is one of encouraging development of the natural resources of the Nation to maintain national security and to foster economic growth. The basic mineral law of the United States, which is composed of the Mining Laws and the Mineral Leasing Acts, provides for exploration, development, and extraction by private enterprise of mineral deposits found on federally owned land. The Internal Revenue Code of 1954, as amended and in force on January 3, 1961, contains specific provisions designed to reduce the impact of Federal taxation on the mining industry. Treaties with foreign countries are designed to improve conditions with respect to friendship, commerce, and navigation. Legislation administered by the Securities and Exchange Commission protects the interest of the public and investors against malpractices in the securities and financial markets. Antitrust laws prohibit activities in restraint of trade, monopolies in commerce, and discriminatory and unfair trade practices.

In addition the Federal Government conducts a number of public service activities in the field of minerals, including the collection and dissemination of statistical, economic, and technical data. Special programs are designed to promote health and safety in mining. The information derived from the work in many projects is disseminated to industry and the general public by press releases, reports, bulletins, and other methods.

REGULATIONS

Mining Laws

The basic mineral law of the United States is composed of Mining and Mineral Leasing Acts which provide for exploration, development, and extraction by private enterprise of mineral deposits found on Government-owned land. The Act of July 14, 1866 (14 Stat. 86; Rev. Stat. 2318) was the first effort of Congress to create a system of Federal mining law. It was the first act giving citizens the right to enter upon the public domain for mining purposes and undoubtedly stimulated and encouraged development of the mining industry in the West. The Act of May 10, 1872 (17 Stat. 91), incorporating necessary changes to the Act of 1866, became the foundation of present United States mining laws. It continued the policy of free access to public domain for exploration and mining and set forth obligations and rights for unpatented claims and the procedure for acquiring a patent.

Unpatented Claims.—A summary of the steps involved for an unpatented claim follows: One may claim minerals in unoccupied public land by establishing a discovery, marking the boundaries of the location, and recording the claim with the local recording office where required by State law. Thereafter the locator must perform not less than $100 worth of development work each year; failure to do so opens the possibility of location of the same ground by another party. A locator is not required to record his claim with the Federal Government. Lode locations may not exceed 1,500 feet in length along the vein, and 300 feet in width on each side of the middle of the vein. The United States mining laws do not limit the number of locations that can be made by an individual or association provided each contains a discovery. A valid discovery is one that "would justify a person of ordinary prudence in the further expenditure of his time and means in an effort to develop a paying mine."[5] Once a valid discovery and location have been made, the locator acquires a vested interest in the mining claim and may begin extracting minerals.

Patented Claims.—Title to claims covered by location may be had by obtaining a patent from the United States. The steps required in patent application proceedings include: Posting of notices on the claim, in the local land office, and in newspapers; proof of citizenship; an official survey; proof of mineral character; proof of $500 worth of improvements; and presentation of an abstract of title. These proceedings are initiated in the local land offices of the U.S. Department of Interior Bureau of Land Management. After satisfactory compliance with the preliminary regulations a fee or purchase price of $5.00 an acre is

[5] *Cameron, et al.* v. *United States*, 252 U.S. 450, 459 (1920).

required for lode claims. Issuance of a patent gives the claimant complete legal and equitable title and relates back to the date of discovery and location. The owner of a patented claim not only has title to the mineral estate but to the surface as well.

The United States is one of the few countries of the world in which mineral wealth may be privately owned. Transfer of mineral rights and titles among private owners is subject to State laws relating to property titles, sales and conveyances, leases, and contracts.

Indian Lands.—Two general acts of Congress govern development of oil and gas and other minerals on Indian lands. These are the Act of March 3, 1909 (35 Stat. 783; 25 U.S.C. 396), which authorizes leases for mining of lands allotted to individual Indians; and the Act of May 11, 1938 (52 Stat. 347; 25 U.S.C. 396 a-f), authorizing leasing of tribal lands for mining. In addition, there are special acts authorizing or affecting mineral leasing on certain Indian reservations.

All of the authorizing acts relating to leasing Indian lands for mining provide for leasing the lands under regulations promulgated by the Secretary of the Interior. While not all acts require advertisement of the land for bids, Bureau of Land Management regulations in all cases require such advertisement. The acts require execution of the leases by the Indian owners, except minors and persons not of sound mind. In such cases the leases may be executed on behalf of the Indian owners by the Secretary or his authorized representative.

There is a fundamental difference in the interest of the Government regarding mineral development on public domain and on trust or restricted Indian lands. The United States has proprietary interest in public lands, but it is not the proprietor of restricted Indian lands, and leases on such lands can be executed only by the Indian owners, subject to the approval of the Federal Government in its capacity as guardian acting through the Secretary of the Interior. After leases are executed the Government, again as guardian, participates in supervision of operations and regulations.

Import Taxes

The basic legislation imposing duties on imports into the United States is the Tariff Act of 1930. It included copper raw materials on the free list and levied tariffs on copper and copper-base alloy manufactures. Since 1932, the Internal Revenue Code has provided for an excise on imported copper raw materials, copper alloys, scrap, and manufactured products—4 cents per pound on most items. The Internal Revenue Code Tax rates are:

1. Four cents per pound on the copper content of copper-bearing ores, concentrates, other raw materials, and copper and copper-base alloy products.
2. Three cents per pound on all other articles in which copper, including copper in alloys, is the component material of chief value.
3. Three percent ad valorem or ¾ cent per pound, whichever is the lesser, on all other imports containing 4 percent or more of copper by weight.
4. No tax is imposed on copper lost in metallurgical processes.
5. Ores or concentrates containing not more than 15 percent copper when imported as a sulphur reagent or for fluxing purposes shall be admitted tax-free in an aggregate amount not exceeding 15,000 tons of copper content in any one year.

All of the excise and tariff rates were adjusted downward as a result of concessions granted by the United States in the General Agreement on Tariffs and Trade (GATT) effective January 1, 1948; March 16, 1949; June 6, 1951; and June 30, 1958. The duties under the Tariff Act of 1930 and the Internal Revenue Code of 1954 and the changes effected by the GATT agreements are shown in table 87.

The first adjustment was included in a treaty with the United Kingdom effective January 1, 1939, when the tariff on brass and bronze tubes was halved—Treasury Decision (TD) 49753. At the GATT conference held at Geneva in October 1947 most all duties on copper were reduced 50 percent, becoming effective on various items January 1, 1948, and March 16, 1949. Again, at the June 1956 GATT meetings in Geneva, the United States agreed to a 15-percent reduction of duties on copper and other metals and minerals in exchange for similar action by other countries with respect to United States exports. The reduction was accomplished in three years, 5 percent per year. The effective beginning date was June 30, 1956, and the rates for most copper forms were: 1.9 cents per pound for fiscal year 1957; 1.8 cents for fiscal year 1958; and 1.7 cents for fiscal year 1959 and thereafter. A provision of the concession specified that if and when the price of copper fell below 24 cents per pound the excise would revert to 2 cents per pound.

The Internal Revenue Code import taxes on copper were suspended by congressional action from April 30, 1947, to June 30, 1958, except for the period from July 1, 1950, to March 31, 1951. Public Law 42, 80th Congress, suspended these duties from April 30, 1947, through March 31, 1949; Public Law 33, 81st Congress, extended the suspension through June 30, 1950; Public Law 38, 82d Congress, suspended the excises from April 1, 1951, through February 15, 1953; Public Law 4, 83rd Congress, amended Public Law 38 to provide for a continuation of the suspension

TABLE 87.—*Rates of duty under Tariff Act of 1930 and import tax rates under Internal Revenue Code of 1954, modified by General Agreement on Tariffs and Trade (GATT)* [1]

Schedule A import class No.	Tariff paragraph No.	Description	Tariff rates under Tariff Act of 1930: Unit of quantity	Full rate, cents	GATT: Rate, cents	GATT: Effective date	Import-tax rates under sec. 4541, IRC of 1954 [2 3]: Unit of quantity	Full rate, cents	GATT: Rate, cents	GATT: Effective date
		Copper for smelting, refining, and export								
6400400	1658 (a)	Ore	Pound, copper content	Free	Free	3/16/49	Pound, copper content	Free	Free	3/16/49
6400500	1658	Concentrates	do	Free	Free	3/16/49	do	Free	Free	3/16/49
6401600	1658	Regulus, black, or coarse copper; cement copper.	do	Free	Free	3/16/49	do	Free	Free	3/16/49
6401700	1658	Unrefined, black, blister, and convertor, in pigs or convertor bars.	do	Free	Free	3/16/49	do	Free	Free	3/16/49
6401800	1658	Refined in ingots, plates, or bars	do	Free	Free	3/16/49	do	Free	Free	3/16/46
6401900	1658	Old and scrap copper, fit only for remanufacture; scale or clippings.	do	Free	Free	3/16/49	do	Free	Free	3/16/49
		Copper and copper manufactures, dutiable								
6404100	1658	Ore	do	Free	Free	3/16/49	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6405100	1658	Concentrates	do	Free	Free	3/16/49	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6408100	1658	Regulus, black, or coarse copper; cement copper.	do	Free	Free	3/16/49	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6416100	1658	Unrefined, black, blister and convertor in pigs or convertor bars.	do	Free	Free	3/16/49	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6417100	1658	Refined in ingots, plates or bars	do	Free	Free	3/16/49	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6418100	1658	Old and scrap copper, fit only for remanufacture, scale or clippings.	do	Free	Free	3/16/49	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6418300	1657	Composition metal	do	Free	Free	6/ 6/51	do	4	2 1.9 [4] 1.8 [4] 1.7 [4]	3/16/49 6/30/56 6/30/57 6/30/58
6430000	381	Copper in rolls, sheets, or rods	Pound, gross	2.5	1.25 1.25	1/ 1/48 6/30/56	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6430010	387	Phosphor or phosphorus copper	do	3			do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6430020	381	Copper engravers plates, not ground	do	7	3.5	1/ 1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6430030	381	Engravers plates, ground	do	11	5.5	1/ 1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58

See footnotes at end of table.

TABLE 87.—*Rates of duty under Tariff Act of 1930 and import tax rates under Internal Revenue Code of 1954, modified by General Agreement on Tariffs and Trade (GATT)* [1]—Continued

Schedule A import class No.	Tariff paragraph No.	Description	Tariff rates under Tariff Act of 1930: Unit of quantity	Full rate, cents	GATT: Rate, cents	GATT: Effective date	Import-tax rates under sec. 4541, IRC of 1954 [2 3]: Unit of quantity	Full rate, cents	GATT: Rate, cents	GATT: Effective date
		Copper and copper manufactures, dutiable—Con.								
6420040	381	Copper tubes and tubing, seamless	Pound, gross	7	3.5	1/ 1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6430050	381	Copper tubes, brazed	do	11	5.5 5.25 4.9 4.5	1/ 1/48 6/30/56 6/30/57 6/30/58	do	4	2 1.9 1.8 1.7	6/30/49 6/30/56 6/30/57 6/30/58
6430060	316 (a)	Telegraph, telephone, and other wires and cables of copper—covered with cotton, jute, silk, or other material, with or without metal covering.	Ad valorem	35%	17.5% 16.5% 15.5% 15%	1/ 1/48 6/30/56 6/30/57 6/30/58	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6430080	316 (a)	Wire, n.s.p.f.	do	25	12.5%	1/ 1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6430100	397	Manufactures of copper, n.s.p.f., not plated with platinum, gold, or silver or covered with gold lacquer.	do	45	22.5%	1/ 1/48	Pound, gross	3	1.5 1.425 1.35 1.275	3/16/49 6/30/56 6/30/57 6/30/58
6430300	(5)	All articles, dutiable, n.s.p.f., containing 4 percent or more copper by weight.[6]	(5)	(5)	(5)	(5)	Pound, gross, or percent ad valorem, whichever is the lower.	3% or ¾¢	1.5% or ⅜¢. 1.4% or 0.36¢. 1.3% or 0.34¢. 1.25% or 0.32¢.	3/16/49 6/30/56 6/30/57 6/30/58
6430200	(5)	All articles, dutiable, n.s.p.f., copper chief value.[6]	(5)	(5)	(5)	(5)	Pound, gross	3	1.5 1.425 1.35 1.275	3/16/49 6/30/56 6/30/57 6/30/58
		Brass and bronze manufactures								
6453000	1634(a)	Old brass and clippings from brass or Dutch metal, for remanufacture.	Pound, copper content.	Free			Pound, copper content	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6458000	381	Brass rods, sheets, plates, bars, and strips	Pound, gross	4	2	1/1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6458200	381	Muntz or yellow metal sheets, sheathing, bolts, piston rods, and shafting.	do	4	2	1/1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6458300	381	Brass tubes and tubing, seamless	do	8	4 2	1/1/39 [6] 1/1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6458450	381	Brazed brass tubes, angles, and channels	do	12	6	1/1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6458600	316(a)	Brass wire	Ad valorem	25%	15% 12.5%	1/1/48 6/6/51	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58

6458900	397	Manufactures of brass, n.s.p.f., not plated with platinum, gold, or silver, or colored with gold lacquer.	do	45%	22.5% 21% 20% 19%	1/1/48 6/30/56 6/30/57 6/30/58	Pound, gross	3	1.5 1.425 1.35 1.275	3/16/49 6/30/56 6/30/57 6/30/58
		Bronze manufacturers								
6459000	316(a)	Bronze wire, includes phosphor bronze wire	do	25%	15% 12.5%	1/1/48 6/6/51	Pound, copper content	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6459600	381	Bronze rods and sheets	Pound, gross	4	2	1/1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6459700	381	Bronze tubes	do	8	4 2	1/1/39 [6] 1/1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6459900	397	Manufactures of bronze, n.s.p.f., not plated with platinum, gold, or silver, or colored with gold lacquer.	Ad valorem	45%	22.5% 21% 20% 19%	1/1/48 6/30/56 6/30/57 6/30/58	do	3	1.5 1.425 1.35 1.275	3/16/49 6/30/56 6/30/57 6/30/58
6760020	1620	Bell metal and bells, broken, fit only for remanufacture.	Pound	Free			do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6760100	380	German silver, or nickel silver, unmanufactured.	Ad valorem	20%	10%	6/6/51	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
6760150	380	Nickel silver, sheets, strips, rods and wire	do	30%			do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58
8263000	1659	Copper sulfate (blue vitriol)	Pound	Free			do	4	2 [7] 1.9 [7] 1.8 [7] 1.7	3/16/49 6/30/56 6/30/57 6/30/58
8380369	1659	Copper acetate and subacetate (verdigris)	do	do	Free	1/1/48	do	4	2 1.9 1.8 1.7	3/16/49 6/30/56 6/30/57 6/30/58

[1] All products subject to tariff rate plus import tax.

[2] Import tax was suspended until June 30, 1958, provided price of electrolytic copper delivered Connecticut Valley was 24 cents or more per pound. (Public Law 38, 82d Cong.; amended by Public Law 91, 84th Cong.) When price of copper is less than 24 cents per pound, Mar. 16, 1949, rates are applicable.

[3] Copper-bearing ores and concentrates from Cuba were tax free until enactment of the Tariff Classification Act of 1962; by virtue of section 401 of this act preferential or other reduced rates of duty were suspended. Products of Philippine Republic are subject to preferential rates until Jan. 1, 1974

[4] Import tax is presently collected on composition metal suitable in both composition and shape, without further alloying or refining, for processing into cast forms. (Public Law 38, 82d Cong.; amended by Public Law 91, 84th Cong.)

[5] This classification is applicable to any product not especially provided for in the Internal Revenue Code of 1954. Products are subject to individual tariff rates plus import tax.

[6] Treaty between United Kingdom—Treasury Division (TD) 49753.

[7] Import tax is presently collected on copper sulphate. (Public Law 38, 82d Cong.; amended by Public Law 91, 84th Cong.)

through June 30, 1955; and Public Law 91, 84th Congress, extended the suspension from July 1, 1955, through June 30, 1958. Public Law 38 and subsequent legislation, extending suspension, provided that the suspension would end whenever the average price of copper fell below 24 cents per pound for any calendar month.

The excise tax was reimposed July 1, 1958, at 1.7 cents a pound as a result of the GATT meetings in Geneva in 1956. The 1.7-cent rate was to remain in effect when the price of copper was 24 cents a pound or more; if the price dropped below 24 cents, the tariff was to be 2 cents a pound.

Treaties

Treaties entered into by the United States since World War II have emphasized the encouragement and protection of investment abroad. These treaties cover such subjects as protection of persons and property; establishment, control, and operation of business enterprises; taxation; exchange control; trade and shipping. The treaty provisions, however, are not intended to shield the investor against economic risks to which venture capital is subject.

Provisions of the standard friendship, commerce, and navigation treaty regarding the right of nationals and companies of either treaty country to engage in mining activities in the other include the following:

1. Limitation of alien participation in mining activities: Mining activities are excluded from coverage under the national treatment rule because existing legislation limits the right of aliens to engage in mining or to hold interests in mining enterprises in the United States.
2. Protection of established mining enterprises: A general reservation for mining raises the question of affording a proper measure of treaty protection for established mining enterprises or those permitted to become established. Foreign countries may permit alien mining enterprises to become established and operate within their territories and may accord them national treatment. Hence the treaty usually provides that new restrictions permissible under the reservation for mining activities shall not be applicable to alien enterprises existing and doing business in this field at the time such new restrictions become effective.
3. Most-favored-nation treatment: A provision covering mining as well as other economic activities usually assures protection against discriminatory application of such alienage restrictions as may be adopted in this field.
4. Reciprocity: It is usually provided that any rights to engage in mining on the public domain to which an alien enterprise may become entitled through operation of the most-favored-nation rule may be made dependent upon reciprocity.

The provisions of treaties most directly related to mineral production are those concerning taxation of royalties. Several U.S. treaties reduce such taxes or exempt U.S. citizens from them on the basis of reciprocity. The general purpose of these treaties is to eliminate wherever possible double taxation existing between two countries.

Legislation modifying the protection objectives of tariffs and excise taxes has been enacted from time to time, beginning with the Reciprocal Trade Agreements Act of 1934. Under the Act, the President can reduce tariffs or other import restrictions on goods from foreign sources in return for reduction in their barriers against U.S. goods. The Congress has extended the authority a number of times. The Act is explicit in stating its objectives. It authorizes the President to enter into foreign trade agreements for the purpose of expanding foreign markets for products of the United States. This authority delegated to the President is subject to certain limitations. No duty may be increased or decreased by more than 50 percent and no article may be transferred between dutiable and free list. See GATT concessions under section on import taxes.

Securities Regulations

Securities of companies engaged in the mining and mineral industries are subject to the Securities Act of 1933 and related legislation administered by the Securities and Exchange Commission. The general purpose of these laws is to protect the interests of the public and investors against malpractices in the securities and financial markets. These laws provide for public disclosure of pertinent facts concerning new securities offerings to the public and securities listed on exchanges; regulation of trading in securities on exchanges and in over-the-counter markets; enforcement of sanctions against companies and persons guilty of securities frauds and other violations; supervision of investment companies engaged in purchase and sale of securities; regulation of investment advisers; and advice by the Securities and Exchange Commission to courts in proceedings for reorganization of bankrupt companies. Certain mining companies are exempt under section 3 of the Securities Act of 1933, which authorizes the Commission to exempt from registration requirements securities with an aggregate offering price not exceeding $300,000.

Anti-Trust Laws

The principal anti-trust statutes now in effect are the Sherman Act (1890) and the Clayton Act (1914), as amended by the Robinson-Patman Act (1936). Associated with these statutes are the Federal Trade Commission Act (1914) and other related statutes applicable to this field. The laws apply to all business activity, including the mining industry, and prohibit activities among private individuals or firms that are designed to restrain trade or commerce or cause monopoly in commerce between States, with foreign nations, or in territories of the United States. They also prohibit discriminatory and unfair trade practices.

The Sherman Act prohibits contracts, combinations, or conspiracies which restrain interstate or foreign commerce. It also prohibits monopolies, attempts to monopolize, and conspiracies to monopolize domestic and foreign trade.

The Clayton Act of 1914, as amended, makes unlawful tied leases or sales and acquisition by one company of the stock or assets of another when the effect may be to substantially lessen competition or tend to create a monopoly in any line of commerce. It forbids interlocking directorates under certain circumstances. It makes it unlawful for persons to discriminate in price between different purchasers of commodities of like trade and quality to lessen competition or create a monopoly. It also prohibits commissions or discount allowances on goods in interstate commerce, except for services rendered, and forbids discriminations in rendering services, giving rebates or discounts, or underselling to destroy competition.

The Federal Trade Commission Act prohibits unfair methods of competition and unfair or deceptive acts or practices in interstate or foreign commerce.

Government Barter Program

The barter program was originally developed to acquire materials for the strategic stockpile authorized by Public Law 520, 79th Congress, approved July 23, 1946. Little barter was done until after passage of Public Law 480, 83rd Congress, authorizing establishment of a supplemental stockpile for strategic and other materials acquired by disposing of surplus agricultural commodities. Interdepartmental committees directed first by the Munitions Board then by the Office of Civil and Defense Mobilization (OCDM) or its predecessor agency, Office of Defense Mobilization (ODM), designated the kinds and quantities of material to be acquired through barter. With the passage of Public Law 85–931, September 1958 and subsequent Executive action, this responsibility was transferred to the Secretary of Agriculture.

Copper was eligible for barter negotiations from the latter part of 1955 to early 1956 and again from the middle of 1957 until almost the end of 1958 when it was taken off the barter list. Beryllium copper was on the list from March to September 1956; oxygen-free, high-conductivity copper (OFHC) became eligible in September 1961 and was on the list authorized through fiscal year 1962.

TAXATION

Most forms of taxation are employed by the Federal and State Governments and to some extent by local governments. The revenue systems used overlap in many instances. Exceptions are custom duties which are imposed only by the Federal Government and property, severance, franchise, general sales, and motor vehicle license taxes which are employed only by State and local governments. The types of taxes most important to producers of copper are: Income taxes, severance taxes, and property taxes.

Income Taxes

The Federal Government and a few of the State Governments levy taxes on incomes of copper-producing corporations. Because virtually all the copper mined and processed in the United States is done by corporations, this discussion will be confined to corporate taxes.

The Federal tax on corporation income originated as an excise tax in 1909 and was levied at the rate of 1 percent on net income in excess of $5,000. This excise tax was superseded by the income tax law of 1913, which followed adoption of the 16th amendment to the Constitution of the United States. Corporation income taxes have been an important part of the Federal revenue system, having contributed annually between one-sixth and one-half of total Federal tax revenues. Since World War II, the corporate income tax has been second only to the individual income tax in importance.

Corporations producing copper are subject to a normal tax of 30 percent on the total amount of taxable income and a surtax of 22 percent on taxable income in excess of $25,000. Generally taxable income is gross income less the actual monetary costs of producing that income. However, the tax law contains several special provisions regarding income derived from mineral deposits (natural resources). In recognition of the wasting character of mineral deposits, a special deduction, known as percentage depletion, is allowed which may have no relationship to actual costs. In addition, the tax law provides special treatment for certain capital expenses incurred in finding and preparing mineral deposits for production, Federal Government loans or grants for encouraging exploration, development or mining strategic minerals or metals, and taxable income earned in foreign countries.

Depletion Allowance

Capital invested in copper properties may be recovered tax free through depletion allowances. These allowances are computed according to a cost depletion or a percentage depletion method, the taxpayer being required to take the higher of the two. To compute allowable depletion under the cost systems, the adjusted basis of the property which would be used for determining the gain upon the sale of such property is divided by the total estimated remaining units (tons of ore, pounds of metal) and the result is multiplied by the number of units sold during the year. Cost depletion deductions are exhausted when the adjusted basis of the property has been reduced to zero.

Allowable depletion under the percentage depletion method is computed as a special percentage of gross income from the property but must not exceed 50 percent of the net income. Percentage depletion allowances may be claimed on the income from a property although the estimated value has been completely written off through prior cost or percentage depletion. The percentage depletion allowance on income from copper mines (domestic or foreign) is 15 percent.

Exploration and Development Costs

Sections 615 and 616 of the 1954 Revenue Code permit the taxpayer either to write off the costs of exploration and development of mineral deposits as they occur or to set up these costs as deferred expenses to be deducted proportionately over the life of the deposit. Expenditures covered are those required to ascertain the existence, location, extent, or quality of any ore or mineral deposit, or for shafts, tunnels, raises, stripping, drainage and other items attributable to development of the mine or deposit until it reaches a level of full production.

Deductions for exploration expenditures are limited to $100,000 per year and to a total of $400,000. The current expense deductions for exploration and mine development costs were first granted in the Revenue Act of 1951, which limited the annual deduction for exploration expenses to $75,000 in each of any four years; the 1954 code raised this limit to $100,000. In 1960, the 4-year limitation was replaced by a total limitation of $400,000, which may extend any number of years. This ceiling limitation is not applicable to unsuccessful exploration projects. Expenditures for such operations are deductible as operating losses regardless of amount.

Federal Loans or Grants for Exploration, Development, or Mining

Recipients of loans or grants from the United States (or any agency or instrumentality thereof) for encouragement of exploration, development, or mining of critical and strategic minerals or metals for national defense may exclude such loans or grants from income.

Income From Foreign Sources

Generally, domestic corporations are subject to Federal income tax on their entire income, regardless of where the income was earned. Because income taxes of most countries apply to all income derived within their jurisdictions, this feature of the U.S. law would result in substantial double taxation were it not for basic provisions designed to relieve such situations. Some double taxation is eliminated by specific treaties with various countries. In addition, the Federal income-tax law includes several statutory provisions adjusting income-tax liabilities. These include (a) the deduction of foreign taxes paid, (b) credit for foreign taxes paid, and (c) special tax-rate reductions for Western Hemisphere trade corporations. Also, special consideration is accorded corporations operating in U.S. possessions.

In determining the United States liability, corporations subjected to foreign income taxes may either:

1. Deduct the full amount of foreign taxes paid from their gross income; or
2. Take a credit against U.S. income tax for income, war profits, or excess profits tax (or other taxes in lieu of such taxes) paid to a foreign country or to any possession of the United States. The credit limitation is based on Sections 901, 902, 903, and 904 of the Internal Revenue Code of 1954, as amended.

Western Hemisphere trade corporations, defined as U.S. corporations whose total business is done in North, South, or Central America or the West Indies, are granted a special rate reduction of 14 percentage points. To qualify they must satisfy the following requirements for 3 years immediately preceding the close of the taxable year:

1. Ninety-five percent of their gross income must be derived from sources outside the United States.
2. Ninety percent of their gross income must be derived from active conduct of a trade or business.

If a Western Hemisphere trade corporation is a subsidiary of another U.S. corporation, dividends received by the latter are subject to the regular tax on dividends received, that is, 52 percent on 15 percent of such dividends. The Western Hemisphere trade corporation may credit its foreign taxes against its U.S. tax.

State Income Tax

Only three of the seven major copper producing States levy income taxes on corporations engaged in mining—Arizona, New Mexico, and Tennessee. Rates are moderately low and are not progressive; except for very small taxable incomes, when a sliding scale may be used. The determination of gross income, and the deductions allowed to compute net or taxable income, are patterned after the Federal Tax System. Two States, Montana and Utah, base their corporation franchise taxes on net income.

General Property Taxes

The Federal Government does not levy property or ad valorem taxes on the value of mineral or surface rights or plant facilities owned by mining companies. In most States such taxes provide the principal revenues for counties, municipalities, and school districts. States tend to rely on franchise, income, and other specific taxes for their revenues and to leave property taxation to local governmental units.

The tax base varies from State to State, and some States have variations in certain sections. The basis for taxation of property in some States is present worth, in others it is net proceeds, and a few States use both. Present worth is evaluated by a number of methods with tax rates ranging from 1.5 to 10 percent. Reasons for the wide spread are:

1. The ratio that the assessed value bears to the true value.
2. The need of the district for revenue.

Present worth is considered differently in some States. In Michigan, mining plants and equipment are exempt from taxation, but ore bodies are carefully appraised for present worth. In Tennessee only real estate and plant facilities are subject to the property tax.

Severance Taxes

Severance taxes, like royalties, are based on gross production. A true severance tax is one measured by applying a specific rate per unit (ton, pound) to the total quantity produced. Alternatively, the measure is a percentage of the gross value of the material removed or severed during the tax period.

Four of the major copper producing States are recorded as imposing severance taxes; however, in Arizona it is classified as a sales tax, in Montana it is called a Mine Metal License, and in Utah it is known as an Occupational Tax. These all apply if no profit is realized from the operation of producing, and therefore are rightfully considered severance taxes. New Mexico levies a severance tax and a sales tax, which is essentially another severance tax.

GOVERNMENT LOAN PROGRAMS

Exploration Loans

By direction of the Defense Production Act of 1950, the Defense Minerals Exploration Administration (DMEA) was created in 1951 to promote exploration for unknown and undeveloped sources of strategic and critical metals and minerals in the United States, its territories, and possessions by providing financial aid for exploration projects. Such assistance was furnished pursuant to exploration project contracts with provisions requiring specified exploration by the operator, Government participation in payment of costs as they accrue, and repayment of the Government share by the operator from net proceeds of production resulting from the exploration work.

For copper exploration projects, the Government and operators each shared 50 percent of the costs. Through June 30, 1958, the DMEA had entered into 53 contracts for exploration of copper deposits. As of December 31, 1958, the total estimated approved cost was $3,485,182 of which the Government share was $1,742,591. Copper reserves were developed in several areas as a result of this program.

Public Law 701 enacted in 1958 established the Office of Minerals Exploration (OME) in the Department of the Interior. OME assumed the functions and obligations of DMEA. Under OME, copper continued eligible for exploration assistance; through December 31, 1960, three new contracts and an amended contract were executed for an estimated total cost of $144,650, the Government share being $72,325.

Export-Import Bank Loans

The purpose of the Export-Import Bank, as stated by Congress, is "to aid in financing and to facilitate exports and imports and the exchange of commodities between the United States or any of its territories or insular possessions and any foreign country or the agencies or nationals thereof." The Bank has provided financing in connection with the expansion of copper production in Peru, Chile, and Turkey.

The $237-million project of the Southern Peru Copper Corp. that was started in 1955 for developing the Toquepala mine and constructing a concentrator and smelter was partly financed by Export-Import Bank loans totaling $110 million. Production began January 1, 1960, and as of December 31, 1961, this debt had been reduced to $89,199,992. In 1959, an Export-Import Bank credit of $1.5 million was granted to Eti Bank, an agency of the Turkish Government, for developing new production facilities at the Government-owned Ergani mine. An Export-Import Bank loan of $45,000,000 was approved in 1962 for Compania Minera Andina, S.A., a subsidiary of Cerro Corp., as partial financing of an $80-million project to bring the Rio Blanco copper property in central Chile into production.

PUBLIC SERVICES

Collection and Dissemination of Basic Data

The Department of the Interior, through the Bureau of Mines and the Geological Survey, conducts scientific and technologic investigations and statistical studies directly pertaining to mining, preparation, treatment, and utilization of minerals. Data also are collected concerning health and safety conditions in the mining industry. This information is disseminated to industry and the general public by press releases, reports, bulletins, and other methods. The Department of Commerce conducts statistical and census studies and provides economic and technical data to the minerals industries and the general public to promote and develop domestic commerce.

Government Technical Assistance

The Federal Government renders technical assistance relating to production and utilization of minerals in both domestic and foreign areas. Much of the technical research is done under cooperative agreements with institutions, States, foreign governments, and private and public organizations. Surveys and studies are made to determine and appraise the distribution and reserves of mineral deposits. The Federal Government also collects and disseminates technical and statistical information on domestic and foreign mineral activities, renders services that assist the minerals industry and the general public, and conducts and assists in training programs.

Mine Health and Safety

Health and safety in mining is advanced by the work of the Bureau of Mines, the Public Health Service of the Department of Health, Education, and Welfare, and the Department of Labor.

FOREIGN MINERAL LAWS

A summary presentation of mining laws, effective in most mineral-producing areas of the world, dealing with the mineral codes governing acquisition and tenure of mineral rights and regulations for exploration and exploitation of mineral lands in foreign countries was published in 1961.[6]

Unlike the United States, most foreign governments either maintain ownership or control the title to all mineral lands but grant the right to work the minerals by some form of permit or concession. Eligibility for such rights is subject to conditions and obligations which vary greatly from country to country. Principal legal controls in the major copper-producing countries are discussed in the following sections.

Canada

The Provincial governments of Canada hold legal title to all public (crown) lands except Indian reserves, national parks, the Northwest Territories, and the Yukon, which are owned and administered by the Dominion Government. Aliens, citizens, and other British subjects 18 years of age or more, or authorized corporations, are entitled to engage in prospecting or exploration on crown lands in the Dominion or Provinces. Rights to mine and extract ore are usually granted by renewable 21-year leases, except in Newfoundland, where the period is 50 years. Annual assessment requirements range from $100 per claim to 80 man-days of work. There is specific legislation regulating conservation, health and safety, and other activities of the minerals industry.

Operators of metalliferous mines are given a percentage depletion allowance of 33⅓ percent. New mines may be granted exemption from income tax for 36 months. Other Dominion laws govern tariffs, excise taxes, explosives, and special assistance to coal and gold mines.

Chile

The State owns all minerals, whatever the surface ownership. Concessions to work certain minerals are granted under the mining code,

[6] Ely, Northcutt. Summary of Mining and Petroleum Laws of the World. Bu. Mines Inf. Circ. 8017, 1961, 215 pp.

which permits unrestricted prospecting for minerals on lands not cultivated or enclosed; otherwise, permission of the occupant is required. Exploration of state or municipal lands requires permission of the governor or mayor. Any alien or citizen, except certain Government officials, is eligible for an exploitation or mining concession, which is a multiple of claims of not less than 1 nor more than 5 hectares. The holders of mining concessions are entitled to certain easements that the surface owner must allow in order to facilitate mining operations and that the law imposes upon holders of other concessions.

Until 1952, the Chilean Government obtained its revenues on Chilean copper production through taxes and exchange rate policies and did not participate in sales. However, after the copper sales agreement between the United States and Chile on May 8, 1951, providing that 80 percent of Chilean output be sold in the United States at 3 cents above the market price and the balance be sold by the Chilean Government, legislation was approved authorizing control of amounts to be exported freely by the companies and to be delivered to the Central Bank, the Government agent. Chile abrogated the agreement with the United States on May 8, 1952, and gave the Central Bank control of all sales of copper; the bank immediately set minimum prices for that metal. An accumulation of unsold copper reached 180,000 tons in late 1953, and serious cutbacks in Chilean production were avoided by purchases for the United States stockpile in March 1954. At this time legislation to improve conditions for the major producers (gran mineria) was introduced, but did not become law until May 5, 1955. Until this law was passed taxes and the exhange differential imposed on the gran mineria were approximately 84 percent of profits. The new copper law imposes a tax on net income at a rate between 50 and 80 percent. The specific rate for any one company is determined by a relationship between its production for the year and a base production fixed under the terms of the new copper law. The rate decreases as production increases. Special deductions in computing taxable income are given the three companies in the gran mineria—Andes Copper Mining Co., Braden Copper Co., and Chile Exploration Co.—for approved new investments in electrolytic copper-producing installations.

Mexico

To encourage greater participation by Mexican citizens in mining, the Mining Law of February 6, 1961, was enacted to regulate exploitation of Mexican mineral resources. The law provides that only Mexicans or Mexican corporations with a majority of the capital subscribed by Mexican nationals can qualify to obtain new concessions or to acquire concessionary rights by transfer or assignment. The law restricts the future role of private foreign mining investments. As an inducement for "Mexicanization" of operating companies in Mexico that are predominantly owned by private foreign capital, an amendment provides that mining companies 51-percent owned by Mexican nationals are entitled to receive a 50-percent reduction in production and export taxes on their mining activities. The amendment states that companies that change their capital structures to 51-percent Mexican ownership may also qualify for the 50-percent tax reduction.

To encourage new large investments in copper production, Article 2 of the copper law provides that new companies in the gran mineria category will be subject solely to a flat 50-percent tax. The law also provides that amounts needed by the copper companies for expenses in Chile shall be returned in U.S. dollars and sold to the Central Bank at the free-banking rate and that producers are obliged to reserve bar copper required by national industry, including amounts needed for exportation of fabricated and semifabricated products.

Peru

In Peru all mines and minerals are the property of the State. Surface rights to land are separate from the estate in minerals underground. Mining is open to aliens, citizens (except certain Government officials), or corporations; however, foreigners may not have mines within 50 kilometers of the frontier without special permission of the Government. Exploration and exploitation rights are acquired by concessions granted by the Ministro. Exploration concessions are valid for 5 years, but the right to produce minerals after discovery may continue indefinitely. The State is authorized by law to set aside certain mineral reserves, which the National Government may operate directly or may lease to private individuals or corporations.

Special tax laws apply to mining. The application fee or tax for an exploration concession is S/.05 per hectare and S/1 per hectare for an exploitation concession. Exploitation concessions for metals other than gold are subject to surface taxes of S/20 per hectare. If after 5 years of exploitation the amount paid for wages and materials does not exceed S/50 per hectare per year, an excess surface tax equal to the regular surface tax is imposed and may be credited against subsequent income taxes. These taxes are in addition to profit taxes which are levied on net income. Foreign branch offices also pay a complementary surtax levied on profit tax income. The combined profit tax and complementary tax levies amount to approximately 21 percent of net income before depletion.

Under the income tax law special depletion reserves may be set up from 15 percent of gross revenues for metallic concessions, not exceeding 50 percent of the net profits in any 1 year.

Payments of 4 percent of value on ore exported in excess of S/800,000 per year is required currently from each concessionaire. This payment is credited against the annual profit tax.

Special arrangements may be made with the Executive for royalty payments of from 10 to 20 percent of the profits in lieu of income taxes; or the Executive may agree to set the income tax rate between 10 and 20 percent for a specified period to encourage general development.

Republic of the Congo

Assuming the Congolese law applicable to mineral development will continue under the new government, the following is a summary of the principal regulations:

Mines constitute property distinct from that of soil, and they are the exclusive property of the State. Concessions to exploit mineral resources are granted by the Government, and to a lesser extent by three concessionaires. Persons who have fulfilled the formalities for Congo residence and who have completed the formalities for doing business in the Republic can apply for prospecting rights. Concessions granted by permit are limited to territories declared open to public prospecting. Areas covered by the special concession by convention are not so limited. Less than half of the Congo is open to public prospecting. In order to obtain a concession by permit the applicant must fulfill the requirements of a three-phase procedure—the general prospecting permit, the special prospecting permit, and the exploitation permit. A fourth phase, the treatment permit, is optional. Fixed fees are charged for general and special permits and are doubled with each renewal. No fees are assessed for exploitation or treatment permits.

Royalties of one-tenth the value of the minerals extracted are assessed against a special permit holder. Exploitation royalties are based on the amount of the concessionaires capital. The rate varies, with a maximum of 50 percent payable on profits of more than 35 percent of the invested capital. An exception provides that during the first 5 years of operation the royalty payments shall not exceed 10 percent if, during the period, the company has not paid a dividend equal to at least 5 percent of the capital invested.

Federation of Rhodesia and Nyasaland

The British South Africa Co. through a charter granted by the British Government possesses and administers the mineral rights of Northern Rhodesia and about 16,000 square miles in Nyasaland. These rights in Northern Rhodesia will expire in 1986. The mineral rights of the company in Southern Rhodesia were purchased from the British South Africa Co. by the Southern Rhodesian Government on June 29, 1933.

All prospecting in Northern Rhodesia and Nyasaland must be authorized by permit granted by the British South Africa Co. The company encourages prospecting and issues permits without discrimination as to race or nationality. Individuals or companies may obtain nontransferable prospecting licenses which are effective for one year. License holders are required to register them at the Office of the Commissioner of Mines. The mining company and individual are obliged, upon acquiring mineral concessions from the company, to spend stipulated amounts annually on exploring any mineral area and to pay certain royalties to the British South Africa Co. when the production stage is reached.

Royalty is payable on the copper content of materials produced each month, the rate per long ton being 13.5 percent of the average of London Metal Exchange quotations for the month, less £8. Royalty payments are based on blister copper, and the price is obtained by deducting £8 from the price of electrolytic wirebar unless the metal is sold in blister form. Twenty percent of the net revenue derived by the British South Africa Co. from the exercise of its mineral rights in Northern Rhodesia is paid to the Northern Rhodesia Government.

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CHAPTER 11—STRATEGIC FACTORS

INTRODUCTION

The necessity for regulating supply of important industrial minerals and metals was recognized toward the end of World War I. On March 23, 1917, Bernard Baruch stated, "The United States is deficient in certain minerals of great importance, particularly in war time; the deficiency being due to actual lack of suitable ore deposits, or the fact that our deposits are low grade and more expensive to work. The remedy may mean . . . the accumulation of a reserve supply, either by government or private companies, the stimulation of home production by assurance from competition, research to develop cheaper processes to utilize low grade ores, stimulation of exploration and discovery of new deposits, or development of substitutes and new uses for various products." The final report of the War Industries Board recommended a U.S. stockpile of strategic materials. Later, proponents of U.S. self-sufficiency in certain mineral supplies expressed numerous warnings and made many recommendations regarding stockpiling and broadening our mineral base, but nothing was done until Congress passed the Strategic Materials Act of 1939.

In preparing the pre-World War II lists of strategic and critical materials, the Army and Navy Munitions Board established the following definitions:

Strategic Materials: "Those essential to national defense, for the supply of which in war, dependence must be placed in whole, or in substantial part, on sources outside the continental limits of the United States."

Critical Materials: "Those essential to national defense, the procurement problems of which in war, would be less difficult than those of strategic materials."

Copper was classed as a nonstrategic and noncritical metal because the depression in the early 1930's and a decade of excess productive capacity precluded the concept of a copper shortage. A subcommittee report to the Chairman of the Minerals Advisory Committee of Army and Navy Munitions Board (ANMB), on April 8, 1939, stated, "No contemplated national emergency could call for supplies of copper in excess of those readily available from present mines and plants." And in its final version of the Industrial Mobilization Plan in 1939, ANMB did not include copper as either a strategic or critical material. It was listed as one of the important minerals which should be kept under surveillance. The position of the Board was reaffirmed in November 1940 through a memorandum to the National Defense Advisory Council which said—if the mining and smelting capacity of Mexico and South America were considered to meet part of the national needs—there seemed "Very slight basis for a belief that a serious shortage of copper could develop under the imperative requirements for this metal due to a major war."

DEVELOPMENT OF COPPER CONTROLS

In the year before World War II, however, copper ranked next to aluminum as the most difficult of critical metals to obtain in sufficient quantities. This change in the position of copper was due principally to revised military estimates and to large and rapidly growing commitments of the Lend Lease Act and the Russian Protocol. When it was evident that copper was rapidly becoming scarce the first measures for increasing imports were passed, and mandatory priorities were issued. The first organization for controlling copper was the National Defense Advisory Commission, consisting of seven advisors—each in charge of an area in the national economy: Industrial production, industrial materials, employment, prices, farm products, transportation, and consumer interests. The first steps taken to conserve and increase the copper supply were: (1) Placement on the list of materials requiring license for export, and (2) Authorizing Metals Reserve Co. to purchase 100,000 tons of foreign copper.

At the beginning of 1941 the President created the Office of Production Management (OPM) for more concentrated governmental supervision over production, purchasing, and priorities. On April 30, OPM issued General Metals Order Number 1 to control the inventories of 16 specified metals, including copper. The order was addressed to all producers, smelters (primary and secondary), remelters, brokers, distributors (warehouse or wholesale), processors, and fabricators of the designated materials. The terms of the order restrained any supplier from knowingly delivering any of the specified metals to a purchaser or the purchaser from receiving such metal if such delivery increased the inventory of the purchaser beyond stated levels.

Because of the mounting shortage of copper, mandatory priority controls were required to control supplies, and General Preference Order M–9 became effective May 31, 1941, "To conserve the supply and direct the distribution of copper." The objective of the order was to direct copper into defense uses first, leaving only the overflow available for civilian requirements. In contrast to later conservation orders which prohibited specific uses, order M–9 was implemented through preference ratings.

Although all producers of copper wire mill, brass mill, and brass or bronze foundry products were required to comply with the demands of the preference rating system, the order was addressed primarily to producers of copper in its nonfabricated form. The principal points of the order may be summarized as follows:

1. All defense orders not bearing a preference rating of A–10 or higher were automatically assigned an A–10 rating—conversely all nondefense orders were restricted to ratings lower than A–10.
2. Nondefense orders could be filled only after defense orders, and then only on the condition that filling them neither delayed the delivery of a defense order nor required use of metal that was needed under the order for a reserve pool.
3. Beginning June 1, 1941, each refinery was required to set aside each month an amount of copper equal to 20 percent of his production in April 1941. Production for the individual refiner included copper refined for the company on toll and excluded metal refined by it for others.
4. Quantities thus withheld were subject to allocation by the Director of Priorities to meet emergency requirements.
5. Beginning June 1, 1941, all copper held by the Metals Reserve Co. was made subject to allocation by the Director of Priorities.
6. Copper was removed from control under General Metals Order Number 1. To continue the safeguards of this order, the new copper order contained restrictive provisions—directed to the supplier as well as the purchaser—against building excessive unnecessary inventories of copper.

Allocation of Copper

The growing pressure of requirements for copper, including those for the United Kingdom and Lend Lease, created problems that could not be solved with order M–9. Thus, plans were made to place copper under complete mandatory control with 100 percent of the copper available subject to allocation. The resulting General Preference Order M–9–a became effective August 6, 1941. Under this order no copper produced from domestic ores could move from refineries, except as specifically allocated by the Director of Priorities. The basis used to make the allocations, effected through allocation certificates, was the character of the business of the fabricator, indicated through its preference ratings. The new order incorporated the same directive features for deliveries by manufacturers of copper and copper-base-alloy products that were contained in the replaced order M–9. The principal contribution of the allocation system was that it channeled copper to the areas required by priorities certificates.

Control of Scrap

Since nearly half the total supply of copper available to fabricators of copper and copper-base-alloy products was derived from secondary or scrap copper, extension of priority controls to cover this portion of supply was effected September 30, 1941, by Supplementary Order Number M–9–b which was issued to conserve the supply and direct the distribution of copper scrap and copper-base-alloy scrap. The order provided that all scrap generated in the further fabrication of brass mill products must be returned either directly or through dealers to brass mills. The principal provisions governing all other scrap, as defined in the order, may be summarized as follows:

1. Deliveries were restricted to dealers, or to fulfillment of orders bearing a preference rating of A–10 or higher, with certain exceptions applying to deliveries to foundries until November 1, 1941.
2. Deliveries, including deliveries of brass-mill scrap under toll agreements, were prohibited unless approved by the Director of Priorities.
3. Dealers were prohibited from melting scrap without specific authorization, or from receiving scrap unless they had turned over their inventory within a 60-day period and had filed required reports with OPM.

With this order all raw material sources for manufacturers of copper and copper-base-alloy products were under the control and direction of OPM.

Conservation and Limitation Orders

Orders M–9–a and M–9–b were both directed toward conservation, but this aim was incidental to that of directing the flow of copper into defense channels, which frequently were not preferred commercially. The control provided by these orders was not adequate and leakage of copper into nonessential uses was inevitable so long as the manufacture of such products was not specifically prohibited. Recognition of this lack of control and constantly increasing defense demands led to issuance of a prohibitory order designed to control uses beyond the reach of the original orders. This order, aimed at conservation by preventing manufacture of certain products and by definitely limiting manufacture of other products using copper, was known as Conservation Order M–9–c and was issued October 21, 1941.

Supplementing the direct control over copper exercised through the M-orders was the indirect control over use of copper that was enforced through the limitation or L orders. These orders effected conservation of copper and other critical materials through limitations on manufacture of products involving use of one or more critical materials. These orders were expected to reduce consumption of scarce materials in the automotive, domestic-mechanical refrigerator, and household-laundry-equipment industries—three leading durable goods consuming industries—by as much as 50 percent in the ensuing 12 months. The orders affecting these industries were respectively Limitation Orders L–2, L–5, and L–6.

The need for continued control of production and distribution of copper and copper-base-alloy products was more urgent after Pearl Harbor. Order M–9–a was amended January 7, 1942, to provide tighter control over copper by (1) placing privately imported copper, except duty-free copper for re-export, under the controls of the order; (2) requiring that toll agreements for processing copper must have the approval of the Director of Priorities; (3) prohibiting previously allowed deliveries of 50 pounds or less of copper per month to a single customer without preference rating; and (4) requiring that copper must "Be physically incorporated into the material or equipment to be delivered" before it could be rated as a defense order. Further amendment to the order provided for replenishment of stock sold for war orders. Except for minor amendments adopting the order to meet changed operating conditions, clarifying terms of the order, and changing reports required of industry, the order as thus amended continued through 1942 as the basic control over manufacture and distribution of copper.

Production Requirements Plan

A major step in the evolution of basic control devices was introduction by the War Production Board of the Production Requirements Plan, generally known as PRP. The plan was described as "A streamlined scheme for granting priority assistance to manufacturers engaged in essential production." Its principal objectives were to simplify the use and issuance of priorities and to provide better overall information on material requirements and end-product uses to facilitate scheduling material production and distribution.

The plan as introduced, may be briefly outlined as follows:

1. Except for certain industrial users not fabricating material for resale, all concerns using in any quarter more than $5,000 worth of metals included under the plan had to apply under it for preference ratings covering their requirements for such metals.
2. Applicants under the plan had to report their consumption and inventories of the metals involved in addition to their requirements for such metals—listing by preference ratings.
3. From tabulations of reported requirements, the Armed Services, the Civilian Supply Division and Industrial and Material Branches of the War Production Board (WPB) submitted overall end-use allocations of the respective materials to the Requirements Committee.
4. Using these proposals, and taking the advice of the Requirements Committee, the Committee chairman issued tentatively adjusted requirements that, following review by and receipt of recommended changes from the respective agencies concerned, were adopted or modified by the chairman as the broad determinations of the Requirements Committee.
5. Using these determinations for each of the metals included in the plan, the WPB Director of Industry Operations directed processing applications that were subject to review by the industry branches concerned. This final review by the industry branches was subject to final determination by the WPB Priorities Bureau.
6. Provision was made for emergency allocations by establishing a reserve for each material.
7. Requirements of small and other users not coming under the plan continued to be handled through regular priority channels. Materials allowances were made for these uses in the Requirements Committee determinations.

In July 1942, PRP became fully operative on a mandatory basis for controlling distribution of copper and other metals. In the evolution of a control system for the flow of materials, PRP acted as a control mechanism coordinated with and superimposed upon the priorities system. Its purpose was to increase effectiveness of the priorities system by reducing to one revised form the multiple separate applications needed for several materials in a 3-month period, and to make possible a closer identification with the end-use of the material covered by ratings.

From its inception PRP was widely criticized. A principal weakness of the plan was its association of quantities of materials input with quantities of dollar output. For example, trying to schedule tons of copper input per million dollars worth of battleships per quarter was almost meaningless. This prevented allotment of specified quantities of materials to particular firms to produce stated quantities of end-products in a specified time.

In September 1942 a concerted effort was made to design a system of strong and effective control of the production and flow of materials.

Controlled Materials Plan, World War II

A preliminary draft of a plan embodying ideas drawn from numerous plans and variations of plans was developed by October 18, 1942, and labeled the Controlled Materials Plan (CMP). Agreement on the fundamentals of the plan among all participating governmental agencies was reached by November 2, 1942. It was to be transitionally operative in the second quarter of 1943; fully, in the third quarter. In its application, the plan was restricted to steel, copper, and aluminum products, the three most basic and critical materials. Its main purpose was "To make certain that production schedules are adjusted within materials supply so that production requirements are met." This was accomplished by adjusting requirements for critical materials to the supply and making the required kind and quantities of materials available to meet scheduled programs.

Under CMP applications for material, as well as its distribution, were processed through three broad layers of a procedural pyramid. The base layer comprised secondary consumers receiving allotments of controlled materials "From a prime consumer or another secondary consumer." The intermediate and numerically smaller layer included the prime consumers receiving their allotments "From a claimant agency either directly or through the office of such agency." In the apex of the pyramid were the claimant agencies to whom allotments were issued by the Requirements Committee for reissuance to prime consumers. The claimant agencies were: The War and Navy Departments, the Maritime Commission, the Aircraft Scheduling Unit, Lend-Lease Administration, the Board of Economic Warfare, and the War Food Administration. Each of the seven claimant agencies subdivided the products manufactured under its jurisdiction into programs. Each program was defined as a "Plan specifying the total amount of an item or class of items to be provided in a specified period of time." Programs were subdivided into schedules which were plans specifying the total amount of an item or class of items to be produced or used by an individual consumer in a specified period of time.

Bills of materials submitted by claimant agencies show the amounts of materials required for physical incorporation in the production of a given product, including the portion of these materials consumed or converted into scrap during processing. Requirements for respective CMP materials were aggregated for the several programs of each claimant agency by codes. These identified the particular program in which the product would be used, the calendar quarter in which production of the item and for which the material required was scheduled, the claimant agency, and offices within the claimant agency responsible for the program.

Products manufactured under the plan were divided into two broad classes, with special provisions for those used for maintenance, repair, and operating supplies. These two broad classes were identified as class–A products and class–B products. The terms A products and B products were never given complete precision of meaning, except that B products were those included in an official B product list, while A products were the products containing controlled materials not on that list. Broadly speaking, class–B products were those used in manufacturing other and more comprehensive products. Class–B include, for example, such items as bolts and electric motors, both could be used in manufacturing such A products as an airplane, a truck, or a tank.

A vast amount of energy was expended to make CMP workable for industry as well as Government. Problems in distribution were constantly arising and various regulations were adjusted to correct them. However, there were no drastic departures from the original plan. CMP remained in force through World War II, and Priorities Regulation 32 was issued incorporating the rules contained in the former Priorities Regulation 1 and Controlled Materials Plan Regulation 2 for continuing the basic inventory controls following termination of CMP, September 30, 1945.

Controlled Materials Plan, Korean Conflict

In the fall of 1950 after the outbreak of the Korean conflict the rate of copper consumption had almost reached the peak level attained in World War II. It was evident that some action was necessary if the defense requirements for copper were to be met. To cope with this problem a Copper Division was established in the National Production Authority (NPA), Department of Commerce to control distribution of supply.

Regulatory measures were devised late in 1950. First, on November 29, 1950, NPA Order M–11 was issued, which established rules for placing, accepting, and scheduling rated orders for copper and copper-base alloys. Order M–12, issued at the same time, limited the amount of copper any consumer could use to a percentage of the average rate of consumption prevailing the first six months of 1950; it also limited consumer inventories to 45 days supply. A third order, M–16, was issued 2 weeks later establishing control over distribution of copper scrap and copper-base alloy scrap.

Almost from the time the orders were issued it was recognized that these preliminary steps were inadequate, and a modified version of the Controlled Materials Plan (CMP) to direct the flow of products and materials into essential programs was established in July 1951.

The Requirements Committee of the Copper Division programed the allocation of copper for the third and fourth quarters of 1951. Beginning with the first quarter of 1952, programing became centralized in the Requirements Committee of the Defense Production Administration (DPA), with that committee functioning as the recipient of stated requirements for Claimant Agencies, NPA Industry Divisions and DPA–NPA reserves for program adjustments. Screening requirements for program recommendations was accomplished by DPA–NPA Requirements Committees meeting with claimant agencies and industry divisions representatives, to discuss and evaluate the proposed requirements and arrive at preliminary program recommendations. These preliminary recommendations were submitted to the Program Adjustment Committee of the Defense Production Administration, which conducted meetings to hear appeals submitted by the claimant agencies and industry divisions and to make necessary adjustments when advisable to the recommended programs. The programs and appeals were then submitted to the Requirements Committee of the DPA. At a meeting in which all claimants were represented, the Requirements Committee, DPA, affirmed or denied the appeals and announced the final program determinations for the quarter.

In all of the conferences and meetings with claimants conducted by the DPA–NPA Requirements Committees, the Program Adjustment Committee, and the Requirements Committee of DPA, either the Directors of the three NPA Controlled Materials Divisions (steel, copper, and aluminum) or their representatives served in a technical staff capacity to the Chairman of the Requirements Committee, DPA, on determinations as to product feasibility with respect to such controlled materials.

PRICE CONTROLS

World War II

On August 12, 1941, Price Schedule 15 issued by the Office of Price Administration (OPA), provided a price ceiling of 12 cents a pound on copper, delivered Connecticut Valley. The 12-cent ceiling applied to electrolytic-grade copper in wirebars or ingot bars delivered in carlots. Lake copper, which had been sold at a slight premium, was placed on the same basis as electrolytic. A top price of 11¾ cents a pound, Connecticut Valley, was set for casting copper made by fire refining to a standard of 99.5 percent pure, including silver as copper. The casting-copper ceiling was revised to 11¾ cents, f.o.b. refinery, in early September. Premiums ranged from ¾ cent to 2 cents a pound on less than carlots sold by other than refiners or producers.

The price order exempted sales of copper to the Metals Reserve Co. to enable that organization to purchase high-cost copper at higher-than-ceiling prices. Other provisions referred to other kinds, grades, shapes, or forms, to contracts entered into before the order, and to other items.

In January 1942, ceiling prices were revised on less than carlots, effective February 1, to 12⅛ cents or electrolytic and Lake copper and 12 cents a pound on other fire-refined and casting copper, f.o.b. shipping points. Premiums were no longer permitted on casting copper sold by persons other than a producer or refiner.

Effective June 3, 1946, ceiling prices for copper were increased; the price for electrolytic copper, delivered Connecticut Valley, was raised to 14⅜ cents, contingent on completion of certain wage agreements. This resulted in a two-price condition. Uncertainty attended the almost month-long interim (July 1–25) in the operation of OPA. The two prices were eliminated August 2 when 14⅜ cents was established for all sales. All price controls for copper were removed November 10, 1946.

Price Regulation 12, effective July 22, 1941, established maximum prices for brass mill scrap. On August 19, 1941, ceilings were placed on unalloyed copper scrap. Copper-alloy scrap, except for certain grades of brass mill scrap, was free from formal price ceilings until February 27, 1942 (Price Regulation 20, Copper Scrap and Copper Alloy Scrap). An amendment to the brass scrap price schedule on April 17 encouraged refining of copper from yellow brass scrap and eliminated the need for sorting the yellow grades as refinery brass. On May 11 copper-base scrap prices were revised downward, and a license was required for dealers selling to consumers. On August 17, maximum prices for 13 classifications of copper-alloy scrap were reduced to their proper relationship to the basic 12-cent price of electrolytic copper. On December 31, price ceilings were removed from copper-base scrap imported for Metals Reserve Co.

Establishment of specifications and cents-per-pound prices for 16 new grades of copper scrap and copper-alloy scrap, effective March 22, 1943, brought under specific prices the entire field of such material when sold to consumers. Price controls were removed November 10, 1946.

As early as 1941 the Office of Price Administration began to study methods for encouraging production of copper by marginal mines without raising the ceiling price. In late 1941 arrangements were made for Government purchases of copper from three Michigan companies at 1 cent a pound above out-of-pocket costs.

In January 1942 the Metals Reserve Co. was authorized to buy copper produced at other domestic mines and fulfilling certain requirements at 17 cents a pound, 5 cents above the ceiling price. Payments were to be made on production from February 1, 1942, and were to extend for 2½ years. The payments were to be made only on production above quotas set by the War Production Board and the Office of Price Administration. The plan was inaugurated to stimulate production from either new or high-cost properties, or both. When individual quotas were established the mines falling into perferred classes were found largely to have zero quotas, which entitled the total quantities produced to bonuses. Well-established, large properties were assigned such high quotas that they were entitled to virtually no benefits, and it was necessary, during the year, to revise a number of quotas. In late 1942 and in early 1943 it became desirable to revise downward many more quotas to take care of the generally increased costs of production. In January 1943 the plan was extended to July 31, 1945; later it was extended, first to the end of June 1946, and then to June 30, 1947. On May 1, 1943, it was announced that a special additional premium would be made available to small copper mines that produced less than 2,000 tons of copper in 1942 and required increased revenue to obtain maximum production. Individual cases were to be considered separately, and a special premium was to be paid at a rate to be fixed for each mine on production in excess of a special quota. The Metals Reserve Co. announced that royalty payments on production entitled to premium payments would be paid at ceiling prices only unless the lease specifically instructed otherwise, as it was not the intent of the order to have anyone other than the actual operator participate in the plan. Royalties paid by domestic mine operators for copper, lead, and zinc ores mined from leased properties were frozen by the Office of Price Administration on April 1, 1943, at rates in effect December 31, 1942.

The premiums for less-than-carload lots (l.c.l.) sold by producers and refiners were revised in January 1942, effective February 1. The ceiling prices, l.c.l., were 12⅜ cents per pound on electrolytic and Lake copper and 12 cents on other fire-refined and casting copper, f.o.b. shipping points. Premiums were no longer permitted on casting copper sold by persons other than a producer or refiner.

In November 1943 it was announced that no applications for special premiums postmarked after December 31, 1943, would be accepted.

Table 88 shows premium-payment data for February 1942 through June 1947. Ceiling-price restrictions on copper ended in November 1946. Immediately thereafter the price rose to a point where the A bonuses were not applicable; that is, the price was higher than the 12-cent ceiling plus a bonus of 5 cents.

Korean Conflict

The Defense Production Act of 1950, which became law in September, provided for expansion of copper output at mines then operating or idle or for maintenance of production that might be lost without such aid. The properties were to receive Government loans, Government purchase contracts, or tax amortization benefits, or combinations of the three types of assistance (table 89). In the years following the outbreak of hostilities in Korea, the Defense Minerals Administration in the Department of Interior, and its successor, the Defense Materials Procurement Agency, in General Services Administration continued efforts to expand output.

In the General Ceiling Price Regulation issued by the Economic Stabilization Agency on January 26, 1951, prices of copper were not to exceed the highest prices received by individual producers between December 19, 1950, and January 25, 1951, inclusive. Primary producers in general had been selling electrolytic copper, delivered Connecticut Valley, at 24½ cents a pound; this figure became the ceiling price. There were, however, companies whose ceiling prices substantially exceeded the the 24½-cent price. The quantities to which higher ceilings applied were relatively small.

In May 1951 an agreement between the United States and Chilean Governments provided for payment of 3 cents a pound more than the ceiling price for Chilean copper sold in the United States. The agreement provided for expansion in production by Chile and for discontinuance of abnormal trade in semiprocessed copper by Chile. Chile was not to withhold more than 20 percent of production of U.S. companies operating in Chile. It also provided for a Chilean embargo on exporting copper to countries of the Soviet bloc.

The Office of Price Stabilization (OPS) announced that, effective July 25, 1951, the ceiling price for copper refined in the United States from imported crude materials would be 27½ cents a pound, delivered Connecticut Valley. The increased cost of foreign copper was not to be passed on to customers by the fabricators.

In May 1952 Chile abrogated the agreement because of its dissatisfaction with the 27½-cent price. Exports to the United States were embargoed for a short time; but on May 21 the Office of Defense Mobilization (ODM) authorized importers to pay higher prices for imported copper and to pass on to consumers 80 percent of costs greater than 27½ cents. This was revised in early June to the increase over 24½ cents. Shipments of Chilean copper to the United States were resumed. On June

TABLE 88.—*Salient statistics covering bonus payments [1] of the Government, 1942–47*

	1942, February-December		1943		1944		1945		1946		1947, January-June		1942–47	
	Short tons	Percent of total	Short tons	Percent of total	Short tons	Percent of total	Short tons	Percent of total	Short tons	Percent of total	Short tons	Percent of total	Short tons	Percent of total
Production:														
At ceiling price	881,711	89.23	841,286	77.12	722,791	74.53	561,851	72.57	392.828	65.22	389,156	90.39	3,789,623	78.04
At overceiling prices:														
Under premium price plan:														
A quota only, 17 cents a pound	102,352	10.36	217,382	19.93	194,483	20.06	179,389	23.17	[2] 98,219	[2] 16.31				
Special, 17.01–27 cents a pound	716	.07	14,003	1.28	26,168	2.70	22,917	2.96	[2] 87,060 [3] 24,248	[2] 14.45 [3] 4.02	41,391	9.61	1,066,212	21.96
	103,068	10.43	231,385	21.21	220,651	22.76	202,306	26,13	209,527	34.78				
Metals Reserve mine contracts	[4] 3,315	.34	18,147	1.67	26,347	2.71	10,075	1.30	------------	---------				
Total overceiling production	106,383	10.77	249,532	22.88	246,998	25.47	212,381	27.43	209,527	34.78	41,391	9.61	1,066,212	21.96
Total production [5]	988,094	100.00	1,090,818	100.00	969,789	100.00	774,232	100.00	602,355	100.00	430,547	100.00	4,855,835	100.00
	Total	Price per pound, cents	Total	Price per pound, cents	Total	Price per pound, cents	Total	Price per pound, cents	Total	Price per pound, cents	Total	Price per pound, cents	Total	Price per pound, cents
Payments:														
Under premium price plan:														
A quota only	$10,306,829	17.00	$23,138,490	17.00	$22,065,137	17.00	$20,230,618	17.00	[2] $13,684,190	[2] 19.59				
Special	20,623	18.44	1,735,266	23.20	3,450,898	23.59	3,198,357	23.98	[2] 7,270,723 [3] 1,559,173	[2] 21.18 [3] 22.39	$2,148,937	23.16	$118,860,342	([6])
	10,327,452	17.01	24,873,756	17.38	25,516,035	17.78	23,428,975	17.79	22,514,086	19.24				
Metals Reserve mine contracts	[4] 188,117	14.84	3,488,489	21.61	4,258,562	20.08	2,115,933	22.50	------------	---------				
Total overceiling payments	10,515,569	16.94	28,362,245	17.68	29,774,597	18.03	25.544,908	18.01	22,514,086	19.24	2,148,937	23.16	118,860,342	([6])
Total U.S. production	------------	12.25	------------	13.30	------------	13.54	------------	13.65	------------	15.70	------------	21.25	------------	([6])

[1] From published and unpublished reports of the Office of Price Administration and the Office of Premium Price Plan for Copper, Lead, and Zinc. Excludes exploration premiums totaling $6,213,545 paid for July 1, 1946, through December 31, 1947, to encourage exploration and development of copper, lead, and zinc deposits; this total cannot be broken down by metals.

[2] January–October. *A* and Special quotas and premium payments for November and December are not separable and are shown with footnote 3.

[3] Total *A* and Special quotas and premium payments for November and December; separation by kinds not available.

[4] Treasury Procurement Division contracts in 1942.

[5] From monthly reports of Bureau of Mines; do not exactly check final annual totals for the United States except for 1943.

[6] Not reported.

TABLE 89.—*Contracts for expansion and maintenence of supply of copper under Defense Production Act of 1950*

Type of contract or assistance, name of contractor, and location of project	Quantities involved (pounds)		Effective date of contract	Date production started	Approximate term of contract	Commitment purchase price (per pound)
	Total	Contingent purchase commitments [1]				
Floor price:						
American Smelting & Refining Co., Silver Bell mine, Pima County, Ariz	197,000,000	177,000,000	Nov. 28, 1951	Not later than Nov. 28, 1953	7½ years	$0.245 or market.[2]
Anaconda Copper Mining Co., Yerington, Lyon County, Nev	384,000,000	256,000,000	Nov. 10, 1951	Not later than Dec. 6, 1953	8 years	0.255 or market.[2 3]
Calumet & Hecla Consolidated Copper Co., Osceola mine, Houghton County, Mich.	106,000,000	106,000,000	July 18, 1952	July 1, 1955	10 years	0.2525.[2 3]
Copper Cities Mining Co., Copper Cities, Gila County, Ariz	192,500,000	170,000,000	Sept. 24, 1951	Apr. 1, 1955	8¼ years	0.230.[2]
Phelps Dodge Corp., Bisbee East ore body, Cochise County, Ariz	300,000,000	225,000,000	do	Not later than Sept. 24, 1955	8 years	0.220.[2]
White Pine Copper Co., White Pine mine, Ontonagon County, Mich	550,000,000	487,500,000	Feb. 26, 1952	Not later than Feb. 26, 1955	9¾ years	0.255.[2 3]
Campbell Chibougamau Mines, Ltd., Merrill Island, Dore Lake, Quebec, Canada	63,200,000	63,200,000	June 10, 1952	Not later than Dec. 10, 1954	4½ years	0.245.[2]
San Manuel Copper Corp., Pinal County, Ariz	730,000,000	[4] 695,000,000	Aug. 29, 1952	Not later than Feb. 29, 1957	10 years	0.24.[2]
Bagdad Copper Corp., Yavapai County, Ariz.[5]	216,000,000	216,000,000	Oct. 16, 1952	Oct. 15, 1952	do	0.245.[2]
Subsidy: [6]						
Banner Mining Co., Miser's Chest mine, Hidalgo County, N. Mex	5,400,000		Mar. 3, 1952	Dec. 1, 1951	2 years	None.[3]
Calumet & Hecla Consolidated Copper Co., three mines in Houghton and Keweenaw Counties, Mich.[7]	14,780,000		Jan. 8, 1952	do	12–17 months	Do.[3]
Copper Range Co., Champion No. 4 east ore body, Houghton County, Mich	6,372,000		Mar. 13, 1952	Jan. 1, 1952	2 years	Do.[3]
Howe Sound Co., Holden mine, Chelan County, Wash	8,834,000		June 12, 1952	Feb. 1, 1952	1 year	Do.[3]
Sam Knight Mining Lease, Inc., Christmas mine, Gila County, Ariz	2,390,000		Mar. 14, 1952	Dec. 1, 1951	2 years	Do.[3]
Yucca Mining & Milling Co., Inc., Antler mine, Mohave County, Ariz	5,205,000		Apr. 10, 1952	do	3 years	Do.[3]
Maintenance of production:						
Copper Range Co., Champion mine, Houghton County, Mich		7,965,000	Aug. 12, 1953	July 1, 1953	2½ years	0.32.
Riviera Mines Co., Christmas mine, Gila County, Ariz		3,000,000	Sept. 29, 1953	Not later than Oct. 15, 1953	2¼ years	0.32.
Howe Sound Co., Holden mine, Chelan County, Wash		18,700,000	Nov. 3, 1953	Sept. 1, 1953	2⅓ years	0.315.
Appalachian Sulphides, Inc., Orange County, Vermont		[8] 4,000,000	Mar. 19, 1954	July 1, 1954	1½ years	0.3106.
Purchase:						
National Lead Co.,[9] Madison County, Mo		7,200,000	Dec. 1, 1956 [10]	Apr. 1, 1953	6 years	0.36.
Falconbridge Nickel Mines, Ltd., McKim and Hardy mines, Ontario, Canada [11]	25,000,000	25,000,000	Feb. 14, 1952	Jan. 1, 1952	10 years	0.19 or market.[3]
Miami Copper Co., Miami mine, Gila County, Ariz		120,000,000	Feb. 13, 1953	Not later than June 30, 1955 [12]	8–8½ years	0.2735.[2 13]
Banner Mining Co., Mineral Hill and Plumed Knight mines, Pima County, Ariz		12,960,000	May 26, 1953	May 1, 1954	3 years	0.31.[14]
Copper Creek Cons. Mining Co., Old Reliable mine, Pinal County, Ariz		5,500,000	June 17, 1953	Dec 31, 1954	3 years	0.29.
International Nickel Co. of Canada, Ltd., Sudbury district, Ontario, Canada [15]		100,000,000	May 29, 1953	June 1, 1953	5 years, 7 months	0.27.[2]
Falconbridge Nickel Mines, Ltd., Ontario, Canada [16]		32,000,000	Mar. 27, 1953	Dec. 31, 1953	3 years	0.275–0.30.
Advance-repayment:						
North Butte Mining Co., Granite Mountain mine, Silver Bow County, Mont	5,250,000		Sept. 19, 1951	Dec. 1951	21 months	([17]).
Banner Mining Co., Mineral Hill and Plumed Knight mines, Pima County, Ariz		12,960,000	May 26, 1953	May 1, 1954	3 years	([18]).

Type of contract or assistance, name of contractor and location of project	Approximate amount involved	Date loan approved or certificate of necessity issued
Loan:		
White Pine Copper Co., White Pine mine, Ontonagon County, Mich	$57,185,000	Nov. 15, 1951
San Manuel Copper Co., Pinal County, Ariz	94,000,000	July 10, 1952
Yucca Mining & Milling Co., Antler mine, Mohave County, Ariz	50,000	Oct. 30, 1952
Campbell-Chibougamau Mines, Ltd., Merrill Island, Dore Lake, Quebec, Canada	5,500,000	May 18, 1953
Rhodesia Congo Border Power, Ltd., Northern Rhodesia	22,400,000	June 17, 1953
Tax amortization: [19]		
American Smelting & Refining Co., Silver Bell mine, Pima County, Ariz	11,555,000	Jan. 4, 1952
Anaconda Copper Mining Co., Yerington mine, Lyon County, Nev	24,565,000	Oct. 15, 1951
Phelps Dodge Corp., Bisbee, East ore body, Cochise County, Ariz	12,401,000	July 6, 1951
White Pine Copper Co., White Pine mine, Ontonagon County, Mich	40,912,000	Nov. 16, 1951
C. L. Maguire, Unida Copper, Yavapai County, Ariz	76,000	June 15, 1951
Kennecott Copper Corp.:		
Deep Ruth mine, White Pine County, Nev	3,988,000	Apr. 4, 1951
Utah mine, Salt Lake County, Utah	3,330,000	May 20, 1952
Do	1,374,000	July 31, 1952
Do	1,946,000	July 6, 1951
Do	670,000	Aug. 3, 1951
Sierra Copper Co., Calaveras County, Calif	27,000	Oct. 9, 1951
Allied Chemical & Dye Co., Grayson County, Va	561,000	Feb. 7, 1952
San Manuel Copper Co., Pinal County, Ariz	64,691,000	Dec. 19, 1952
Anaconda Copper Mining Co., Greater Butte project, Silver Bow County, Mont	3,939,000	May 21, 1952
Bagdad Copper Corp., Yavapai County, Ariz	11,134,000	July 15, 1952
Banner Mining Co., Pima County, Ariz	790,000	Apr. 29, 1953
Copper Creek Consolidated Mining Co., Pinal County, Ariz	245,000	Apr. 21, 1953
U.S. Metals Refining Co., Carteret, N.J	68,000	June 8, 1954
Pima Mining Co., Pima County, Ariz	8,873,000	Sept. 29, 1955
Inspiration Consolidated Copper Co., Gila County, Ariz	[20] 6,824,805	Sept. 15, 1955
The Anaconda Company, Greater Butte, Mont	3,963,000	Oct. 28, 1955
Inspiration Consolidated Copper Co., Inspiration, Ariz	8,505,000	Mar. 15, 1956

[1] Some contracts provided for larger production which could be sold to other producers.
[2] Includes escalator clause.
[3] Contracted at over ceiling price—ceiling price was 24½ cents a pound for most producers.
[4] Also 30,660,000 pounds out of 32,120,000 pounds of molybdenum at $0.60 per pound.
[5] Also 3,760 short tons of molybdenum.
[6] All subsidy contracts were automatically terminated February 25, 1953.
[7] Original contract covered four mines, but contract was amended August 11, 1952, to include only three mines.
[8] Original contract provided for 12 million pounds.
[9] Also 9,240,000 pounds of nickel and 7,320,000 pounds of cobalt.
[10] Replaces original contract effective October 11, 1951. Production was scheduled to start April 11, 1953, and was subsequently extended to February 11, 1954.
[11] Also 75,000,000 pounds of nickel, of which 25,000,000 is at contractor's option, and 1,500,000 pounds of cobalt.
[12] Date reflects beginning of term of production.
[13] Government purchase obligation for part of molybdenite production at floor price—$1.00 per pound of contained Mo—but option to purchase all of it at market price.
[14] Option to purchase all or part of molybdenite production at market price.
[15] Also 120 million pounds of nickel.
[16] Also contractors option to deliver an additional 20 million pounds of copper; and 150 million pounds of nickel, of which 50 million pounds is deliverable at contractors option, and approximately 2 million pounds of cobalt.
[17] Terms of repayment of $60,000 loan were 1 cent a pound on first 300,000 pounds of contained copper and 2 cents thereafter, until repaid with interest, but not later than June 30, 1953.
[18] Terms of repayment of $430,565 were 17½ cents per pound of refined copper plus interest, until $43,100 has been paid, and 3½ cents per pound of refined copper thereafter with interest. Repayment to be made by or before 4½ years from date of contract.
[19] Amortization—5 years at 75 percent of total amount involved.
[20] Original contract provided for $3,600,000.

24, OPS exempted from price control in Amendment 21 to GOR–9 imported refined copper and copper refined from imported copper-bearing materials and scrap purchased after June 16. Amendment 23 extended the exemption to such copper imported between May 8 and June 16. Amendments were issued to orders for wire mills and brass mills, effective July 1, to reflect increases permitted by the ODM directive. Ceilings were revised from time to time, based partly on the proportion of foreign to domestic copper available.

To make as equitable a distribution as possible of the different-priced supplies, NPA allocated copper to all consumers on the basis of estimated supply—60 percent domestic and 40 percent foreign. Prices of products were based on this assumed distribution until the end of 1952.

Ceiling prices on brass and bronze ingots were established on February 27, 1952, by OPS order CPR–127, effective March 3. The regulation gave specific ceiling prices for carlots of all the listed alloys of brass and bronze ingot normally produced, and made provision for transportation costs and shipments of less-than-carload lots. Under the General Ceiling Price Regulation (GCPR) there were diverse selling prices for these products.

Effective March 12, Amendment 2 to order CPR–46 established ceilings on dealer-to-dealer sales that were identical to those previously provided for other persons. In addition, payment was permitted of a maximum premium of 1.75 cents a pound on sales between dealers.

On June 30 the OPS issued, effective July 1, Amendments 1 to CPR–68 and CPR–110 on brass mill products and wire mill products respectively—establishing higher prices for these products, based on passing on to consumers 80 percent of increased costs of imported copper that were more than 24½ cents a pound. The increases usually amounted to 3.84 cents a pound for brass-mill products, and allowing for scrap loss and insulation, 3.25 cents for weatherproof wire.

On August 14, Amendment 7 to CPR–60 permitted copper and copper-alloy castings producers to pass on increased costs from use of foreign copper.

Special Regulation 125 to GCPR, effective November 24, permitted producers of products in which primary copper was used, and whose ceiling prices were established under GCPR, to adjust their ceiling prices for these products to reflect the increased cost of foreign copper.

On February 13, 1953, OPS removed price controls on nonferrous scrap, and on February 25 controls were abandoned on primary copper and copper products.

STOCKPILING

Strategic Materials Act of 1939

The Strategic Materials Act of June 7, 1939 (Public Law 117), provided the first authority for Government stockpiling. In this act the Congress authorized expenditure of $100 million to purchase, move, and store stocks of strategic and critical materials, and an immediate appropriation of $10 million was made for that purpose. Additional appropriations of $12.5 million and $47.5 million were made in March and June 1940, respectively, bringing the total available for stockpiling to $70 million. The terms of the act required advertised bidding, prohibited negotiations, and allowed as much as a year for production and delivery.

Reconstruction Finance Corporation Act of 1933, Amended

The urgency of the international situation demanded faster action than that available under the Strategic Materials Act, and on June 25, 1940, the Reconstruction Finance Corporation Act of 1933 was amended to permit establishment of subsidiary corporations, having power to produce, procure, and store strategic and critical materials and to make loans for such purposes. Under this amendment the Metals Reserve Co. was created on June 28, 1940.

Toward the end of 1940 a shortage of copper developed, and the Metals Reserve Co. began making arrangements to purchase Latin American copper. Receipts were to form a buffer stockpile, and manufacturers that were unable to obtain their copper requirements from domestic refiners were permitted to draw from Government stocks. By April 30, 1941, Metals Reserve Co. had arranged to buy 500,499 tons of copper. Deliveries from the stockpile to consumers began in March 1941. At the beginning of 1946, Metals Reserve had nearly 600,000 tons of refined and unrefined copper for allocation, but by the end of the year this supply had been reduced to 92,758 tons, and on December 31, 1947, there was only 9,986 tons in inventory.

Surplus Property Act

Early in the third quarter of 1944 it seemed possible that the European phase of the war would end, and it appeared that a surplus of copper would develop which would have an adverse effect on the industry. The Surplus Property Act was passed, effective October 3, 1944, to prevent excess materials from reaching markets. The act provided that all Government-owned accumulations of certain strategic minerals and metals (including scrap), when determined to be surplus, should be added to the permanent stockpile authorized by the Strategic Materials Act of 1939. This action would prevent flooding the postwar markets with Government inventories. In effect, it froze the entire Government stocks of copper that would be on hand at the end of the war.

A postwar surplus of copper did not develop. Domestic production was far short of expectations as the result of a difficult labor situation. With the postwar increase in demand, the Government stocks prevented a serious copper shortage. Most of the Office of Metals Reserve (formerly Metals Reserve Co.) stock of copper was released to industry, and the balance was transferred to the Strategic Stockpile.

Strategic and Critical Materials Stockpiling Act of 1946

Congress enacted the Strategic and Critical Materials Stockpiling Act of 1946 (Public Law 76–117, 1939; Public Law 79–520, July 23, 1946, Rev.) in order to provide for acquisition and retention of stocks of strategic and critical materials and to encourage conservation and development of sources of these materials within the United States; thereby decreasing and preventing whenever possible a dangerous and costly dependence of the United States upon foreign nations for supplies of these materials in times of national emergency. The passage of this act reaffirmed the will of the Government to pursue a stockpiling program on a scale adequate for national defense.

Administration of Stockpile Act.—The Act of 1946 placed responsibility on the Secretaries of War, Navy, and Interior for determining what materials and what quantities of each should be stockpiled. Stockpiling functions assigned to the Secretaries of the Army, Navy, and Air Force were delegated December 19, 1947, with concurrence of the Secretary of Defense, to the Munitions Board. To facilitate maintenance of a proper relationship between the national economic and military interest, the Munitions Board constantly advised the National Security Resources Board of stockpiling plans and operations. (Under the National Security Act, approved August 5, 1947, the Munitions Board was instructed—Section 213-3-(8) "To maintain liaison with other departments and agencies for the proper correlation of military requirements with the civilian economy, particularly in regard to the procurement or disposition of strategic and critical material, and to make recommendations as to policies in connection therewith.") Purchasing, storage, and rotation, directed by the Munitions Board, were functions of the Bureau of Federal Supply of the Treasury Department.

The Federal Property and Administrative Services Act of 1949, as amended, transferred to the General Services Administration the functions of the Bureau of Federal Supply of the Department of the Treasury, including its functions, under the Strategic and Critical Materials Stockpiling Act. The Emergency Service was established by the Administrator of GSA on September 1, 1950, to administer these stockpiling functions. This organization was renamed the Defense Materials Service on September 7, 1956.

Reorganization Plan Number 3 of 1953 reorganized, among other things, various activities relating to stockpiling strategic and critical materials. Subsection 2(b) of the Plan transferred to the Director, Office of Defense Mobilization, all functions under the Stockpiling Act vested in the Secretaries of the Army, Navy, Air Force, and Interior or in any of them or in any combination of them, including the functions which were assigned to the Army and Navy Munitions Board, but excluding the functions vested in the Secretary of the Interior by Section 7 of the said act with respect to investigations of domestic ores and minerals. In July 1958, all functions under the Strategic and Critical Materials Stockpiling Act, as amended, were redelegated by Executive Order to the Office of Civil and Defense Mobilization in the Executive Office of the President pursuant to Reorganization Plan 1 of 1958. Another reorganization in 1961 placed the administration of all stockpiling under the Office of Emergency Planning in the Executive Office of the President.

Other Government Stockpiles.—Three other Government stockpiles or inventories, in addition to the strategic or national stockpile were authorized by specific legislation. The Defense Production Act of 1950 authorized the Government to encourage expansion of productive capacity and supply by purchasing materials for Government use or resale. The reserve thus accumulated is referred to as the DPA inventory or stockpile. The supplemental stockpile was authorized by the Agricultural Trade Development and Assistance Act of 1954 (Public Law 83–480, 1954), and materials acquired by the Department of Agriculture in exchange for surplus agricultural commodities that deteriorate and are costly to store are placed in this inventory. Some of the materials are being held against strategic stockpile objectives, but most of the material is additional to the strategic stockpile. Then there is the CCC (Commodity Credit Corporation) inventory acquired by the Department of Agriculture by barter of surplus agricultural commodities under several statutes. If there is no other Government use for the materials, they are required by law to be transferred to the supplemental stockpile.

Copper Stockpile.—The projected accumulation of a strategic stockpile of copper under the Strategic and Critical Materials Stockpiling Act made little progress from approval of the Act July 23, 1946, through June 30, 1948, because of a provision that industrial reconversion must not be retarded by diversion of supplies to the stockpile. The objective, established at 1,250,000 tons of copper, was scheduled for completion by June 30, 1951, but at mid-1948, the inventory amounted to only 6,300 tons, most had been obtained from postwar surplus transfers (5,200 tons). However, in the next three years almost 600,000 tons of copper was acquired. The objective was raised to 2.1 million tons in 1950, then lowered to 1.1 million in 1952.

In 1954, ODM rulings called for the establishment of two types of objectives: (1) Basic objectives, which assume partial dependence during an emergency on imports from areas beyond North America; and (b) maximum objectives, which provide a higher degree of security by completely discounting emergency supply from distant overseas sources. (Between 1954 and 1958 there were two objectives for metals and minerals; before 1954 there was only one objective for each material.) The basic objective for copper was raised to 1.6 million tons in 1954, and the maximum objective was set at 3.5 million tons. These goals were maintained through 1957. The basic and maximum objectives were reduced tentatively to 860,000 tons and 1,900,000 tons, respectively, in 1958 and to zero tons and 1 million tons in 1959, where they remained through 1961.

The strategic stockpile had accumulated more than 855,000 tons by the end of 1954, and in that year about 4,300 tons was purchased with Defense Production Act funds. Some copper was procured through barter by the Commodity Credit Corporation from 1957 through 1961, and acquisitions for the supplemental stockpile were made from 1959 through 1961. The status of the Government stocks of copper as of December 31, 1961, was as follows:

	Million dollars	*Thousands of short tons*
Basic objective	------	0
Maximum objective	------	1, 000
National stockpile	------	1, 009
DPA inventory	------	122
CCC and supplemental stockpile	------	11
Total	------	1, 142
Acquisition cost	$596. 6	--------
Market value (Dec. 31, 1961)	710. 9	--------
Excess over maximum objective	------	142, 000
Value (Dec. 31, 1961)	88. 0	--------

Included in Government stocks were 21,066 tons of oxygen-free, high-conductivity copper in the national and 5,199 tons in the supplemental stockpiles.

PREPAREDNESS PROGRAMS

When the Korean conflict ended, the need was recognized for improving our preparedness position as to industrial mobilization to meet any future emergency. Renewal of the Defense Production Act in 1953 reflected the concern of both the Congress and the executive branch of the Government for achieving a continuing state of readiness for effective mobilization, resulting from the unsettled world situation.

The Office of Emergency Planning in the Executive Office of the President recommends Executive Orders designed to develop defense-mobilization plans and programs by several departments and agencies of the executive branch of the Government to meet all conditions of national emergency, including attack on the United States.

The Office of Minerals Mobilization, under supervision of the Assistant Secretary of the Interior-Mineral Resources, carries out functions authorized by the Defense Production Act, as amended, and delegated to the Secretary of the Interior by Executive Order and by orders of the Office of Emergency Planning with respect to strategic and critical metals and minerals. The Office is concerned with the adequacy of the supplies of certain metals and minerals and facilities to fulfill both civilian and military requirements under partial and full mobilization.

The Business and Defense Services Administration (BDSA) in the Department of Commerce carries out the industrial defense mobilization planning responsibilities of the Department under the general guidance of the Office of Emergency Planning. The major mobilization planning programs include developing and administering systems for scheduling and controlling production and distribution of materials and products during an emergency. Such a system has been developed by BDSA and is known as the Defense Materials System (DMS), which is basically similar to the Controlled Materials Plan administered during both World War II and the Korean conflict.

The Defense Materials System (DMS) is a body of Government regulations, orders, and procedures issued under the authority of the Defense Production Act. The priorities provided under DMS were being used in 1962 despite a relatively easy supply situation with respect to most materials and products needed in defense programs. Examples of such programs are: Missiles systems, space programs, atomic energy developments, and equipment needed to maintain the combat readiness of the military forces. Operation of DMS results in maintenance of an administrative means of promptly mobilizing the total economic resources of the United States in the event of war.

The Defense Materials Service in General Services Administration is responsible for acquisition of strategic and critical materials for the national stockpile, for expansion and or maintenance of production of industrial raw materials including domestic purchase programs, and for the qualitative maintenance and management of strategic and critical materials in the national stockpile and the other Government inventories of industrial raw materials.

SELF SUFFICIENCY

Before 1940 the United States was a net exporter of copper. Since that time, because of World War II and postwar demands, a substantial portion of the copper supply of the Nation has been imported except for the years 1958, 1960, and 1961. The largest quantities were imported during World War II, the peak year being 1945 when net imports reached 721,000 tons (table 90). From 1946 through 1956 copper in unmanufactured forms received from foreign sources ranged from 200,000 to 500,000 tons per year. In 1957 and 1958, demand and imports decreased. A prolonged strike in 1959 caused a substantial loss of domestic production and created the need for a larger quantity of net imports. In 1960 imports and exports were almost equal, and in 1961 the United States again became a net exporter.

For the short term, the U.S. position with respect to an adequate supply of copper is satisfactory. This outlook is supported by an estimated annual mine production capacity of 1.5 million tons of copper, an annual availability from secondary sources (old scrap only) of 450,000 tons, and a reserve of 1,142,000 tons of copper in the national stockpile. Furthermore, expansion of copper production in Canada, Chile, and Peru provide sample sources of imports in the Western Hemisphere.

TABLE 90.—*Import and export balance, 1939–61, short tons*

Year	Imports of unmanufactured copper	Exports of metallic copper	Net imports (+) or exports (−)
1939	336, 297	427, 517	+91, 000
1940	491, 342	427, 650	−63, 000
1941	735, 545	158, 893	−576, 000
1942	764, 393	210, 518	−554, 000
1943	716, 596	294, 459	−422, 000
1944	785, 211	237, 515	−548, 000
1945	853, 196	132, 545	−721, 000
1946	396, 380	97, 475	−299, 000
1947	413, 890	196, 999	−217, 000
1948	507, 449	207, 022	−300, 000
1949	552, 709	195, 990	−357, 000
1950	690, 389	192, 339	−498, 000
1951	489, 135	166, 274	−323, 000
1952	618, 880	212, 390	−406, 000
1953	676, 104	171, 393	−505, 000
1954	594, 829	312, 433	−282, 000
1955	594, 100	259, 942	−334, 000
1956	595, 747	280, 575	−315, 000
1957	594, 032	430, 446	−164, 000
1958	496, 301	428, 015	−68, 000
1959	570, 891	196, 012	−374, 000
1960	524, 357	512, 332	−12, 000
1961	458, 690	498, 198	+39, 508

Source: Salient Statistics Tables, Minerals Yearbooks, Bureau of Mines.

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