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STRATEGIC MINERALS

Strategic Minerals

A SUMMARY OF USES, WORLD OUTPUT STOCKPILES, PROCUREMENT

by

JOHN B. DeMILLE

Consulting Geologist
Senior Engineer, Mining Section
The Reconstruction Finance Corporation

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STRATEGIC MINERALS

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PREFACE

In assembling and editing material here presented, generous assistance has been given by representatives of government agencies in Washington, with whom the author was associated from October, 1942, to July, 1945. Company officials directly concerned with various phases of the mineral industries have made information available. The author's 25 years of field and editorial experience has been drawn upon. Acknowledgments are gratefully made for expert guidance in the various sections of this work in which the author had no training. Gratitude for many courtesies is extended to the following: Dr. Oliver Bowles, Dr. Francis B. Simkins, Dr. Alexander Lesser; L. M. Kniffen, R. J. Walley, Dr. Hugh S. Spence, V. L. Eardley-Wilmott, and to Louis Brochu and Frank Willcox.

References have been included in the text concerning the application of new methods in metallurgy, the development of new uses in industry, the distribution of materials, and the available statistics on output, particularly in North and South America. Data have been utilized relating to wartime applications of each material, with a brief review of regulations and legislation and the distribution of supplies. These 76 minerals and metals are likely to receive continuing attention for some years after the war in consequence of stockpiling directives and the anticipated disputes in connection with contracts that were negotiated under the urgency of war demands.

JOHN B. DEMILLE.

MONTREAL, QUEBEC,
March, 1947.

CONTENTS

PAGE

Preface v
Introduction 1
Bibliography 27

REVIEWS OF STRATEGIC MINERALS AND METALS

Aluminum (*refined and reclaimed, alumina, alumina hydrate*) 30
Antimony Ore 49
Apatite (*calcium phosphate*) 56
Arsenic (*crude, trioxide, speiss*) 62
Asbestos (*African and Canadian*) 66
Barite and Lithopone 72
Bauxite 78
Beryllium (*ore and oxide*) 86
Bismuth Ore 92
Cadmium 97
Calcium and Calcite (*optical*) 103
Chalk (*English*) 107
China Clay (*English*), Bentonite, and Fire Clay 109
Chromium Ore (*chemical, metallurgical, refractory*) 117
Cobalt (*ore and oxide*) 128
Columbite 134
Copper (*ore, matte, refined*) 138
Corundum (*ore and grain*) 166
Cryolite Ore 173
Diamonds (*industrial*) 176
Emery Ore (*Turkish*) 183
Feldspar 186
Fluorspar 191
Graphite (*flake, lump, amorphous*) 201
Indium 208
Iodine (*crude*) 210
Iridium 212
Iron and Steel (*ore, pig, scrap*) 217
Kyanite (*Indian*) 245
Lead (*ore, bullion, refined*) 250
Lithium Minerals (*amblygonite, lepidolite, spodumene*) 270
Magnesite (*dead burned*) 276

PAGE

Magnesium 281
Manganese Ore (*ferro-grade, electrolytic*) 298
Mercury 314
Mica: Amber Phlogopite and Muscovite (*block, splittings, and films*) . 326
Molybdenite 339
Monazite Sand 349
Nickel (*matte and refined*) 355
Nitrogen Compounds (*natural and synthetic*) 368
Osmium and Osmiridium 381
Palladium 387
Platinum Ore 393
Potash (*muriate*) 403
Quartz Crystal and Plastic Optics 410
Rhodium 416
Ruby 419
Ruthenium 421
Sapphire (*natural Montana*) 424
Selenium 427
Sillimanite (*andalusite and dumortierite*) 431
Silver (*foreign*) 435
Sodium 447
Strontium Ore (*celestite*) 454
Sulfur and Pyrites 459
Talc (*steatite, Indian block, pyrophyllite*) 468
Tantalite 477
Tin (*ore, slags, reclaimed*) 482
Titanium (*ilmenite and rutile*) 501
Topaz 511
Tungsten Ore 513
Uranium 525
Vanadium Ore 546
Zinc (*concentrates and refined*) 555
Zirconium Ore and Baddelyite 577
Index 583

INTRODUCTION

Material resources unequaled elsewhere on the earth made possible the war industry and military power of the United States. These prodigious supplies provided the mechanized implements of the Second World War. Materials produced by industry have been fabricated by the vastly expanded American workshops and factories into equipment that was largely powered by coal and petroleum as a supplement to electric energy.

The nation's rise to a peak of military production not ever before conceived offers a tribute to American enterprise that is worthy of permanent record. This review of the uses and fabrication of essential mineral products indicates that in the war years, the mining industry reached a high point of achievement far above any previous record in this nation's history and that of any people in world annals.

Tribute is due the multitude of workers who supplied materials for our war machine. They organized and successfully administered the minerals-procurement program, assembling machines and parts in quantities beyond the conception of their fathers. Theirs was an accomplishment involving selective intelligence as well as diplomacy and tireless energy. Never has a war been decided so far behind the line of battle. Japan was not demolished by the force expended by military might, as Germany was, but surrendered to force in being and superior scientific and productive power. The hard work of men and women who never heard a shot fired contributed to the productive efficiency and research that gave critical support to naval and military power.

Government initiative was of primary consequence in the war expansion of the mineral industries. Factors contributing to the phenomenal production of minerals at home and abroad included the following:

1. Fixed capital and working funds for war production provided by Federal agencies.

2. Mining and metallurgy, as well as broad exploration, initiated, guided, and controlled in many projects by the government.

3. Available production resources put to increased use by setting up longer hours in two- and three-shift operations.

4. Resources diverted from the domestic civilian economy to the war economy, both at home and at foreign sources of supply.

5. Resources increased in the rate of production through greater rates per man-hour and machine-hour.

Men whose efforts contributed to the broad success of this great enterprise were Henry A. Wallace, Jesse Jones, J. A. Krug, Donald M. Nelson, Philip D. Wilson, and many other individuals of special skills and inspiring leadership. This book is concerned with preliminary statistics to the end of 1945, relating to the expansion of mineral-output and mineral-processing facilities, together with a survey of basic war materials. The tribute due those responsible for the broad program remains to be given by one who is able to speak more authoritatively and more eloquently than the present author.

The domestic economy of the United States was held under close controls for the first time in any major war; and in the period of postwar adjustment, these controls appeared to give safety from any disastrous price collapse. Credit for such stability was given by President Truman to the Congress, the Office of Economic Stabilization, War Labor Board, Office of Price Administration, War Production Board, and other stabilization agencies.

Of all combat munitions produced in 1944 by the Axis and the United Nations together, the United States supplied 45 per cent, as estimated by the Foreign Economic Administration. This compared with our contribution of only 12 per cent of the comparatively small world armament output in 1941, it was stated in the first annual report issued by the WPB on July 4, 1945. It was "a year of brilliant achievement on the production front," according to Chairman J. A. Krug. Since the summer of 1943, war plants held to a monthly production rate of better than $5,000,000,000, while over-all output in this country amounted to $199,000,000,000. War materials, including construction and certain other items, accounted for $61,300,000,000 of the total. Arms output showed a steady increase from the 1940 figure of $400,000,000. The loss in 1944 of nearly 1 million workers from the civilian labor ranks resulted largely from inductions into the armed forces, which averaged 11,380,000 persons.

The President of the United States on Apr. 25, 1941, defined certain strategic and critical minerals as war essentials. This list was subsequently extended to approximately 100 minerals and metals (not including coal and petroleum) of at least 5,000 important raw materials that are needed to keep industrial economy operating in satisfactory balance. In all, about 100,000 different materials are used to some extent by industry. The Conservation Division of the WPB modified the minerals list from time to time and frequently declared materials to be insufficient for war uses and for essential industrial demands. Military and naval supply services, by May, 1945, reached a stage of development that made possible a well-integrated schedule for the war in the Pacific.

The Second War Powers Act, including priority and inventory controls,

was extended by Congress to June 30, 1946. President Truman recommended that the date be further advanced, presumably another 6 months, continuing those subsidies and wartime statutes which were designed to stimulate increased production, until a formal state of peace was declared. The general objective was to streamline government into a peacetime organization, but those functions of wartime agencies which must be retained through the reconversion period were transferred promptly to the permanent government agencies.

In his message to Congress on Sept. 6, 1945, President Truman said:

> The development of our natural resources is . . . startling. We have torn from the earth copper, iron ore, tungsten, and every other mineral required to fight a war, without regard to our future supplies. We have taken what we needed. We were not able to, and we did not, take account of tomorrow. At the same time our splendid prewar program to build up our natural resources was sharply halted. The diligent and constant search for additional deposits of minerals was almost abandoned in favor of a frantic effort to discover and make possible the production of the materials of war.
>
> In brief, although during this war this nation has reached the apex of its power . . . our national capital account has greatly suffered. We must proceed with all possible diligence not merely to restore these depleted resources to their prewar standards but to make them greater and richer than ever before. We must make a diligent effort to discover new deposits of the precious and indispensible minerals upon which our national life is founded. We must develop for the use of industry new technologies so that the vast deposits of low-grade ores that have not heretofore been considered usable may be put to work for the good of all of us.

After studying the materials problem in relation to permanent stockpiles, the Army and Navy Munitions Board announced on Mar. 6, 1944, a new definition of strategic and critical materials as follows:

> *Strategic and Critical Materials* are those materials required for essential uses in a war emergency, the procurement of which in adequate quantities, quality, and time is sufficiently uncertain for any reason to require prior provision for the supply thereof.

No distinction was made between "strategic" and "critical" materials, but recognition was given various factors that impeded prompt procurement of war-essential materials in the period of national emergency. These factors included not only geographic distribution of mineral production but also man-power and transportation difficulties and time required to create additional plant capacity and to accumulate adequate reserves.

The relative availability, on Mar. 1, 1944, of metals and minerals essential to the war effort was defined by the Conservation Division of the WPB as follows:

GROUP I.—INSUFFICIENT FOR WAR USES PLUS ESSENTIAL INDUSTRIAL DEMANDS

Metals.....Bismuth, cadmium, platinum, sodium, tantalum, tin
Ferroalloys.....Columbium, nickel
Minerals.....Low-silica bauxite, corundum, fluorspar, muscovite and phlogopite mica, quartz crystal, Indian block talc

GROUP II.—SUFFICIENT FOR WAR USES PLUS ESSENTIAL INDUSTRIAL DEMANDS

Metals.....Aluminum, beryllium, copper, lead, magnesium, silver, zinc
Minerals.....Barite, bentonite, English china clay, cryolite, industrial diamonds, feldspar, lump graphite, mica (except as above), refractory dolomite, rutile, spodumene

GROUP III.—READILY AVAILABLE FOR ESSENTIAL USES

Metals.....Antimony, calcium, gold, cast and pig iron, mercury, palladium
Ferroalloys.....Cobalt, ferroboron, ferrochromium, ferromanganese, ferrosilicon, ferrotitanium, ferrovanadium, molybdenum, silicomanganese, silvery iron, zirconium, ferroalloy
Minerals.....High-silica bauxite, diatomite, flint, garnet, magnesium oxide, mineral wool, nepheline syenite, salt, silica sand, sulfur, vermiculite, amorphous graphite, gypsum, kyanite, lime
Refractories.....Dolomite, fire clay, magnesite, olivine, silica, sillimanite

The fourteenth and final number of the Material Substitutions and Supply List, issued by the WPB, followed the general easing in supply of the essential metals and minerals. Materials insufficient for war use late in October, 1944, were limited to those included in the following revised schedule:

GROUP I

Metals.....Cadmium, chromium metal, sodium, tin
Ferroalloys.....Nickel, monel metal, steel castings, wire rope

On this list, columbium was moved from Group I to Group II; tantalum and zinc were shifted to Group III, along with mica, graphite, and quartz crystal. Tin, corundum, certain ferroalloys, certain grades of talc and mica, platinum and some of the platinum metals, lead, cadmium, certain grades of graphite, bismuth and bismuth chemicals, antimony and oxide all remained in short supply after VJ-Day. WPB demands were filled or surpassed by supplies of 23 minerals and metals stockpiled by the Metals Reserve Company, as reported by its president, Charles B. Henderson, in March, 1945. The MRC also accumulated a minimum of 50 per cent of recommended stocks of 22 additional minerals and failed to obtain adequate supplies of 16 others.

Becoming effective on Oct. 3, 1944, the Surplus Property Act had the effect, under the adjustments that followed the termination of expanded

war output, of stabilizing metal markets and was designed to prevent widespread suspension of mining and smelting operations. The act controlled the disposal of government-owned facilities and surpluses valued from $16,000,000,000 to $100,000,000,000, including aluminum, magnesium, iron and steel plants. It required submitting to the Attorney General for approval all sales projects that involved property values at $1,000,000 or more, while approval by the Surplus Property Board was required for the sale or lease of any plant costing more than $500,000 and classified as aluminum, magnesium, or iron and steel. War goods costing about $265,000,000 were sold in the 10-month period that ended Mar. 31, 1945, when undisposed surplus, largely aircraft, was valued at almost $1,000,000,000. The SPB was technically under the Office of War Mobilization and Reconversion (OWM), holding authority to carry out the entire disposal program; the Smaller War Plants Corporation was given authority to buy surplus equipment for resale to small business. The WPB was empowered to maintain adequate stocks of strategic minerals and metals (including scrap) for war requirements and "war-supporting" industries. It was also given authority to maintain such stock for the needs of nonwar production for a period of 12 to 15 months after the establishment of peace. All but negligible surplus supplies were frozen for the government stockpile. Amendments submitted to Congress in July, 1945, would give the SPB full power, independent of the authority and responsibility of various government agencies and responsible only to the President and Congress. W. Stuart Symington was confirmed on July 12, 1945, as chairman of the three-member board, which controlled the disposal of industrial plants representing more than one-fifth of the country's total facilities.

The return to a peacetime economy was cited as the first duty before Congress at the opening of the session in September, 1945. Immediately after the surrender of Japan, the OPA acted to eliminate certain rationed items, and one commodity after another was removed from price controls. Price adjustments were made as required in order to bring about rapid reconversion and reemployment. This was accomplished by the orderly removal of all restraints that had been necessary in the emergency and by the termination of wartime agencies that imposed these controls. The national economy had been conducted in time of war by the government. In peacetime, private enterprise was able to assure an efficient and balanced production having a framework within which the traditional American civil liberties might flourish.

Recommendations as to the minimum and maximum quantities of each strategic material for permanent defense stockpiles were submitted to

Congress in February, 1945, by the Army and Navy Munitions Board. The Strategic Materials Committee was authorized under the act of June 7, 1939, to purchase and release stockpile materials during the period of national emergency. The Strategic Materials Committee represented the War, Navy, and Interior Departments. A stockpile bill was introduced in Congress in March, 1945, and on July 9, 1946, it finally cleared the Senate and was sent to the President for signature. This bill authorized the government to build up war stockpiles of strategic and critical materials during the next five years. The amount of money to be spent annually for the stockpiling was left to later decisions of Congress. The War Assets Administration (established Feb. 1, 1946) issued on Aug. 21, 1946, new procedures whereby all government-owned surplus materials determined to have strategic possibilities would be transferred to the government stockpile. Of the 48 specific metals and minerals recommended for stockpiling, 35 were required for minimum stocks, the shortage of which, it was believed, would endanger national security. The Army and Navy Munitions Board recommended that no preference be shown for domestic materials in specifying delivery of these critical supplies usable by industry in time of war. The new stockpile board, however, would be required to "buy American" and would hold materials for use in a future war emergency. These materials would be released only by special authorization of Congress.

The setting up of stockpiles of deficient minerals necessary to national defense was again recommended by the President to Congress on Sept. 6, 1945, and on Jan. 21, 1946. One of the costliest lessons of unpreparedness for war was stated to have been the danger involved in dependence on foreign sources for certain minerals and other strategic raw materials.

Special provision for emergency supplies in time of war is required in the case of manganese, chromite, nickel, and others of the 33 principal minerals and metals that are essential to industry and may become critically scarce at some future time. Within the next 10 years, this country is expected to lose self-sufficiency in copper, which will be added to various other metals of which the United States now is a net importer, as discussed by Elmer W. Pehrson, U.S. Bureau of Mines. Increased imports are indicated for mercury, block mica, bauxite, cadmium, lead, platinum, tungsten, vanadium, and zinc. Domestic reserves or installed capacity (in the case of such materials as iron ore, barite, magnesium, molybdenum, nitrogen, phosphate rock, potash, sulfur, and possibly fluorspar) are believed to be adequate for supplying domestic requirements over a period of more than 100 years (for fluorspar, 40 years). Relatively large submarginal resources are now

available at high prices contingent on a national emergency, including bauxite, chromite, flake graphite, manganese, mercury, nickel, and vanadium.

Army and Navy Munitions Board recommendations for stockpiling provided for a reservoir of domestic ores and for importing those materials not otherwise available. Rather than certain domestic mines being closed and ore reserves maintained for production only in time of emergency, it was advocated that exploration be carried on to locate new ore deposits and methods developed for emergency production of various submarginal resources. Stockpiling was defined as a device for supplementing the domestic supply through purchase of foreign materials.

War production was coordinated in the United States, Britain, and Canada by the Combined Production and Resources Board. This same board continued its jurisdiction through the reconversion period, after Japan's surrender, for exchange of economic data and directed various stages of reconversion. Policies were recommended for disposing of surplus supplies and facilities, liquidating war contracts, and releasing materials for civilian use. The combined armament program called for continuing the full war economy until the defeat of Japan and then gradually removing all controls.

The production of minerals adequate for peacetime requirements depends on securing detailed information as to domestic ore reserves. Postwar projects on a large scale were announced for the purpose of providing mine operators with information to serve as a "reliable inventory of our mineral resources." Information preserved in company files will be required for study by the U.S. Bureau of Mines and the Geological Survey, which will make possible the continuance of the successful cooperative relationship established in the war period between government and private industry. The search for vitally needed mineral deposits can be accomplished, it is believed, only through increased activities of government agencies.

Postwar utilization of vastly expanded metals industries was cited by the WPB as one of the more difficult problems facing industrial and financial leaders. The wartime development of these metals industries had run counter to the long-term trend, as shown by the WPB report on the effect of the war on industrial economy, issued Sept. 5, 1945. If the metals industries should put to full use both facilities and labor, it would be necessary to contribute to the expansion of the peacetime economy or the export market. These industries more than ever before were turning out a large proportion of "the national product."

The expansion period of metallic and nonmetallic mineral production was mainly completed in 1943, although enlarging and replenishing the

country's stockpiles through conservation was recognized as a continuing process. Before the end of 1944, few materials remained on the critical list. A basis for prompt disposal of inventories remaining under government ownership was explained by the War Department in Procurement Regulation No. 7. Provision was made for retaining the 42 minerals and metals described as "stockpile items."

Mineral production in the United States and Alaska, in 1944, exceeded all previous years with a value estimated at $8,543,000,000; in 1945, $8,067,000,000. This compares with $8,056,000,000 in 1943 and the 1918 figure of $5,540,708,000. Of the 1944 total, mineral fuels amounted to $5,254,000,000, metallic minerals were $2,377,000,000, and nonmetallic minerals were valued at $912,000,000 compared with $1,109,000,000 in 1942 and $788,200,000 in 1939. Certain metals and nonmetallics declined as a result of reduced demand, man-power shortages, and curtailed activity of the building industry. Because of special military or civilian value, some of the nonmetallics were produced in generally higher quantity than in 1943.

A broad expansion of the minerals industries took place from 1941 through 1943. Mounting demand led to a maximum output in 1944. New plants were built, and the capacity of old facilities was increased. It became general practice for millmen to process tonnage greatly in excess of the rated capacity of their equipment. Curtailment began in 1944. The number of "insufficient" items was reduced from 15 to 8 between March and October. Adequate government stockpiles for the majority of strategic materials were reported at the end of the year. Their production was being either curtailed or stopped. Great quantities of ores were made available for urgent war requirements as a result of closely integrated procedures. Of dominant importance was the sevenfold expansion in capacity for producing new fabricated aluminum, which had tripled output from 1942 through October, 1944. Magnesium production showed a fiftyfold rise in the 5 years ending in October, 1944, and steel output was one-third higher in 1944 than in 1940. Quantities of tungsten, mercury, and chrome far in excess of former operations were also provided. Future use of light metals and alloys will involve competitive costs and technologic progress in developing new applications.

The chief war contribution of the U.S. Bureau of Mines was the uncovering of large reserves of critical ores, working out new methods of utilizing domestic minerals, and improving known metallurgical processes. Ore samples were analyzed and beneficiation tests performed in laboratories and pilot plants. Skilled workers of the bureau tested military and industrial explosives, advanced safety and efficiency in mining industries, and per-

formed many other jobs (particularly in connection with coal, petroleum, and helium gas) directly linked with the prosecution of the war. These operations developed successful methods for the production of manganese, chromium, aluminum, and titanium from domestic low-grade ores. Both titanium and boron were added to the list of materials having important applications in the future.

Information concerning foreign mineral deposits was secured after 1941 by the U.S. Bureau of Mines and the Geological Survey in conjunction with the FEA and other offices of the Department of State. The cooperation of agencies of South and Central American governments was secured. More than 440 mineral deposits were investigated outside the United States. Promising discoveries in Mexico, Brazil, and Peru included corundum, mica, lava talc, quartz crystal, mercury, tantalite, and tungsten. The urgent need for various materials resulted in fostering close relationships. It was the opinion of the Mexican-American Commission for Economic Development that cooperative projects between the United States and Mexican enterprises were "setting a pattern for the world of tomorrow."

Work carried out in 1942 by the American Technical Mission to Brazil indicated the need of supporting the internal economy of Latin America because of the crisis caused by submarine attacks on shipping. Its imports largely cut off, Latin America was faced with the necessity of making the largest possible use of home products. Basic objectives of the mission, which collaborated with the Coordinator of Inter-American Affairs, the WPB, and the Department of State, were as follows:

1. To increase local production of essential products, particularly those formerly shipped from the United States.
2. To convert local industry to the use of substitute materials.
3. To maintain and improve transportation facilities.
4. To strengthen the whole industrial economy of Brazil.

Mineral missions from the United States on both commercial and technical projects were active in Africa as well as in Latin America (Argentina, Cuba, Colombia, Guatemala, Peru, Mexico, and Brazil). Results accomplished not only contributed to the successful prosecution of the war but will also promote hemisphere solidarity in the years to follow.

The important program for securing essential materials from Latin America was initiated late in 1940 by the MRC. It secured from Bolivia a contract for the delivery of tin concentrate; this was followed in May, 1941, by a contract for the purchase of Bolivian tungsten. An agreement was also made in May for the purchase by the MRC from Brazil of all available minerals. The third agreement in this foreign procurement plan was with Mexico,

effective on July 15. The same general terms applied in all cases; Mexican purchases were controlled by current market prices; and the agreement was renewable after 18 months, whereas purchases in Brazil were to be at fixed minimum prices for a 2-year period. Peru accepted similar terms in October, and Chile and Argentina were negotiating agreements at the end of 1941. The result of this policy, as described by J. S. McGrath, director of the Foreign Minerals Division, U.S. Bureau of Mines, was to secure the entire exportable output of Latin American minerals.

Financing through government agencies was of major importance both in developing mining properties and in purchasing stategic minerals of domestic and foreign origin. The MRC was created by the Reconstruction Finance Corporation on June 28, 1940, for the purpose of acquiring, holding, and selling materials necessary to the war program, the original objective being the purchase and stockpiling of tin and manganese. Major classifications of commodities were increased to 49, of which 7 were first purchased in 1940, 21 were added in 1941, 14 in 1942, 6 in 1943, and 1 (barium) in 1944. To Oct. 31, 1944, the MRC had disbursed $2,041,350,000, of which $1,086,393,000 was recovered through sales to war industries, as reported in March, 1945. Actual cost to the United States of the MRC procurement program, after inventory and other assets were deducted, was something over $300,000,000, of which $195,000,000 was paid in subsidies. Other expenditures were made in neutral countries for preclusive buying. Before he was succeeded as Secretary of Commerce by Henry A. Wallace, Jesse Jones stated on Jan. 17, 1945, that the Defense Plant Corporation (created Aug. 22, 1940, for the broad purpose of expediting the national defense program) had disbursed $7,177,700,000. Under directives from the WPB and the War and Navy Departments, part of this was applied for the purpose of increasing production and processing ores of aluminum, magnesium, iron and steel, chromium, manganese, tungsten, vanadium, and other metals and minerals required as war materials.

The mining and metallurgical industries of Canada contributed to the war effort in many notable respects, assisted by the MRC (also active in 49 other countries and territories outside the United States) and the mining section of the RFC. Canada is the greatest metal-exporting country in the world and was the largest single supplier of "fighting" metals to the United Nations. Nickel and platinum-group metals from Sudbury, Ont., supplied about 95 per cent of the United Nations' requirements. Canada holds second place as a producer of uranium and asbestos and as a processor of aluminum (about 40 per cent of the total Allied war requirements); third place in mining cobalt, copper, mercury, silver, and zinc; and fourth place in lead.

Civilian use in Canada of nonferrous metals was reduced in the war years to less than 10 per cent of total domestic production. The metals controller directed the supply of base metals, making allocations for war industry and securing increased sources of industrial minerals. The Canadian program, supported jointly with Washington and London, was marked by a high degree of success.

Canada considers it possible to maintain mining over a period of years at wartime capacity, under favorable domestic and international economic conditions. Mining in the Dominion advanced from 4 to 12 per cent of the total value of national production, 1919–1939. Expanded mining facilities were an important factor in bringing the Dominion to the stage where nonagricultural industry accounted for 75 per cent of the national wealth. War goods of all kinds valued at more than $10,000,000,000 were supplied, 13 per cent going to the United States, 34 per cent supplying Canadian war activities, and the balance being delivered to Britain. Of the total value of mining products, 80 per cent was utilized for war purposes compared with 70 per cent of forestry products, 60 per cent of manufactures, and 25 per cent of agricultural products. The new skills and productive facilities gained during the war enabled the Dominion to provide civilian goods and services estimated at $5,000,000,000 a year, with 4,500,000 workers available for employment. In June, 1945, Ottawa announced a goal of $1,750,000,000 a year for export trade, the major items being minerals and mineral products. This is about 60 per cent higher than total exports in 1938 but only half the market that has been built up since that year. It is proposed to develop trade by extending credits to devastated countries, by expanding all possible markets, and by enlarging the Canadian Merchant Marine.

Future exploratory work in the northern half of Alaska, as well as in the Northwest Territories, promises to lead to increased production of silver, tin, tungsten, lead, chromium, platinum metals, antimony, and mercury, as reported on May 17, 1945, by the U.S. Geological Survey. Occurrences of 10 other metals and minerals have been mapped and await exploration. Although large areas remain to be explored, new maps prepared in recent years from air surveys by the War Department will facilitate the projected expansion. Only limited production of critical materials for war purposes has been possible, but this great area presents possibilities for important production in the postwar period.

The United Kingdom Commercial Company and the U.S. Commercial Company were set up as economic warfare agencies to engage in preclusive buying regardless of price, in neutral Europe and elsewhere, in order to keep strategic commodities out of German hands. Most important in this cam-

paign was gaining control of tungsten ore, of which more than 90 per cent comes from Spain and Portugal. Other critical materials were obtained in neutral Europe, Turkey, Africa, and South America by means of the ruthless buying methods employed by the commercial companies with the assistance of the FEA. These materials included copper, chrome, industrial diamonds, specialized steels, platinum, quartz crystal, and certain other items. Economic warfare was carried on through purchases made at inflated prices by agents of the United States. It succeeded in bringing to an end the activities of Nazi smugglers.

War demand for various other minerals of Latin America was assisted in another respect by the U.S. Commercial Company, which succeeded the MRC in 1944, in procuring minerals from foreign sources. The MRC took delivery in the United States from foreign sources after the change-over and distributed stocks to the domestic trade. Contracts were negotiated for securing larger shipments from Cuba of chromite, manganese, and copper ore and from Chile of manganese ore, to specify only a part of the broad scope of foreign procurement. Postwar survival of the mining projects developed in Mexico and South America will be contingent on assurances to American investors by native managers and local governments that exports in future will not be restricted. Successful industrialization and trade within the Americas, as discussed by Charles Will Wright, U.S. Bureau of Mines, depend on a number of factors. These include the extension of reciprocal trade agreements, the removal of United States export restrictions before European competition can be established, the modification of Latin-American export and immigration restrictions, and cooperation between North and South America in research relating to development of raw materials so that independence of sources outside the Western Hemisphere can be achieved.

The FEA, which included lend-lease and the Export-Import Bank, was established in September, 1943, under the Department of State as an emergency war agency to "unify and consolidate governmental activities relating to foreign economic affairs." The FEA supervised export controls, bought critical materials from foreign sources, and gathered foreign economic intelligence on which the Army based certain operations, including military bombing. Studies were made of economic controls on Germany, and the FEA was empowered with authority to administer postwar exports in order to prevent Germany and Japan from accumulating stocks of strategic war materials at a future date. In 1941, before lend-lease had been created, the Defense Supplies Corporation made loans to Russia and other countries in order to strengthen armaments against the German attack. Shipments of

chrome ore, platinum, asbestos, and other materials were received in payment of these loans.

The functions of lend-lease were discussed by President Truman, in a letter to Speaker Rayburn on June 5, 1945, as a pooling of resources with those of our Allies in order to make a crushing blow against Japan. Lend-lease funds would make the efforts of our Allies more effective, whereas reverse lend-lease would involve receiving all possible assistance from our Allies. New funds ($1,975,000,000) were required in addition to unexpended balances of $2,400,000,000 from the year ending June 30, 1945. War-usage limitations on supplies and equipment for certain war-ravaged countries (not including France, Belgium, and the Netherlands) were specified under lend-lease agreements, making necessary the financing of such supplies through the Export-Import Bank. Reverse lend-lease gave us all possible assistance from Britain and other countries in financing both the redeployment of United States troops from Europe to Asia and the United States control over enemy bases. Budget Director Harold D. Smith summarized the lend-lease program as (1) an indispensable weapon for waging fully effective war against Japan in close collaboration with our Allies, (2) funds limited to purposes of the war and national defense, (3) raw materials provided under lend-lease agreements only when they were needed to maintain or increase the industrial contribution of the lend-lease country to the war effort. Lend-lease to Russia and other European countries was cut back drastically after VE-Day, and it was intended that before Dec. 31, 1945, all aid would be ended for Belgium, France, and Holland. FEA administrator Leo T. Crowley reported in June, 1945, that shipments were being made to Siberia but that within 30 days after the defeat of Japan, the entire lend-lease program could be closed out.

Lend-lease came to an end on Aug. 14, as the most gigantic mutual-aid program in history. Immediately after VJ-Day, all countries were advised by the FEA that deliveries of supplies under lend-lease would stop, and negotiations were made for the purchase of all goods in transit or in storage. Although obligations were not canceled, settlement was arranged so as to permit a sound world-wide economy planned to contribute to international peace and to the security of the United States. The transition was intended to move from economic cooperation in war to economic cooperation in peace.

Lend-lease aid through Dec. 31, 1945, amounted to $49,096,125,000, of which metals and minerals accounted for $2,002,000,000. More than half of this sum was received by Britain, amounting to 31,610,456 pounds of brass and other metals. The United States received metals and minerals as

reverse lend-lease aid from the United Kingdom and the Colonies, valued at $14,000,000 in the period from Mar. 11, 1941, through Dec. 31, 1944. The British Empire supplied $6,306,149,000 of the total $7,345,747,000 reverse lend-lease through Sept. 2, 1945.

Where lend-lease stopped, effective aid was continued through loans from the Export-Import Bank, of which Wayne C. Taylor was president. The bank, in July, 1945, became a permanent agency, with FEA Administrator Leo T. Crowley as chairman of the five-man board of directors. Capitalization was increased from $700,000,000 to $3,500,000,000. The Johnson Act, which prohibited loans to governments in default of the First World War obligations to the United States, was repealed as far as loans by the Export-Import Bank were concerned. The main purpose of the bank was stated to be facilitating the movement of American goods in foreign markets. Increasing the capitalization was expected to build foreign trade and assist in the reconstruction of war-devastated countries by further developing their economies, prior to the full functioning of the World Bank under the Bretton Woods agreement.

FEA procedure has been described by Dr. Alan M. Bateman as a method stimulating development of mineral regions in South America, Asia, and Africa to an extent that will have direct bearing on postwar development of international mineral industries. The course of action began with sending technical personnel to inaccessible areas to carry on widespread exploration. Sources of production in excess of the requirements of the United Nations were developed as contingency reserves against war hazards. Purchases of exportable mineral surpluses of neutral countries were made in order to prevent the shipment of such minerals to Germany and Japan.

Procurement of minerals from foreign sources was negotiated in accordance with some five distinct types of contract. Close adherence to ceiling prices had been a condition that was expected to have favorable effects on postwar mineral markets. Foreign materials purchased at prices higher than the ceiling rates included the following: tin and copper; minor amounts of nickel, barite, and corundum; negligible quantities of other minerals. Government procurement in 1945, combined with private purchases from foreign countries, accumulated large-tonnage supplies of the following materials: manganese, chrome, copper, lead, and zinc.

As a result of closely integrated plans, foreign sources supplied various materials required to supplement domestic output. The lack of domestic supplies of certain strategic materials made it necessary to import large quantities of antimony, tin, chrome, manganese, mercury, and of nickel as well as those materials more sparsely distributed, such as cobalt, corundum, mica,

and tungsten. Rare minerals and metals (beryl, boron, columbite, quartz crystal, uranium, and tantalite) were developed and procured in quantities never before required. Large extension in domestic-plant capacity also made other materials available to meet all critical requirements, with price advances involved only in special cases.

After Pearl Harbor, the need for greatly expanded output led to negotiations with foreign countries by the FEA and the MRC. In certain cases, advance payments were made against future delivery for the purposes of development and plant expansion. Although foreign-mineral financing was generally arranged by producing countries, in some cases assistance was given by the DPC, where new plants were to be built or facilities expanded. Foreign mineral trade in the postwar period must take place on a large scale in order to supply vital materials for which new or increased applications have been developed through research. A strong competitive position in this trade will require close cooperation among producers, local governments, and, under certain conditions, the United States government.

Postwar imports of various materials will be required in increasing quantities to compensate for the depletion of domestic sources and to meet requirements that have been greatly enlarged by the development of new uses. Copper, lead, and zinc from foreign countries will be needed in excess of domestic supplies, as will other minerals and metals. The expansion of foreign mineral trade will involve drastic changes in our tariff policy.

In the years ahead, even when the government withholds surpluses from the market for its stockpile, it is doubtful that prosperity can be achieved in several branches of the mineral industry. Stockpiling schedules on a long-term basis appear indispensable in order to keep available all minerals that are vital to domestic industry, in times of both peace and war. Such a policy would contribute to the postwar problem of keeping mines and industries active. Imports of various minerals would expand foreign trade and assist in settling adverse balances resulting from exported finished products.

Experience with manganese has been cited by Dr. Bateman as an example of stockpiling under war conditions. Industry had accumulated large prewar stocks of this material which, after Pearl Harbor, became the concern of government rather than of private business. Global warfare imposed an urgency that involved such risks as shipping uncertainties, tariff barriers, ceiling prices, and the necessity of marginal and uneconomic production. The government stockpile created in Cuba as a safeguard was later—when normal manganese supplies were greatly reduced from West Africa, India, and Brazil—to fill our requirements, in large part, from foreign sources.

War risks seldom were assumed by industry, which had the import trade returned to it by government agencies as soon as war conditions permitted.

In November, 1944, the United States Army adopted the policy of stockpiling all ferrous scrap for future disposal, probably in Europe. At that time, brass scrap being returned to the United States from battle areas decreased from 7,600 to 2,500 tons monthly, owing to shipping and personnel shortages. Only small quantities of aluminum, copper, lead, and zinc scrap were returned to this country in the first half of 1945, when the deployment of troops left no shipping space available.

As metal supplies gained in stability, however, labor shortages became critical; and in January, 1945, the War Manpower Commission issued a directive calling for deferment, at the discretion of Selective Service, of men in the age group twenty-six to twenty-nine for employment in mining, metallurgy, and other industries necessary to war production. Metals designated as essential included the following: aluminum, chromium, copper, iron, lead, manganese, mercury, molybdenum, tungsten, vanadium, and zinc. The priority directive specified the removal of overburden, sinking of shafts, and other work required to establish new operations and plant construction for the treatment of ore. Smelting, refining, and rolling of metals used in the production of war materials were classified as essential. Mine operators were warned not to expect more than the total man power available in January, 1945. It is significant that output per worker in 1944 increased one-third, on a quantitative basis, with a third less workers than in 1923. This was a result of mechanization of mining operations and improvements in mineral technology, as reported by Elmer W. Pehrson, U.S. Bureau of Mines. It was announced on Apr. 30, 1945, that the WMC foresaw new labor shortages in the second and third quarters after VJ-Day, as reconversion hit full stride and peacetime industry absorbed workers laid off by war plants. Not more than a dozen American cities were expected to develop labor shortage following armament cutbacks in the first 3 months after VJ-Day.

On Apr. 17, 1945, WPB Chairman J. A. Krug announced the restoration of the "spot authorization" plan for civilian goods manufacture. The first 65 of some 500 WPB controls on industry were to be revoked at the rate of perhaps 10 a day in order to keep up with armament cutbacks already announced and others to be effective before VE-Day. Under the "spot" plan, which had been prepared in August and terminated in December, 1944, the scope of reconversion was dependent on men and machines available in mines and at war plants in the 187 major industrial centers as contracts were completed. It was estimated that some 350 controls would be removed from

industry within three or four months after VE-Day, the remaining 150 to be retained possibly until VJ-Day. Relaxing the allocation orders governing steel, copper, aluminum, and other critical materials would take effect by permitting producers to fill nonpriority civilian orders after obligations to the Army and Navy had been met. Civilian-goods production authorized under the "spot" plan or by the lifting of control orders was to be determined by the WPB as plants were freed from war production.

By means of this new line of action, the WPB was enabled to authorize resumption of civilian output of metals and other commodities in those areas where materials and man power became available, but only after fighting in Europe ended and after the war against Japan had been outlined more clearly. Under the original plan, WPB as well as Army and Navy spokesmen, in 1944, counted on cutbacks up to 45 per cent within 30 days after VE-Day. However, in April, 1945, estimates by the OWM indicated that war output would be continued until some months later with few changes, pending the outcome of war with Japan. Rather than an abrupt transition, the revised procedure called for gradual reconversion designed to allow for prompt action on sudden demands from war fronts for new materials. The War Department took precautions not to repeat the overconfidence that had seriously curtailed essential production late in 1944. The WPB announced on May 28, 1945, that industry controls would continue through the year at above nine-tenths of the 1944 peak rate in order to secure adequate supplies for war in the Pacific. In 1946, industry could be turning out durable consumer goods at a rate more than 30 per cent higher than in 1939. Postwar prosperity was to be facilitated by removing curbs on "initiative, imagination, and resourcefulness" of private industry.

On June 30, 1945, the WPB announced that plans had been completed for removing virtually everything except military requirements from priority controls within 6 months. Changes in the priority system provided for business to adjust operations before Jan. 1, 1946, when the full effect of the new policy would be felt. The Army, Navy, and other war agencies were to assign a new MM rating for war-supporting and essential civilian goods in order to meet urgent needs. This replaced the AA classification that had been enforced under priority regulations; the AAA designation was to be continued for emergency use only. After Oct. 1, the only AA ratings assigned would be for deliveries required before the end of the year. Following VJ-Day, however, the last AA rating was canceled on Sept. 30.

The program for reconversion submitted on Sept. 5, 1945, by John W. Snyder, director of war mobilization and reconversion, stated that release of materials for expansion of peacetime production was a double process

involving termination of war use and removal of restricting controls. Consumption of steel was reduced 99 per cent by the cancellation of contracts by the War Department after VJ-Day. Copper and aluminum consumption had been reduced 98 per cent, in addition to the wide release of these and other minerals and metals by cancellations of the Navy Department and other government agencies.

Up to Sept. 5, 1945, the WPB had canceled all but 160 out of a wartime peak of 650 orders and schedules that allocated materials for war. Priority ratings on all military orders were canceled on Aug. 17. AA priority ratings and Controlled Materials Plan tickets, calling for delivery after Sept. 30, were also canceled. On such scarce materials as tin, lead, and antimony, the WPB consolidated inventory controls applying to distributors, large retailers, and producers. This was done for the purpose of distributing scarce materials as widely as possible. A tight grip on steel, copper, and aluminum had been maintained by the WPB, specific quantities being directed to the armed services and other uses essential to the war-production program. Assistance was being given to the mining-equipment manufacturers in order to increase production of scarce machinery and supplies. An orderly transition to a peacetime economy was believed to require the use of some controls into 1946. Tin was foremost among those critical materials of which the war had caused a shortage and which was expected to continue inadequate for some time.

Two new systems of priority were adopted by the WPB in an effort to assure all required military production. These systems consisted of MM ratings, for military manufacture, and CC ratings, to break reconversion bottlenecks. Price controls of the OPA had been suspended on mercury, aluminum, and magnesium, as well as most of their products. The suspension of price controls on other metals was planned as soon as danger to economic stability no longer existed. Broad removal of price ceilings was not to be attempted until the threat of inflation was ended, after reconversion was well advanced to the point where production balanced demand.

Mr. Krug said on Aug. 20, 1945:

> The nation faces a remobilization of industry on a scale that matches the mobilization for war. We all have a tremendous stake in the speed with which this remobilization is accomplished. . . . Every opportunity must be given to private business to exercise its ingenuity and forcefulness in speeding the resumption of civilian production. We do not want to perpetuate Government controls.

In the first full postwar year, the Committee for Economic Development estimated increased production, as compared with 1939, amounting to 58.2

per cent in chemicals and allied products; 43.2 per cent in stone, clay, and glass products; 37.3 per cent in iron and steel and their products, except machinery; 44.2 per cent in nonferrous metals and their products. All manufacturing industry would increase an estimated 41.6 per cent, from the prewar (1939) value of $56,843,000,000 to $80,515,000,000 in 1946.

At the end of the fiscal year 1945, the WPB announced that peak production of munitions had been reached in March. In May, the volume was 7 per cent lower, at $4,600,000,000, and a slight further decline was expected for June. Armament cutbacks in May affected 979 war plants, leading to an estimated reduction of $7,668,000,000 in total output for the 2 years 1945–1946. Arms production was planned for the fiscal year 1946 to be almost $42,000,000,000 compared with the 1945 program which, before Germany's collapse, had been set at $60,000,000,000.

Many materials of strategic value, imported under normal conditions from foreign countries, were available from domestic sources as a vital contribution to the war effort. As far as minerals and metals were concerned, this resulted largely from metallurgical research in the treatment of certain ores and waste products that, formerly, had been considered too low grade to be workable. The refractory nature of many domestic ores has required technologic advances in the field of froth flotation of nonsulfide minerals. Research, engineering, and the scrap-metal industry have been credited as the greatest forces of conservation now supporting the minerals industries.

Technical improvements leading to cost reduction have made it possible to mine lower grade and marginal ores, thereby eliminating waste of mineral resources. Flotation has been applied as an effective method in beneficiating such ores as graphite, iron, barite, beryl, clay, magnesite, and vanadium oxide, as well as certain base-metal nonsulfide minerals. Heavy-mediums separation (sink-float) has been applied in treating iron, zinc, lead, magnesite, fluorspar, and tin. The present importance of both flotation and heavy-mediums separation in beneficiating minerals promises to be maintained in the postwar period. "The millman of tomorrow will not only have to know metallurgical engineering and ore dressing, but will have to qualify as a chemical engineer . . . to produce the finished product," stated F. M. Jardine. This more complex procedure, involving cost reductions in the treatment of sub-ore and waste products that formerly could not be classified as ore, is an important factor in making such materials commercially treatable. Conservation, rather than extravagant use of materials whether scarce or abundant, is needed in order to plan intelligently for postwar mining.

Achievements in addition to the beneficiation of low-grade ores and other production records have been the conservation and substitution of

various alloying elements. Innumerable examples might be cited, particularly the National Emergency Steels, of a series of alloys developed through the liberal attitude toward change of both the producer and the user of metals. Fabricators learned to select metals under the fluctuating conditions for engineering applications based on metallic properties. Under prewar standards, metals were adopted in accordance with specific chemical composition. Under postwar competition among the various metals and between metals and plastics, this new criterion of economy in the selection of alloying elements—based on metallic properties—offers many advantages.

As a part of the effort to develop either new or improved applications of minerals for military and postwar purposes, work was in progress by various research agencies, including Armour, Mellon, Batelle, and Southern research institutes; the Office of Scientific Research and Development; and the Electrodevelopment Laboratory, U.S. Bureau of Mines. In England, the British Iron and Steel Research Association and other foundations are equipped to produce cooperative studies of the effect on the postwar world of extensive developments in the field of mining and metallurgy; in Canada, similar work is in progress by the Department of Mines. Various trends to new uses have been indicated by the application of mineral products under the stress of war. The demand for metals early in 1945 to supply the greatly expanded armament program was the cause of research activity on a broader scale than at any time since 1942. Technologic investigation is being continued with a view to the economic well-being of several regions of the United States as well as foreign countries. A broader plan of action is maintained in order to advance basic knowledge of processes and products of many different industries in preparation for the postwar struggle for domestic and foreign markets. Further research is required to develop new uses and to discover methods of reduction for such rare metals as calcium, lanthanum, yttrium, gallium, gadolinium, germanium, thallium, and thorium. Some of these are available in quantity, but laboratory study has not resulted in large-scale commercial applications.

Activity in chemical, metallurgical, and engineering research in the United States advanced rapidly in the period between the First and the Second World Wars. This country, now believed to be far in advance of similar research in Germany-Austria, Great Britain, France-Belgium, and Russia, in 1940 had 2,264 industrial research laboratories, according to the National Research Council. It has been questioned whether or not this dominance will continue into the postwar period. However, it would appear that rapid headway in this field, as in others, has been fostered by war conditions; so the United States may face, in the future, less competition than formerly

in the development of fundamental and applied research, as well as in studies to improve products or reduce manufacturing cost.

The premium-quota plan to stimulate domestic production of copper, lead, and zinc was initiated on Feb. 1, 1942, by the Emergency Price Control Act as a joint function of the MRC, the OPA, and the WPB's predecessor, the Office of Production Management. Additional premiums were established to compensate operators of marginal properties for the extra cost of expanded output. General price increases were avoided, and there was a very substantial saving to the government, which, under war conditions, was the major purchaser affected. The original 30-month period of the premium-price plan was extended to July 31, 1945. Congress again approved continuing these subsidy payments through June 30, 1946, with an appropriation including $88,000,000 (zinc, $40,000,000; copper, $33,000,000; lead, $15,000,000) which the RFC was authorized to administer.

These price controls gave generally satisfactory results in acquiring metals and minerals for stockpiling and for distribution to industry. The First World War was marked by metal prices that were more than double the average cost in November, 1944, of domestic copper (15 cents a pound), lead (6 cents), and zinc (11 cents). The same metals from foreign sources have been secured since 1942 at 12, 6½, and 8¼ cents a pound. Composite prices representing five metals (aluminum, copper, lead, tin, and zinc) were 18.64 cents in the First World War, 11.43 in the Second World War, and 9.52 cents in the prewar period 1930–1939, as reported by *American Metal Market.* Through Feb. 28, 1945, premium payments made by the MRC on copper totaled $61,392,214 (on about 17 per cent of total domestic production); on lead, $28,800,075 (about 27 per cent); on zinc, $84,557,987 (about 43 per cent). Although shown in government records as a loss, these payments served as a safeguard against advancing prices for metals and a wide range of finished products.

Mechanics of the premium-price plan for metals administered by the quota committee, composed of WPB and OPA representatives, were subject to approval by reviewing officers of the WPB, the OPA, and the MRC. When the price was approved, the producer was required to comply with MRC specifications; processing plants receiving the materials acted as agents for the MRC on the basis of producers' sworn data. Producers received a preliminary payment on delivery of the ore, and final payment was made after data were approved by the Washington office of the MRC (except in the Tri-State district, where payment was made direct by the Federal Reserve Bank of Kansas City). In November, 1944, terms of settlement by the MRC were modified to allow for a longer notice than the 30-day cancellation

privilege on B and C quotas. Basic A quotas were not to be subject to cancellation before June 30, 1945, and the higher B and C premiums were adopted as a stimulus for greater production at the higher cost mines.

The danger of continuing the payment of subsidies on strategic metals beyond the war emergency was noted by President Truman when he signed the new bill. He gave notice that the whole subsidy program would be either reduced or discontinued as soon as needed war production had been secured under the existing price ceilings. High-cost marginal producers, in wartime, were given support in order to secure maximum output and at the same time hold prices to a relative stability. In gaining this result, government premiums amounted to less than metal costs in the First World War without subsidies. The success of the whole program encouraged some spokesmen for the mining industry to urge that subsidy payments be continued beyond the war emergency. Further use of these production aids after critical war needs have been met, however, would result in destroying regulatory controls over both prices and production. These are generally considered to be germane to a free economy. In normal times, there is no place for official controls; judgments of how much should be produced and at what prices for market determinations should depend on supply and demand.

Important bearing on national defense and domestic prosperity was indicated by the new tariff policy that was given Congressional approval on June 30, 1945. This favored imports on a considerable scale of various materials, particularly copper, lead, and zinc. Ceiling prices for domestic metals were higher than rates paid for metal imported from Canada, Mexico, and other countries. The new policy allowed imports to supplement the inadequate supply that was apparently available from domestic sources. Domestic supplies of marginal metals purchased in 1944 included almost 25 per cent of the copper, 50 per cent of the lead, and over 60 per cent of the zinc. In future, the Department of State proposed that imports of various ores approaching exhaustion from domestic sources would contribute an important factor to our export trade—required on a scale of upward of ten billion dollars a year, three times the rate in 1939.

The unanimous report submitted to Congress in May, 1945, by the Colmer Committee on Postwar Economic Policy recommended a program designed to stimulate prosperity through foreign trade. Plans were outlined for the creation of new markets and new wealth. Approval of the reciprocal trade agreements has been generally acknowledged as a move to break down those forces which, prior to 1939, led to economic warfare. Provision has now been made for lowering trade barriers to the approximate average

level of the Underwood tariff law, the production of goods feasible under the most favorable conditions regardless of national boundaries. Loans to such countries as Brazil, Mexico, China, and India would be required if their industry were to be developed through making use of minerals and other natural resources. Thereby it is hoped that the purchasing power of American goods will be increased to make better customers. In the 1920's, the United States had made foreign loans on a large scale but counteracted the resulting advantages by raising our own tariffs to the highest level in American history. When, after 1934, tariffs were reduced, the withholding of foreign loans made the expansion of foreign commerce difficult. Other countries retaliated with a confusion of trade restrictions. "Our record in the thirties," the committee reported, "can hardly be described as reflecting anything but a temporary and, in some respects, harmful expedient." It is proposed to secure an expanding economy in the United States on a world basis by further reducing tariffs and making loans to other countries for industrial advance. In the 12 years that trade agreements have been operating, our economy has suffered no substantial injury. Serious competition from such countries as Germany, Japan, China, or Russia is not anticipated before June, 1948, when the trade agreements expire.

"World order directed at ever expanding and ever more free markets" was stated as the central purpose of the economic peace envisioned by William L. Batt, vice-president of the WPB. The cartel system has been described by William L. Clayton, Assistant Secretary of State, as the economic counterpart of Nazi political philosophy. It must be replaced by a commercial program that will eliminate restrictive practices. Internal prosperity, in the postwar world, will be dependent on full participation in world economy. Direct benefits in gaining these ends have been stated as the main purpose of extending the trade agreements in order to reduce tariffs by as much as 50 per cent below the level of January, 1945, an over-all reduction of 75 per cent under the 1930 rates. This is expected to induce other nations to lower their trade barriers against American goods. The Committee for Economic Development advocated that the United States assume leadership in reducing artificial trade barriers among nations. An adequate protective device of management would be set up by an international committee representing producers, distributors, and the public, in the movement of such minerals as tin, chrome, and tungsten, along with other products, to world markets. Tariffs, quotas, restrictive exchange practices, subsidies, and restrictive business agreements all have been scored as conflicting with trade expansion and are not designed to achieve mutually higher standards of living.

International commodity agreements, under which are included produc-

tion and distribution of tin and copper, were studied in November, 1944, by experts of the commodities division of the Office of Economic Affairs, Department of State. As in all plans for postwar activity, the export of capital goods was again emphasized as a requirement for national prosperity. An important objective under the program endorsed by the Department of State was to secure from other countries tariff concessions favoring the export of surpluses from the United States. Problems involving international commerce and the broader questions pertaining to the needs of industry and trade were placed under the jurisdiction of the Executive Committee on Foreign Policy, representing six agencies; a lower committee representing seven agencies was given the responsibility for making preliminary recommendations.

Depletion of various domestic resources has left the United States more dependent than formerly on foreign supplies of minerals, in addition to other strategic materials. Although the United States, in 1944, secured greater mineral output than ever before, it is apparent that the level achieved in that year probably never again can be attained. In the future, foreign sources may be expected to gain greater importance in meeting industrial requirements as more remote areas come under exploitation. Plans being followed by the U.S. Department of State are designed to facilitate far-reaching developments in the postwar period by making available information on the natural resources and mineral economics of foreign countries.

World supply of various essential minerals may be expected to decline gradually, while domestic production limited to only a few years has been indicated for those alloying elements now in demand which occur in deposits of rich ore. However, the numerous alloying elements can be combined or interchanged, and it seems reasonable to expect the development of new alloys adequate for all requirements of the fabricators. Copper, lead, and zinc occurring in low-grade and submarginal deposits of almost unlimited extent, in the United States and elsewhere, will be available after the rich ore has been exhausted. It is proposed by Pehrson that no further need will be found for certain minerals by the time that we have exhausted all known deposits.

The discovery rate of recent years cannot be taken as a gauge of future expectancy, it was stated in March, 1946, by W. E. Wrather, director of the U.S. Geological Survey. He said: "I have enough faith in a bounteous nature to predict that in a land of such wide diversity and size as the United States we will eventually come to realize that great mineral resources still remain to be developed."

Certain fundamental steps required to overcome the "major deceptions of German industrialists" were reported by the Kilgore Committee to the Senate on July 10, 1945. One of the threats to a lasting peace continued

after VE-Day to be the complex network of world-wide German cartels and relationships to monopolies of other countries. The success of Allied bombing failed to destroy the German iron and steel industry, nitrogen production, and other elements of German industrial economy beyond the point where quick repairs could be made. Germany's power to make war and the Nazi science of aggression must be destroyed by removing all military power from German industry. It was recommended that reports be secured each year for the next 15 years on the progress of German disarmament. The same unity that resulted in German military defeat is required to make the world-security charter an effective tool in securing lasting peace.

Minerals necessary to warmaking must be withheld from any aggressor nation that threatens our security, in the opinion of Dr. C. K. Leith, WPB consultant on minerals. The need for equal access to the world's minerals by all peaceful nations is at the very heart of world peace. The responsibility of mapping broad policies concerning a world plan, including minerals and other commodities, formed a major concept for study at the Yalta conference in February, 1945, after the meetings held at Moscow, Teheran, and Cairo. An approach to the important field of international cooperation by the functional method was defined. It was proposed that such restrictive practices as cartels, trade barriers, and trade discriminations should be replaced by a liaison among financial, labor, and trade organizations. Former Secretary of State Hull's shrewd warning must be sounded through every conference hall where postwar plans are debated: "The free nations were brought to the brink of destruction by allowing themselves to be separated. If any lesson has ever been hammered home with blood and suffering, that one has been."

In two world wars, America's natural resources, as well as the blood of some of her finest manhood, were given generously to the support of freedom as opposed to regimentation. Inspired by the Atlantic Charter principle of "sovereign equality of peace-loving nations," the Inter-American Conference of War and Peace, at Mexico City in February, 1945, worked out a model arrangement in the Act of Chapultepec for regional security "consistent with the purposes and principles" of the world alliance that had been proposed in August, 1944, by the Dumbarton Oaks conference. Representatives of the 21 American republics were to convene later for the purpose of putting into permanent treaty form the regional peace machinery. Arrangements similar to those adopted at Mexico City for the Western Hemisphere have been suggested for Europe and Asia.

The world-reconstruction and -stabilization proposals of the Bretton Woods monetary agreement commit the United States to partnership in the management of world economic affairs, extending the functions of the Ex-

port-Import Bank, setting objectives for an international monetary fund and an international bank in expanding world trade, which was expected to be in operation by September, 1946. Stabilized currencies were considered to be indispensable in preventing economic warfare, encouraging investment in productive enterprise, and providing loans for reconstruction. The Bretton Woods proposal was closely related to the whole structure of postwar foreign trade, enabling "the peace-loving nations of the world to become self-supporting in a world of expanding freedom and rising standards of living." The Bretton Woods agreements were formally ratified in Washington on Dec. 27, 1945, by representatives of 28 nations, bringing into being the International Monetary Fund and Bank for Reconstruction and Development. The fund will have $8,800,000,000 in gold and currencies at the start; the bank will have initial subscriptions of $9,100,000,000. The seat of these two institutions, together with the United Nations Organization, is to be in the United States near New York City, as tentatively selected in February, 1946.

While plans were being considered for calling a meeting to consider reducing or eliminating restrictions from world trade and applying to economic relations the Dumbarton Oaks idea of political cooperation, the San Francisco conference was brought to a successful end on June 26, 1945. Relations among the nations were on the highest level to be attained since Yalta. This world-security charter followed the Dumbarton Oaks plan, based on a coalition of the United States, Britain, Russia, China, France, the so-called "middle powers" such as the Netherlands and Canada, and the 35 smaller nations. The Security Council of 11 nations forms the most important part of the organization, responsible for world peace and including the Atomic Energy and Military Staff Committees; the General Assembly forms the broad base as the "town meeting of the world," with each nation having an equal voice and appointing members of seven committees, including the Economic and Financial Committee directly concerned with mineral and strategic materials; the Economic and Social Council is to study international problems and promote higher living standards, full employment, educational cooperation, and "universal respect for, and observance of, human rights and fundamental freedoms for all."

Cordell Hull described the new charter as "one of the great milestones in man's upward climb toward a truly civilized existence." Chairman Tom Connally, of the Senate Foreign Relations Committee, described this as the "finest charter and plan of organization for peace and security that has ever been presented to the world." President Truman said "The most important thing is that all our thinking and all our actions be based on the realization that it is in fact only a first step" toward world peace. "The strong nations of

the world should lead the way to international justice . . . the foundation stone of the charter. For a good peace, a lasting peace, the decent peoples of the earth must remain determined to strike down the evil spirit which has hung over the world for the last decade."

The first real peace conference following VJ-Day opened in London on Sept. 11, 1945, when the council of foreign ministers, representing the Big Five, took steps to convert victory into peace. The council had been established by the Potsdam conference for the purpose of drawing up treaties of peace with Italy, Rumania, Bulgaria, Hungary, and Finland and preparing a peace settlement with Germany for action after a representative government was established in that country. The UNO and the Moscow agreement of the Big Three, in December, 1945, were described as the first two pillars of the peace structure. All United Nations are assured a voice in enforcing peace, including regulation of the atomic bomb and the control of Germany and Japan.

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ALUMINUM

(Refined and Reclaimed, Alumina, Alumina Hydrate)

Properties. The most abundant metal aluminum is one of the eight elements that account for about 98.5 per cent of the composition of the outer 10 miles of the earth's crust, of which aluminum represents 8.13 per cent. Although abundant in nature, aluminum is difficult to reduce to metallic form. It is one of the 16 metals used in substantial quantities in the pure state or serving as the base metal for alloys. (Al, atomic number, 13; atomic weight, 26.97; melting point, 660°C.; boiling point, 1800°C.; density, 2.7.)

The only metals lighter than aluminum are beryllium and magnesium. Other fundamental properties are malleability, resistance to corrosion, high electrical and thermal conductivity, silvery luster, and high power of reflecting light and radiant heat.

Aluminum is one of the most adaptable materials in alloying and heat-treating procedures. A basic problem of the fabricating industry has been to develop the required strength with a minimum reduction in its other desired properties. The metal can be readily colored, joined, forged, cast, extended, and spun. The hardness and strength are increased and certain fabricating qualities are improved when aluminum is alloyed with other materials, particularly copper, manganese, silicon, magnesium, and zinc. Aluminum alloys are divided into two main groups: wrought alloys and casting alloys.

Although aluminum has only 55 per cent of the tensile strength of copper, aluminum cable, owing to lighter weight, supports itself over a longer span than copper cable of similar cross section. Duralumin, containing only 4 per cent of copper, has a tensile strength of 52,000 lb. per sq. in. This compares with a tensile strength of 5,000 lb. for pure aluminum and 9,000 lb. for pure copper.

Aluminum was little known up to 1850 and became available only after important metallurgical discoveries made its extraction possible. The Hall-Héroult process was first commercially operated in 1888. By 1900, price reductions led to wide industrial applications.

Production involves two initial steps: (1) preparation of high-purity alumina (aluminum oxide) from bauxite and certain other materials, such as the hydrous aluminum silicates halloysite and kaolinite, by digestion with sulfuric acid and (2) reduction of alumina to metallic aluminum by electrolysis in a bath of molten cryolite and other salts. The combination lime-soda-

sinter process for recovering alumina from low-grade high-silicon bauxite restores the alumina and soda lost in the Bayer process by sintering the "red mud" with limestone and soda ash, leaching the sinter, and returning the liquors to the Bayer digesters. This process has made it possible to use bauxite containing up to 13 per cent of silica. To make 1 lb. of metal, 9 to 10 kw-hr. of electricity are required. A difference of 1 mill per kilowatt-hour makes a difference of 1 cent per pound in the cost of producing aluminum ingot.

Alumina is extracted from clay by the carbothermic process developed in Germany. Processes in the experimental stage in the United States for extracting alumina from clay and similar materials include the use of hydrogen chloride gas and hydrochloric acid.

Uses. Essential applications for war materials included the pure metal, wrought alloys and rolled products, castings, forgings, and extrusions. The large volume of aluminum-alloy sheet required by the aircraft industry allowed the adoption of high-production methods, including the use of large ingots and continuous-strip rolling. Recent developments in aluminum alloys of high-strength though of low ductility have played a considerable role in increasing the speed and efficiency of modern aircraft. Strength and other properties of alloys of the duralumin type containing copper and magnesium have been improved by new treatments. The Reynolds new aluminum alloy, R-301, is tough, corrosion resistant, and easily workable. It has been used as armor plate, reducing the B-29 bomber's dead weight by 5 tons. The average military aircraft is made up of 70 per cent of aluminum in the air frame and 25 per cent in the engine and propeller. Prefabrication of warplane parts takes place in the aluminum plant.

"Modified" aluminum-silicon alloys have a tensile strength increased by 5,000 to 10,000 lb. per sq. in., and elongation may be nearly double what it was before "modification." These alloys have physical properties superior to those of aluminum-zinc alloys or the 8 per cent copper alloy. Silicon alloys have been less used in the United States than in Europe. Another series of alloys, carrying 4 to 7 per cent of silicon and 0.3 to 0.5 per cent of magnesium with or without copper (up to 3 per cent), has been useful in the sand-casting industry, particularly when heat-treated. The low melting point of aluminum has permitted the use of a variety of casting processes that are not suitable for such metals as copper and iron. Heat-treated aluminum alloys containing 4 per cent of copper have been applied where additional strength and ductility have a value that justified the additional cost. Heat-treating has also been applied for certain aluminum-base castings containing magnesium or silicon or both.

The continuous casting process, under development for several years, has demonstrated its importance in turning out large ingots for sheet, plate, bar, rod, and parts forgings and extrusions. The new alloy, 75-S, with a tensile strength of plus 80,000 lb. per sq. in., has been developed and warrants application in forgings and other wrought forms to produce aluminum alloys in pits of the reduction plants, using virgin steel to bring these alloys to the proper analysis. Standard aluminum alloys include the following metals: bronze hardeners, silicon, copper, nickel, titanium, iron, and manganese. Advancement in the welding of aluminum has made possible the speeding up of production and the improvement of strength or life of built-up structures. Castings are unsuitable for many purposes where hammer-forged or wrought articles have been employed, as well as sheet produced by rolling mills.

Aluminum-foil clips played an important part in electronic war as an instrument of "counterradar" to defeat German radar detection. "Window" (aluminum foil) was an effective countermeasure that caused echoes, recorded by German radars, simulating an attack by large numbers of Allied bombers. The foil, produced in Canada, amounted to 20,000 tons. Two ounces of the jamming "paper" looked to enemy radar like an entire bomber. Preceding D-Day, window was released over Germany at the rate of more than 20 billion pieces a month. Although no planes were visible, the Germans thought that huge armadas were in the air. This was one of several effective counterradar measures (CRM) developed at the Harvard Radio Research Laboratory.

Portable landing mats, half the weight of steel, were made of aluminum for advance airfields. The Quartermaster Corps, in June, 1945, ordered 28,000 portable aluminum troop shelters for use in the Pacific. Many uses of aluminum for war needs include engine parts, powder, metal foils to protect supplies from shipping hazards, and various essential war materials not yet made public.

In 1937, applications connected with transportation absorbed 38 per cent of aluminum output; 16 per cent was used in making electrical conductors; 14 per cent for cooking utensils; and 9 per cent for iron and steel, building construction, food, beverages, and chemicals.

In 1944, primary and secondary aluminum consumed in the form of fabricated products (excluding imports) were distributed as follows: aircraft construction (headframes, landing gear, engines, propellers, fittings), 65 per cent; ship construction, tanks, ordnance, and other military uses, 25 per cent; civilian requirements, 10 per cent. The first 30 aluminum boxcars produced by the Reynolds Metals Company went into operation in December, 1944, representing a saving in weight of 5 tons for each car. Aluminum

hopper cars for carrying coal have the advantage of being immune to sulfur. Larger use of aluminum is being made in the manufacture of underground- and surface-mining equipment. A building board has been developed that consists of a sheet of wood sandwiched between two sheets of aluminum. Many household appliances have been proposed, including milk cans, baby carriages, stepladders, wheelbarrows, and clothespins.

The aluminum clothespin produced by Del E. Webb Products Company was manufactured by means of the Alumilite color process under Alcoa license. Annual consumption of aluminum for this product was estimated, in December, 1945, at 2,500,000 lb. New types of roofing sheet were expected to account for hundreds of millions of pounds. Of 1,100 railroad passenger cars under construction in December, 1945, 160 were being fabricated entirely of aluminum, and other cars would require from 1 to 5 tons each.

Mass production of aluminum window frames was started in January, 1946, by the General Bronze Corporation. Precision-built windows using this material were reported to be free of shrinkage and corrosion and do not require painting.

Aluminum sulfate is applied chiefly in purifying water, in dyeing, as a sizing in paper, and in tanning leathers. Aluminum chloride is used mainly in refining petroleum and also as a catalyzer in the manufacture of pharmaceuticals, drugs, dyes, and perfume. Activated alumina is being widely employed as a substitute for fuller's earth or bauxite in oil purification; it is also an efficient desiccator. Aluminum refractories were in strong demand in 1944, due to the great activity of metallurgical furnaces. Aluminum oxide and aluminum carbide are both excellent abrasives; carborundum (aluminum carbide) is one of the most extensively used artificial abrasives. The McIntyre Research Laboratory has sponsored aluminum therapy, which applied atomized aluminum powder in "mine hygiene" for the prevention of silicosis in Canadian mines. Aluminum paint is one of the most durable surface finishes, widely used in industrial plants.

Postwar competition may lead to a general trend to an era of light metals, although difficulties are recognized in finding future markets for today's production. Uses are expected to be in competition with copper; markets will demand reduced prices. Expanded application is expected in railroad equipment, where a potential market for 500,000 tons is estimated in the next few years; automobiles, trucks, and buses offer a potential market for 50,000 tons a year; and possibly ships for naval and merchant services will need a large quantity. All-aluminum ships of 7,780 and 10,280 tons were being designed in 1945, to be used by Alcoa in hauling bauxite from Surinam. Aluminum superstructure and massive smokestacks for passenger vessels were under

construction in December, 1945. Trucks and trailer bodies are to be fabricated from aluminum when man power is available. Aluminum building products for all types of houses and commerical and industrial structures were reported on Aug. 22, 1946, by the Reynolds Metals Company. Aluminum thread and cord having insulating and heat-diffusing qualities are suitable for synthetic rubber tires and can also be woven into cloth.

The Senate small-business committee held hearings, in March, 1945, to receive suggestions for creating some 60,000 new small enterprises in aluminum and magnesium after the war. Officials of the Reynolds Metals Company and the Aluminum Company of America told of enormous commercial opportunity for aluminum in new applications.

Scientific research upon which the light-metals industry is largely dependent has been carried on at the two major laboratories located at Banbury, England, and Kingston, Canada. At the latter, fundamental and applied metallurgical research is devoted to advancing aluminum technology. At Banbury, general technical investigation and fabricating research are the objectives.

Domestic Sources of Supply and Production. National ability to turn overnight from peacetime to war production of aluminum is ensured by a program announced by the Army and Navy early in 1945. The armed services specified (1) peacetime demand for aluminum sufficient to promote aggressive development in production and use, (2) a means of accelerating aluminum output with great rapidity if industrial mobilization on an all-out basis is ever again necessary.

The Controlled Materials Plan was undertaken, in April, 1945, for the purpose of dealing with the problem of completing war work. General Order M-21 gave the Period I Planning Board of the War Production Board sole control over aluminum in the transition period of about six months after VE-Day, providing that producers could sell metal only to those manufacturers who held allocation "tickets" issued for war or essential civilian uses.

Removal of all aluminum controls on June 14, 1945, was announced on June 12, where delivery of aluminum did not interfere with war production or priority consumer requirements, except for automobiles, trucks, refrigerators, stoves, and furnaces. This was expected to free 50,000 to 150,000 tons of aluminum metal (greater than prewar consumption) but left civilian-goods manufacturers faced with various other shortages, including skilled workers.

The WPB released aluminum mills on July 1, 1946, to deliver metal to nonpriority manufacturers of civilian goods. This relaxed allocation of

aluminum and certain other metals included under the CMP made it possible to resume peacetime production within a few months. Action by producers was to be dependent on retooling their plants and securing materials and labor. The CMP was to be terminated on Dec. 31, 1945, when it was planned to end rationing to authorized users. On July 1, relaxing the plan permitted delivery of aluminum and certain other metals after priority users had secured all supplies required.

Sheet aluminum was included with several materials important to the emergency-housing program and industrial reconversion over which inventory controls were tightened on June 14, 1946, by the Civilian Production Administration. The ruling was contained in an amendment to Priorities Regulation 32, limiting stocks to "a practicable minimum working inventory."

The Wall Street Journal reported on July 17, 1944, that stockpiles of refined aluminum amounted to 155,000 net tons, which increased to 250,000 tons on November, 1944, as stated by the WPB. Reserves were expected to be largely utilized in 1945, however, for expanded aircraft and other military output.

Government ownership of 55 per cent of the aluminum industry through the Defense Plant Corporation represented an investment that was variously reported at from $633,000,000 to $800,000,000; this included six aluminum plants, two rolling mills, and other facilities. In 1944, the DPC reported average production costs for pig metal ranging from 10.4 to 16 cents a pound. Alumina plants located in Arkansas, Louisiana, and Mississippi used low-grade high-silicon bauxite; operations were well below capacity in 1944. Two plants [Baton Rouge, La., and Hurricane Creek (Bauxite), Ark.], when operating at or near capacity, produced alumina at costs ranging from 1.68 cents in Louisiana to 2.48 cents in Arkansas.

Alcoa operates alumina plants under its own name at East St. Louis, Ill. (328,000-ton capacity), and at Mobile, Ala. (650,000 short tons). Of all alumina plants installed or under construction in 1944, the combined rated capacity was 2,390,000 tons a year. Facilities owned by Alcoa and Reynolds accounted for 1,078,000 tons, the balance being government owned, as reported by the U.S. Bureau of Mines.

Aluminum capacity of the Reynolds Metals Company, in 1944, amounted to 80,000 tons a year, including the 50,000-ton facilities at Listerhill and the balance at Longview, Wash. Alcoa owns and operates the plant at Alcoa, Tenn., with an annual volume rated at 180,000 tons; at Niagara Falls, N. Y. (20,000 tons); at Badin, N. C. (56,000); at Vancouver, Wash. (91,000); and at Massena, N. Y., where company-owned facilities are rated at 77,000 tons a

year and government-owned capacity is 54,000 tons. The Olin Corporation plant at Tacoma, Wash. had government-owned capacity for 20,000 tons a year. Projected annual aluminum-producing capacity of the United States in 1944, reported by the U.S. Bureau of Mines, amounted to 504,000 short tons in facilities owned by Alcoa and Reynolds and 668,000 tons government owned.

Techniques were provided in 1944 by the U.S. Bureau of Mines, enabling industry to reduce losses by recovering valuable constituents from aluminum drosses, powders, and dust. Postwar consumption of aluminum is estimated by the WPB at 500,000 tons a year compared with the 1940 rate of 206,300 tons. Within 5 years after the war, annual consumption is estimated by members of the faculty, University of Washington, at 750,000 tons, based on a price of 15 cents a pound for basic aluminum—1 million tons if the price is lowered to 10 cents.

Postwar costs per short ton of pig aluminum from selected plants, delivered in New York, are estimated as follows: Pacific Northwest, $236; Niagara Falls, $238; Massena, $240; Alcoa, $259; Torrance, $270; Listerhill, $278. Estimated costs per pound range from 10.63 cents in private plants in the Pacific Northwest to 12.63 cents at Torrance. Of postwar world-aluminum capacity, North America is expected to have about two-thirds, divided four or five to one between the United States and Canada. The producing center of the industry has now shifted from the East and Southeast to the Northwest, according to studies made at the University of Washington. Plants located in Arkansas, New Jersey, and Long Island, New York, are not expected to survive under postwar conditions.

Monthly output of primary aluminum reached a peak of 92,500 tons in 1943 when, of the ingot plants operating, nine were government owned and seven were built and operated by Alcoa and Reynolds. Total output in 1943, reported by U.S. Bureau of Mines, was 920,179 short tons valued at $265,380,000, 77 per cent higher than 1942 production of 521,106 tons; in 1941, output jumped to 309,067 from the 163,500 tons reported in 1939. Aluminum production increased 45 per cent in the period 1929–1939, according to the American Bureau of Metal Statistics. As late as 1940, Alcoa was sole domestic producer, but government ingot-producing plants built in the war emergency now have a combined capacity exceeding Alcoa by more than 50 per cent, and other producers have entered the ingot market.

Capacity in 1945 was 1,100,000 tons, of which 500,000 could be produced by privately owned plants while the balance was under government control, as estimated by I. W. Wilson, vice-president of Aluminum Company of America. Between 1939 and 1944, expansion of producing capacity by Alcoa

was made at a cost of more than $300,000,000, which surpassed the amount spent by any other corporation on behalf of the war effort, as stated by Mr. Wilson on May 21, 1945. Apparent domestic consumption of primary aluminum in 1944 was estimated at 635,000 tons; in 1943, 877,381. Production of virgin ingot, including that derived from imported bauxite, amounted to 776,400 tons valued at $222,416,000 in 1944, as reported by the American Bureau of Metal Statistics. Metallurgical production totaled 1,089,500 tons.

Demand for military uses in 1945 was expected to be about 50 per cent greater than in 1944; production for the first quarter of 1945 was estimated at 137,500 tons, about 50,000 tons below requirements. The deficiency was to be equalized through purchases of ingot from the Metals Reserve Company by Alcoa, and immediate requirements were to be met from the government stockpile of primary metal, which amounted to 267,000 tons at the end of 1944. A further increase in demand would lead to resuming production at several plants that in February, 1945, were either in partial operation or in stand-by condition. In January, the WPB canceled orders for delivery later than March, 1945, but announced, in June, 1945, that aluminum would continue in short supply for nonessential uses.

In March, 1945, Alcoa recommended to the Senate Special Committee that some government-owned aluminum plants be maintained as stand-by facilities until it is known to what extent military establishments would be needed in the postwar period. More information was required on postwar markets and on the status of the aluminum industry in Germany and Japan under terms of the peace treaty. An estimate of future markets cannot be made until sometime in 1947.

Dr. J. R. Mahoney, University of Utah, and Samuel Moment, Bonneville Power Administrator, were appointed in May, 1945, by the Surplus Property Board to prepare a report on the economic and marketing problems relating to government-owned aluminum and steel plants. The studies were to be used as a basis for plant disposal.

Stockpiling of aluminum was started in 1941 by the MRC. The metal ranked third in cost of deliveries ($198,796,696) in the entire stockpile program. Inventories were valued at $61,502,540 on Oct. 31, 1944. The government stockpile, Oct. 31, 1945, was reported by the Office of Metals Reserve at 192,570 tons of primary aluminum and 3,112 tons of secondary metal. Some of the aluminum stocks were stored in Canada. The aluminum supply was estimated by the Civilian Production Administration, on Nov. 30, 1945, to be adequate for the requirements of industry. The OPA on July 1, 1946, recommended to MRC that an additional 25,000 tons of aluminum ingots be withdrawn from government stocks for housing and other needs.

The shortage that developed before the end of 1942 was overcome in April, 1943, and a metal surplus began to be accumulated. Arrangements were made for a government stockpile of 125,000 tons of primary and 37,500 tons of secondary metal; the WPB designated aluminum on Mar. 1, 1944, as sufficient for war uses plus essential demands but stated in June, 1945, that a shortage had developed for all but essential uses.

In 1943, the number of government-owned pot lines increased to 38 with the completion of 24 new lines, of which 3, located on the west coast, were held in reserve. Curtailed operation began to take effect in 1943, and production was reduced by 6,000 tons a month at two plants, in New Jersey and in Long Island, New York.

Primary output in January, 1944, was 84,800 tons, dropping in July to 67,500 and in December to 45,000. In an attempt to bring virgin metal output more closely into line with reduced consumption, the last four pot lines were closed in June, 1944, at the aluminum-reduction works at Maspeth, N. Y. Early in August, the WPB announced that further increases in the surplus of ingot resulted in cutting total monthly output by 6,400 tons.

Ingot production also was terminated in August, 1944, at the Riverbank, Calif., and Burlington, N. J., plants, although processes were maintained. The Aluminum Company of America curtailed operations at Alcoa, Tenn.; Vancouver, Wash.; Badin, N. C.; Niagara Falls and Massena, N. Y., the last erected by the DPC at a reported cost of $20,000,000. At the three last plants, a 2,000-ton increase in monthly output of ingot was ordered by the WPB on Feb. 15, 1945, when 1,000 soldiers were furloughed in order to relieve labor shortage at Alcoa mills in Tennessee.

The WPB announced cutbacks of 15,000 tons on Aug. 29, 1944, at eight plants located in areas of acute labor shortage. Over-all cutbacks reported by the WPB on Dec. 27, 1944, aggregated about 54 per cent of total capacity for producing ingot and a 58 per cent reduction in aluminum output. Full operation throughout 1944 was continued at the plants of Reynolds Metals Company at Longview, Wash., and Listerhill, Ala., and at the government plant at Spokane, Wash., which was under the management of Olin Corporation. The last plant was ordered on Feb. 6, 1945, by the WPB to start the fifth and sixth pot lines in order to secure a 3,000-ton increase in monthly output of ingot. Olin announced in November, 1945, that no attempt would be made to buy or lease the DPC plant because of the large aluminum surplus.

Lease agreements of the Reconstruction Finance Corporation with Alcoa terminated on Oct. 31, 1945, affecting all eight aluminum-reduction plants and related facilities in the United States. Also affected were the alumina plants at Hurricane Creek, Ark., and Baton Rouge, La. The RFC took over

these government-owned plants on recommendation of the SPB for the purpose of disposing of them so as to create competition in the industry and provide additional sources of aluminum supply. Total annual capacity of these plants and the Tacoma plant, operated by Olin, was in excess of 591,000 tons of pig aluminum.

GOVERNMENT-OWNED PIG ALUMINUM PLANTS
(Operated by Aluminum Company of America*)

Location	Annual capacity, short tons	Government investment
Jones Mills, Ark	64,000	$29,300,000
Riverbank, Calif	48,000	11,600,000
Torrance (Los Angeles), Calif	80,000	24,000,000
Burlington, N. J	48,000	16,800,000
Maspeth, N. Y	123,000	32,600,000
Massena, N. Y	48,000	19,100,000
Troutdale, Ore	64,000	18,900,000
Spokane, Wash	96,000	22,300,000
Tacoma, Wash	20,750	6,200,000

* The Tacoma plant was operated by Olin Industries, Inc.

Alcoa built these plants without profit at a cost of nearly $250,000,000, with $50,000,000 provided in working capital by Alcoa for plant operation in addition to the government investment of $175,000,000. Alcoa reported supplying working capital for government-owned fabricating plants built at government cost. From these plants, Alcoa reported the production of more than 2 million tons of pig aluminum for war purposes. Alcoa also operated two alumina plants having annual capacity of 1,277,500 tons, for which the government investment amounted to $65,000,000.

Alcoa, controlled by the Mellon interests of Pittsburgh, has pioneered since 1888 the development of the aluminum industry in the United States and Canada. Holding patents that expired years ago, this company controlled the electrolytic process for the reduction of aluminum from bauxite. At the end of 1944, total assets were reported at $474,195,000; net income was $31,693,000 (in 1943, $40,256,000; in 1938, $15,563,000). Arthur V. Davis, chairman of Alcoa, stated on Dec. 3, 1945:

> We have yet to hear of any military authorities urging the break-up of Alcoa. . . . There is a school of thought in the United States which would break up its most efficient producer of aluminum under the cloak of national defense, while our statesmen and military leaders are breaking up the great aluminum companies of Germany and Japan in order to keep those nations reasonably weak.

Reynolds Metals Company secured 5-year leases, in December, 1945, from the RFC on the Jones Mills aluminum-reduction plant and the Hurricane Creek alumina plant at rentals of $6,000,000 to $12,000,000 for the period. No government subsidy of any kind was involved. The plant at Hurricane Creek, reported to be the world's largest and most modern, has an annual capacity of 777,000 tons of alumina. Jones Mills, 20 miles away, has a rated capacity of 36,000 tons a year of aluminum ingot. It was reported that Reynolds was negotiating for government-owned plants at Troutdale and Spokane. The War Assets Corporation on Mar. 1, 1946, announced the granting of a 5-year lease to Reynolds on the government-owned aluminum sheet mill at McCook, Ill. Annual rentals equivalent to 5 per cent of net sales ranged from a minimum of $750,000 in the first year to $2,482,312 in the fifth year, the latter representing 8 per cent of the depreciated reproduction cost of the plant ($31,028,000). New plants were to be built by Reynolds for turning out corrugated aluminum sheet, and new capacity added for reproducing aluminum foil and aluminum powder. Ingot capacity equal to about three-fourths of United States prewar output was represented by the Reynolds plants at Listerhill, Ala., and Longview, Wash. A five-year lease with an option to buy was granted on July 1, 1946, to Reynolds by WAC on the aluminum extrusion plant at Phoenix, Ariz. Operated in the war years by Alcoa, the plant was to be leased on annual payments of from $140,000 to $568,700. Annual capacity of the plant was stated to be 15,500 tons of extruded shapes and 7,800 tons of finished tubing.

Production of aluminum salts decreased 4 per cent to 600,913 tons in 1942, when shipments were 3 per cent less than in the previous year at 604,558 short tons. Production of alumina (activated, calcined, crude, light and heavy hydrate, converted to a calcined-alumina content) was 58,297 short tons in 1942; in 1941, 53,710. Only 14 per cent of the alumina was used by producers of aluminum salts, the remainder being employed in the manufacture of abrasives, refractories, petroleum products, spark plugs, glass, rubber, paints, and other materials.

The production of sodium aluminate started in 1943 at the California plant of Torrance Aluminum Products Company. Fine aluminum dross from reduction plants on the west coast was used as the aluminous raw material. In 1942, clay replaced bauxite as the aluminous raw material used by General Chemical Company at all of its aluminum chemicals plants. The alumina plant of Kalunite, Inc., Salt Lake City, expanded capacity in 1942 from 10,000 to 36,000 tons, using alunite from Marysvale, Utah, as a raw material. The acute shortage of alumina in 1942 and early 1943 led to placing alumina-plant construction under AA-1 priorities.

Consumption of both primary and secondary aluminum in 1942 increased 94 per cent over 1941. In 1943, the apparent domestic consumption of aluminum increased 49 per cent, and secondary aluminum consumption increased at an even greater rate. About 68 per cent of fabricated products went to aircraft plants, most of the remainder being used for ship construction, tank engines, ordnance, and other military uses. Of the limited civilian needs, only essential categories were filled, particularly tools and chemical equipment.

Sheet-aluminum inventories at aircraft plants were the lowest since 1942 on Jan. 16, 1945, when J. A. Krug, WPB chairman, announced that aluminum had been reclassified on the crucial list, curtailing civilian uses. In December, 1944, and January, 1945, aluminum-sheet production increased from 27,500 to 40,000 tons monthly, which was reported to be lower than requirements on Feb. 15, 1945. Man-power shortages were cited as the main factor. Sheet-aluminum output for the first quarter of 1945 was estimated at 110,000 tons, which was 25,000 tons below requirements.

Secondary output, remelted at the large fabricating plants and at more than fifty smelters, reached a peak in December, 1943, of 27,500 tons and for the full year totaled 265,800 tons. Recovery from secondary sources expanded to 30,500 tons for the month of April, 1944. Aluminum recovery from scrap in 1943 amounted to 313,961 tons valued at $90,546,352, compared with 198,492 tons valued at $57,446,076 in 1942, as reported by the U.S. Bureau of Mines.

Scrap was recovered from aircraft by a new method developed by Alcoa in cooperation with the Air Technical Service Command that employed caustic soda to dissolve aluminum and left other materials solid (such as steel nuts and bolts, copper fittings, and rubber). The end product was pure aluminum ready for reprocessing.

Scrap metal has accumulated too fast in this country to be absorbed into the aluminum industry. In Britain, the procedure has been to consume up to 38 per cent secondary metal in wrought fabrication, which is a much larger proportion to the output of primary metal than has been attempted in the United States. Dealers' stocks of aluminum scrap were reported by the U.S. Bureau of Mines at 54,655 tons on Jan. 1, 1945; on Feb. 28, at 53,396. Scrap included wrecked aircraft; sheet and clippings; machinings, borings, etc.; castings and other solids.

In August, 1945, semifabricated metal shipments were sharply reduced to 52,100 tons compared with 85,100 tons in July. Primary output of virgin aluminum metal amounted to 47,900 tons in July and 45,800 tons in August; secondary output was 20,750 tons in August.

The SPB on June 19, 1945, authorized the RFC to scrap-salvage all "commercially usable surplus aircraft." Secondary metal produced from this source was to be used for both wrought and cast products, and costs lower than alloys of virgin metal were expected to encourage broad application for such products as prefabricated houses, kitchenware, roofing, fencing, and many household articles. The RFC had sold 10,500 aircraft of various types, and the 25,000 on hand, except for 7,000 primary trainers, were classed as commercially unsalable. All aspects of aircraft salvage were under study by a special committee of the SPB. Consideration was to be given to converting motors, instruments, and other components to commercial use.

The Surplus Property Administration, through two orders issued on Dec. 18, 1945, by Administrator W. Stuart Symington, attempted to secure "wide and equitable distribution" of the government stocks of surplus aluminum. The sale of aluminum metal in any form to Aluminum Company of America was forbidden unless the sale was approved by Symington. Alcoa had been found by the courts, in 1940, to hold a monopoly of primary aluminum. This was Regulation 4 under SPA Regulation 9. Special Ruling No. 26 was based on the same court decision, and its objective was to ensure wide and equitable distribution of surplus aluminum metal and scrap. Two conditions were applied for disposal of aluminum by the RFC: (1) not to sell to Alcoa or subsidiaries any aluminum metal or scrap without written approval of the administrator, (2) not to sell more than 2,500 tons of aluminum scrap to any individual buyer in any one month without written approval of the administrator. The SPB announced upset prices on contract-termination aluminum scrap; where these prices were not reached at sales, the scrap was added to the government stockpile.

Estimates of future supplies of secondary aluminum available for disposal as surplus property were announced on Feb. 1, 1946, by the SPA. Information submitted by the aluminum smelters' industry advisory committee resulted in a "drastic downward revision" of estimates, with about 500 tons in sight compared with 1,250 tons on July 1, 1945.

The CMP, regulating distribution of aluminum, steel, and copper, was discontinued by the WPB on Sept. 30, 1945. The way was cleared for competition in the aluminum industry when Aluminum Company of America on Jan. 10, 1946, granted the government free use of aluminum-production patents, as announced by the Surplus Property Administrator. Alcoa's action was described as a "substantial step forward" by Chairman O'Mahony of the Senate small-business committee. This marked a beginning in the effort of the government to establish competition in the aluminum industry. This patent agreement affected aluminum production at Jones Mills, Spokane,

Tacoma, and Troutdale, which had been operated by Alcoa and Olin Industries (Tacoma). Alcoa's capacity was reduced from 80 per cent of the country's total to a little more than 60 per cent.

Kaiser-Frazer Corporation and Kaiser Cargo, Inc., became the third producer in the primary aluminum industry on Feb. 21, 1946, when the War Assets Corporation granted 5-year leases on the government-owned Trentwood and Mead plants at Spokane. This action was taken to "foster the development of new independent enterprises and promote competition in the aluminum industry in conformity with the objectives of the Surplus Property Act." The aluminum produced in these facilities was to be used principally in automobile manufacture. Lt. Gen. Edmund B. Gregory, chairman of the War Assets Administration, said that the disposal of these two plants was expected to promote the disposal of other aluminum plants, subject to the SPA. The Trentwood rolling mill cost $47,630,000; its annual capacity is 144,000 tons. The Mead reduction plant cost $22,270,000 and is rated at 109,392 tons a year from six pot lines. Terms of the lease on the Mead plant provided for annual payments from $208,000 in the first year to $1,248,000 in the fifth year; on the Trentwood plant, $250,000 to $2,667,000 or 5 per cent of gross sales, whichever is greater.

World Production, Imports and Exports. Canada, in second place in aluminum production, supplying 40 per cent of the aluminum used by the United Nations, reported an output in 1943 of 492,000 short tons, almost six times the 82,800 tons recorded in 1939. Total output in the 5 years ending Dec. 31, 1944, was 1,678,495 tons of ingot. Deliveries to the United States amounted to 685,000 tons up to July 2, 1945. Expansion of the Arvida works made possible the following recoveries: in 1940, 109,200 short tons; in 1941, 212,300; in 1942, 335,800; in the first 7 months of 1944, exports of refined aluminum amounted to 150,050 tons valued at $47,570,821, in the primary form of bars, blocks, ingots, sheets, and blooms. Total output in 1944 exceeded 500,000 tons. Ingot operations in the first half of 1945 were at the rate of 46 per cent of capacity as compared with 93 per cent in the first 6 months of 1944. Only 6 per cent of total output has been consumed in Canada, Britain receiving about 55 per cent and the United States 32 per cent. Low costs gave Canadian production a marked advantage over output in Britain, where about 50 per cent of Canadian metal may find a postwar market. Regarding postwar prospects for utilizing the tremendously expanded facilities, an Alcan official stated "We've got a bear by the tail."

Scheduled imports from Canada were reported by the WPB in September, 1944, to be sharply reduced for the remainder of the year, and delivery was indefinitely postponed for 125,000 tons under contract from the great metal-

lurgical works at Arvida, Quebec. The Aluminum Company of Canada stated that 2,500 men were laid off on Dec. 10, 1944, and 73.3 per cent of smelter capacity was closed down at the end of the year. A plant is established at Arvida for refining low-grade high-silicon ore.

In April, 1945, the Senate small-business committee investigated government contracts for Canadian ingot aluminum, by which the MRC was to receive 125,000 tons on and after July 1, 1945, at prices ranging from 13 to 15 cents a pound, depending on the purity of the metal. This contract was justified by Fred W. Vinson, when he was Federal Loan Administrator, on the grounds that the WPB had requested the action because man-power and fuel shortages had reduced domestic output below war needs. Of the 125,000 tons on order from Alcan since Mar. 28, a cutback of 12,500 tons was announced by the WPB on July 18, the balance to be shipped by Aug. 18, amounting to 37,500 tons. The last batch of the total 685,000-ton contract had been delivered to the United States on July 2, 1945, and "every dollar loaned to the company by the United States" had been repaid, an Alcan official stated. A payment in 1940 of $68,500,000 had been made by MRC as an advance against metal deliveries, but this was stated to have no connection with wartime expansion of power facilities on the Shipshaw River, near Arvida. Expansion of hydroelectric power has been financed through the sale, in 1940 and 1943, of $55,000,000 in preferred stock and bonds of Aluminum Company of Canada.

The 1,200,000-hp. Shipshaw project, largest localized power development in the world, was opened in November, 1942. Designed by Henry G. Acres, the Shipshaw development was, for a time, a war secret.

It was stated that production costs lower than those of Arvida were available at plants in the Pacific Northwest using government-produced power from Bonneville and Grand Coulee dams. Interior Secretary Ickes testified, on May 14, 1945, that the Canadian contract should be canceled or negotiated to termination. Early aluminum requirements had been "bungled" by the Office of Production Management and its successor, the WPB, whose policies promoted and strengthened the aluminum monopoly in both Canada and the United States. Mr. Ickes charged that government-built aluminum plants and power resources had been neglected to the advantage of Canadian-produced metal.

Alcoa vice-president in charge of operations, I. W. Wilson, stated on May 21, 1945, that Alcan was formed in 1929 as a subsidiary of Aluminium, Ltd., and "no director or officer of Alcoa has been also a director or officer or employee of Aluminium, Limited." Aluminium reported on Aug. 14, 1945, that deliveries against the more important war orders would soon be sub-

stantially completed. In 1945, the balance of indebtedness to the United States government had been liquidated, comprising $26,000,000 of notes and advance payments.

Direct control of aluminum in Canada was established in 1940; in 1943, the metal was placed under formal allocation, with bauxite and cryolite, and strict regulations were applied on movements of the metal and end uses. Restrictions on uses were relaxed in January, 1944, and the metal was made available for rivets, welding rod and wire, and powder and paste as a pigment in making paint.

The Alcan aluminum plant at Kingston, Ontario, fabricated essential equipment parts for atomic research at Chalk River. Of many uses for the materials, the following were included: protecting uranium from water corrosion, cooling uranium by the rapid transfer of heat from uranium to water, and protecting the water from reactions taking place in the metal.

The Board of Trade reported, on Dec. 28, 1945, that Britain's position, as far as raw materials were concerned, did not give rise to anxiety. Economy in the import of materials was required, particularly where these were of little aid to the export position. Aluminum was in adequate supply. It was announced that 50,000 new-type aluminum houses had been ordered from aircraft plants in Britain, in May, 1945, as a move to draw off much of the war-expanded output of the metal and give employment to large numbers of workers in the light-alloys industries.

Purchases of foreign aluminum amounted to 5 per cent of total foreign metal and mineral procurement from July 1, 1940, through Mar. 31, 1945, valued at $215,000,000 as reported in August by Leo T. Crowley, Foreign Economic Administrator. Agreement to purchase aluminum on uncompleted contracts, largely from Canada, as of Mar. 31, 1945, amounted to $72,000,000.

Prewar aluminum production was largely divided between Germany (28.6 per cent of world total) and the United States (22.5 per cent). Germany also led as a producer of potash and fluorspar and was the second world source of gypsum and steel. Nazi-controlled Europe was able to supply all normal requirements of aluminum. Postwar destruction of Germany's nonferrous smelting industry was reported in November, 1945. The entire capacity for manufacturing aluminum in Germany was to be destroyed, or the machinery removed to other countries as reparations. World aluminum capacity at the end of 1941 was 1,180,000 metric tons a year, of which Japan had 60,000 of the total of 601,000 metric tons controlled by the Axis countries, whereas the United Nations held a refining capacity of 578,000 metric tons.

World production in 1937 amounted to 550,000 tons distributed as follows: United States, 33.6 per cent; Germany, 15.9; Canada, 10.6; France, 9.5; Switzerland, 8.2; Norway, 8; Great Britain, 5.5; Italy, 3.1. The balance of 5.5 per cent was credited to several countries. World production of aluminum has been estimated by the U.S. Bureau of Mines as follows: in 1939, 720,700 metric tons; in 1940, 830,000; in 1941, 1,094,400; in 1942, 1,495,700; in 1943, 2,025,800. In Russia, nepheline is used as a substitute for bauxite in the aluminum industry.

In Brazil, near Ouro Preto, a plant has been built and equipped by United States firms, with a capacity of 10,000 tons of pure alumina and electric furnaces able to produce 2,000 tons of aluminum metal a year. Excess production of alumina is available for export.

The first aluminum plant to operate in Mexico, controlled by Reynolds Internacionale de Mexico, was announced in May, 1945, by Reynolds Metals Company. No ore being available in Mexico, ingot produced in the United States will be used in fabricating sheet and plate, later expanding to roll foil made of aluminum, lead, and tin, in addition to forgings, extrusions, rod, bar, cable, and powder and paste for paint. A plant site was purchased near Mexico City by Aluminium, Ltd. of Canada, which has been authorized also by the Mexican government to fabricate sheet, strip, foil, paste for the manufacture of aluminum paint, and other aluminum products. Operated by Aluminio Industrial Mexicana, S.A., the plant will be supplied with aluminum from Arvida.

Mineral production of Korea in 1943 included 12,000 metric tons of aluminum, as reported by Samuel H. Dolbear in July, 1945. In Russia, information is not available concerning plants established east of the Urals. It has been reported that the German occupation resulted in destruction of the Vokhav and Dnieper aluminum plants which had a combined capacity of 69,000 tons.

In Sweden, a 6,000-ton alumina plant was believed to be operating at capacity in 1943, using andalusite. Swedish aluminum capacity was increased to about 4,000 tons a year.

Prices. The price of 15 cents a pound delivered, for commercial and mill ingot, 99-plus per cent, was in effect from 1941 through Sept. 30, 1946; pig, minimum 99 per cent, 14 cents a pound. The average price in 1941 was 16.5 cents; in 1940, 18.69 cents, as reported by *E & M J Metal and Mineral Markets.* Prior to 1940, the price was 20 cents.

Duty on Canadian aluminum ingots imported into the United States is 3 cents a pound. On Nov. 1, 1943, Canadian aluminum sold to the MRC was reduced in price to 15 cents U.S. Canadian aluminum sold to Britain was

reduced from 16 to 15½ cents Canadian; Australian aluminum was reduced to 16½ cents Canadian.

In London, the Ministry of Supply announced on Apr. 10, 1946, that a price equal to 12 cents a pound had been established for virgin aluminum in ingots or notch bar form, a reduction from £85 to £67 a long ton delivered to the factory. The price in 1944 was £110. The 1946 reduction was made possible by a contract for the purchase in 1946–1947 of 215,000 metric tons from Canada.

Aluminum-scrap prices on Oct. 10, 1944, ranged from 6 cents a pound for segregated solids down to 1.25 cents a pound for wrecked aircraft. Material not sold at these minimum prices was to be turned over for storage by MRC. *E & M J Metal and Mineral Markets* on May 10, 1945, quoted prices on remelted aluminum ingot in lots of 30,000 lb. or more, delivered, as follows: High Grade, 97½ per cent, 12 cents a pound; Piston and No. 1 Alloy, 10 cents; Chemical Warfare, 92½ per cent, 9½ cents; Deoxidizing Grade 1, 10½ cents; Grade 2, 9¼ cents; Grade 3, 8¼ cents; Grade 4, 6¾ cents. Cast-aluminum scrap, pistons, and crankcases were quoted at 3 to 3½ cents a pound; duralumin clips and sheet aluminum, 3½ to 4 cents; aluminum clips, 4¾ to 5 cents; aluminum turnings, 1½ to 2½ cents. Price control on aluminum was removed Aug. 23, 1945, by the OPA. It was stated that aluminum kitchenware would be on sale before the end of the year at 1942 prices.

The metal duties under the tariff act of 1930 and the revenue bill effective June 21, 1932, as revised to Feb. 1, 1943, were as follows: aluminum alloys, crude and scrap, 3 cents a pound; plates, sheets, bars and rods, 6 cents; articles or wares, 8.5 cents a pound plus 40 per cent.

In 1942, prices of fabricated and semifabricated products were reduced substantially owing to mass production, manufacturing improvements, lowered operating costs, and continued research. Price Schedule No. 2, Aluminum Scrap and Secondary Ingot, first issued on Mar. 24, 1941, was the subject of 12 price actions taken in 1942, and a reissue of the schedule became effective on Feb. 17, 1942. This order, however, did not apply to sales of idle inventories to the MRC at the order of the WPB. Prices were set on additional grades of scrap and were reduced on all grades of obsolete scrap except pure cable. A maximum price was set for aluminum-bearing materials.

On Nov. 11, 1942, a premium of ½ cent a pound was announced by the OPA for baled or packaged scrap sales to primary producers and 1 cent a pound for briquetted scrap. The OPA announced, on Jan. 5, 1943, an established maximum base price of 15 cents a pound for secondary ingot, with lower prices for low-grade alloys.

A maximum price for pig aluminum was set by the OPA at 1 cent a pound

lower than the price for the corresponding grade of aluminum ingot on Mar. 31, 1943; on June 17, in order to assist in continuing the normal flow of scrap from dealers and producers to smelters, Maximum Price Regulation No. 2 reduced the maximum base price of secondary aluminum ingot by 1 cent a pound to the 14 cents level of pig aluminum.

A new classification, Wrecked Aircraft (Prepared), was established, prices being based on the quantity of aluminum recovered after melting rather than upon gross weight before melting. A new base price of 12½ cents a pound was set by the OPA on Dec. 18, 1943, a reduction from the previous 14 cents.

Aluminum mill products defined in Maximum Price Schedule No. 41 and both aluminum scrap and secondary aluminum ingot covered by Maximum Price Regulation No. 2 were suspended from price control by OPA on Nov. 15, to be effective Nov. 20, 1945. These rulings followed policies approved by the Office of Economic Stabilization to permit "decontrol of goods and services when supplies balance demand" or when items "are judged to have little effect on the cost of living, the cost of business, or production of other commodities."

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ANTIMONY ORE

Properties. One of the 19 industrial nonferrous metals used essentially as alloying constituents, antimony has the same structure as arsenic and bismuth. These three elements are chemically alike. The metal is bluish-white and exceedingly brittle; it has a low melting point, is easily reducible, can be powdered readily, and is fusible in ordinary cold-working operations. (Sb, atomic number, 51; atomic weight, 121.76; melting point, 630.5°C.; boiling point, 1440°C.) Its hardness is 3 to 3.5; its specific gravity, 6.7 to 6.86. Antimony is a crystalline metallic element having a tin-white color and metallic luster. Stibnite, the naturally occurring sulfide, is the most important ore of antimony; its hardness is 2; its specific gravity, 4.52 to 4.63.

Uses. Antimony is of greater military value than other strategic minerals except mercury. The trichloride is used as a bronzing solution for gun barrels and as a caustic in medicine; the double compound (antimony salts) is used in dyeing. Heavy war demand for oxide as a canvas-fireproofing spray, reported in February, 1945, was made by the Army; the oxide has been used extensively as an ingredient of noninflammable paint, particularly for naval and cargo ships. Standard military applications include detonating caps, shrapnel balls, and bullet cores. Antimony oxide and sulfide in the burning charge of shells produce a dense white "chemical" smoke on explosion.

Normally, about 75 per cent of production is employed in antimonial lead to give stiffness and harness to some types of lead alloy, including type metal and linings of brasses. Hard lead, containing 4 to 12 per cent of antimony, is of primary importance for storage-battery plates, electric-cable sheaths, lead pipes, sheet lead for lining sulfuric acid vats, and lead foil for collapsible tubes. During the war, a major application of antimonial lead was in the manufacture of storage batteries and for bearing metal, in which 3 to 20 per cent of antimony is combined with lead and tin.

White and red pigments are made of antimony trioxide and antimony trisulfide. The use of antimony sulfide has become essential for the dark pigment in camouflage paints, since it has the same infrared-reflectance characteristics as the surrounding green foliage. Medicine and the rubber industry make limited use of antimony.

An important substitute for antimony in hard lead battery grids has been found in calcium. It is reported that 100 parts of antimony in antimonial lead in storage-battery plates can be replaced by 1 to 4 parts of calcium. In

bearing metal, a satisfactory substitute for antimony has been found in cadmium. Peacetime uses of antimony normally depend on antimonial scrap for 40 to 45 per cent of the material, and it has been proposed to increase the percentage of metal recovered.

Domestic Sources of Supply and Production. Output from 31 operating antimony mines in 1942 more than doubled the 1941 production rate of 37 properties and established a new record. In 1943, the number of producing mines was reduced to 17, but production was almost double the tonnage of 1942. At El Segundo, Calif., Harshaw Chemical Company reported that a new antimony smelter and oxide plant would be completed in July, 1945. In the Coeur d'Alene district, Idaho, Sunshine Mining Company produced electrolytic antimony.

Production of antimony ore and concentrate in April, 1941, was 3,460 tons valued at $136,000, as reported by the U.S. Bureau of Mines. Domestic output in 1944 was 65,340 tons, of which 28,840 tons were added to reserves; in 1943, secondary output was 15,483 tons, valued at $4,929,787, and imports were 32,700. Secondary antimony recovered from lead- and tin-base scrap totaled 15,886 short tons, valued at $5,032,685 in 1944.

Lead smelters in the United States convert antimonial lead ores into metallic antimony. Two of these smelters produce metallic antimony from ores imported from Mexico. Antimonial lead at primary refineries, recovered from both domestic and foreign primary and secondary sources, was as follows: in 1944, 57,100 short tons; in 1943, 63,515; in 1942, 51,762; in 1941, 40,237, as reported by the U.S. Bureau of Mines.

The first commitment by the Metals Reserve Company in stockpiling antimony was made in 1943. Antimony ranked sixteenth among stockpile materials in cost of deliveries, and the MRC reported that its total cost, as of Oct. 31, 1944, was $10,360,119; the market value of inventories on that date was $5,181,800. The Office of Metals Reserve reported 10,312 short tons of antimony in the form of metal, ore, and oxide in the government stockpile, on Oct. 31, 1945; on June 1, 1946, 5,538 tons metal content or equivalent. Owing to the short supply of the metal, distribution control by the Civilian Production Administration was continuing, as reported on Nov. 30, 1945. The MRC extended the purchase period in Alaska to Dec. 31, 1944, which was also the date for terminating purchases at Battle Mountain, Nev., at four depots in California, and at Salida, Colo. In spite of ample reserves, a tight supply was reported in February, 1945; the WPB placed the metal back under allocation. The Combined Raw Materials Board reported a critical shortage in May, 1945, and replaced antimony on the reserve list.

Antimony and antimony oxide were included by the WPB in June, 1945,

with a list of materials and products, including nine other minerals and certain alloys, that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and further changes were anticipated. On Aug. 22, 1945, the WPB reported that antimony remained subject to special sales restrictions and to export special sales restrictions. Antimony, lead, tin, and uranium were the only strategic metals retained under government control for use and distribution after August, 1945.

The Antimony Advisory Committee of the WPB reported in December, 1943, that total supply for the year was 77,800 short tons, of which 36,090 would be available for reserve supply. *The Wall Street Journal* reported on July 17, 1944, that 18,363 net tons of antimony ore were in government stockpiles.

General Preference Order M-112 was applied by the WPB in coordinating antimony supply and demand. On Mar. 8, 1943, restrictions were relaxed in order to permit the use of antimony in battery plates and other approved alloys, as well as in the manufacture of white pigments, opacifiers, and frits for non-acid-resisting ceramic enamels. The maximum size of unallocated deliveries of antimony metal and alloys was raised from 25 to 2,240 lb. a month.

On Feb. 1, 1943, the Material Substitutions and Supply List of strategic minerals reclassified antimony from Group II to Group III. Effective on Jan. 1, 1944, the WPB removed antimony from allocation, under General Preference Order M-112. The WPB required consumers to file reports on their activities on a quarterly basis, rather than monthly.

Antimony was on the "free" list during all of 1944. Early in 1945, allocations were again imposed, and the CPA was continuing Order M-112 in effect at the end of 1945. Tight supply of primary antimony resulted from heavy war demands for antimony oxide for use in flame-retarding paints for the Navy and flameproof cotton duck for the Army. The OMR reported on Nov. 30, 1945, that stockpiled antimony would be turned over to private industry in order to help meet reconversion requirements as soon as supplies were demonstrated to be ample. The Reconstruction Finance Corporation was selling antimony from available reserves as directed by the CPA.

Domestic production of antimony, which is essentially a by-product, has been too small to affect national requirements, as reported by Elmer W. Pehrson, U.S. Bureau of Mines. Commercial reserves have an estimated life of 4 years compared with the annual rate of use, 1935–1939.

We have less than a 35-year peacetime commercial supply of antimony and twenty other minerals . . . which we shall have to import in larger and larger

quantities. . . . We cannot afford another prolonged war in 20 or 30 years. The prodigal harvest that we have reaped to win this war has bankrupted some of our most vital mineral resources. We no longer deserve to be listed with the British Empire and Russia as one of the "have" nations. We should be listed with the "have nots," such as Germany and Japan. Even more alarming than the fact that we are coming to the end of some of our known resources is the fact that we are uncovering few, if any, unknown deposits of minerals.

This is according to a statement by Harold L. Ickes, Secretary of the Interior, in December, 1945.

Although domestic production of primary antimony was stimulated by heavy war demand, operations are actually determined by demand for tungsten, which is the more valuable metal contained in the ore mined. The postwar outlook indicates that imports will continue to take care of domestic requirements. The antimony tariff favors imports of ore, rather than metal, from Mexico and Bolivia. The U.S. Bureau of Mines expects the demand for antimony in storage batteries and other metal products to result in consumption greater than prewar requirements. Expanded uses are seen for antimony oxide in the preparation of flameproof and mildewproof compounds for treating canvas and other textiles.

Antimony is one of the strategic and critical materials required for essential uses in a war emergency, for which stockpiling is deemed the only satisfactory means of ensuring an adequate supply for a future emergency. The stockpiling bill passed by Congress in July, 1946, created a development and conservation program to acquire and guard domestic reserves of antimony, as set up by the Army, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated the Procurement Division of the U.S. Treasury to buy reserve supplies of antimony and other strategic materials, aided by the OMR and other government agencies.

World Production, Imports and Exports. World production in 1937 amounted to 34,500 tons, distributed as follows: China, 14,700 tons; Bolivia, 3,900; Mexico, 9.8; Algeria and Czechoslovakia, each 900; Australia, 200; Italy, 500; United States, 1,100; other countries, 2,800.

In 1938, Bolivia supplied 27 per cent of the world output of antimony; China, 24.2 per cent. Other major producing countries were Mexico and Yugoslavia. China is the only world power having antimony in supplies adequate for export; the United States and Russia both have supplies inadequate to meet domestic demands. Other world powers depend almost entirely on foreign sources.

Until Japanese hostilities cut off much of the supply, China had been

responsible for about 70 per cent of world supply from deposits of antimony ore located in the provinces of Hunan and Kivantung. Important deposits are also located in Algeria. Since 1942, sources in Mexico, Bolivia, and Peru have come under development on an enlarged scale; and early in 1945, these countries were reported to have reserves adequate for postwar requirements independent of the major Chinese sources.

Antimony was one of the 25 minerals included in agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus from Latin America as part of the foreign procurement program initiated in 1940. All imported antimony was delivered at ceiling prices or less.

Canada, in 1944, produced 970 tons valued at $280,996; in 1943, 557; in 1942, 1,500. Canada recovers antimony as a by-product of ore from the Sullivan mine, treated at Trail, British Columbia. Early in April, 1945, F. M. Connell, Metals Controller, restored restrictions on the sale and purchase of antimonial lead containing 25 per cent or more of antimony. All who stocked antimony were to make monthly reports regarding consumption, receipts, shipments, and inventory. All metal controls on the use and distribution of antimony were removed on Aug. 28, 1945, by the Department of Munitions and Supply at Ottawa. Sales restrictions first had been applied in June, 1943.

Of world output in 1943, about 80 per cent was under Allied control, the Axis holding sources in Yugoslavia, Czechoslovakia, and part of China. Antimony is one of eight metals for which Europe is dependent on imports.

WORLD PRODUCTION OF ANTIMONY, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1940	1941	1942	1943
Canada	1,083	1,329	1,269	453
Mexico	11,286	10,241	10,759	12,587
United States	412	1,013	2,457	4,963
Bolivia (exports)	10,813	13,680	16,231	16,536
Peru	809	1,440	1,338	2,189
Czechoslovakia	1,104	1,645	3,130	
South Africa	126	420	689	1,045

National policy, in countries producing antimony, has been directed toward obtaining revenue from exports and securing reduced tariffs in the United States and other importing nations. Antimony smelters have been installed in the United States and other consuming nations so that they may benefit from lower export tariffs on crude ore. Mexican ore is treated in Texas

and California. North Africa ore is smelted in France. Belgium and Germany smelted prewar shipments from Bolivia, China, and other sources.

Consumption of antimony in Britain was reported by the Directorate of Nonferrous Metals, in December, 1945, at 4,772 tons in 1944; 3,897 tons in the first 9 months of 1945.

In Alaska, disposal of antimony and four other minerals was made at MRC stockpiles at depots located at Fairbanks, Anchorage, Seldovia, and Nome. Sales to private industry were announced by the Territorial Commissioner of Mines in June, 1945. The U.S. Geological Survey reported on May 7, 1945, that postwar expansion in the output of antimony could be secured through systematic development.

Bolivia has been supplying about 50 per cent of United States requirements since 1941, the annual average being 15,500 tons of concentrate (60 per cent of antimony). Production increased from 14,870 tons in 1941 to 17,642 tons in 1942. In spite of limited reserves and primitive, wasteful methods, Bolivia is expected to continue as an important producer. Limited amounts of concentrate are produced by Peru.

In recent years, Mexico has supplied about 40 per cent of United States requirements, chiefly from mines in northern San Luis Potosi. Ore is processed in the antimony smelter at Wadley near Catorce, on the National Railway. Production in 1941 totaled 10,241 metric tons, of which all but 438 tons were exported, chiefly in the form of ore.

The Foreign Economic Administration followed the policy of withdrawing from public purchase, in 1944, of foreign antimony when possible, returning the trade to former private channels if no impairment to the war effort resulted.

ANTIMONY IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Country	1940	1941	1942	1943
Argentina	31			
Belgium	7*	22†		
Bolivia	5,547	7,094	7,471	13,833
Burma	.....	18		
Chile	.....	.....	808	6
China	194*	7,115*		
Honduras	5	11	93	144
Mexico	9,545	11,664	12,405	12,673
Peru	598	581	343	2,131
United Kingdom	6*	.....	19	

* Antimony metal.

Prices. The price of domestic antimony ore was quoted, 1944 through Sept. 30, 1946, at 15.839 cents a pound for lots of 5 tons or more packed in 224-lb. cases, compared with 15.928 cents in 1943; in 1942, 15.559 cents; in 1940–1941, 14 cents ex store at New York. Other quotations by *E & M J Metal and Mineral Markets* were as follows: Laredo, Tex., in bulk, 14.5 cents; New York, 15.265 cents; China, 16.5 cents.

Antimony ore, 50 to 55 per cent, was quoted at $2.10 to $2.20 per unit of antimony contained; 58 to 60 per cent, $2.15 to $2.20; 60 to 65 per cent ore in Britain was quoted at 11*s.* per long ton unit on Aug. 10, 1944.

Metal duties under the tariff act of 1930 and the revenue bill effective on June 21, 1932, as corrected to Feb.1, 1943, embracing revisions resulting from all reciprocal trade agreements negotiated, set antimony ore as bound free; metal and regulus, 2 cents a pound; needle or liquated, ¼ cent a pound.

The Metals Control, London, maintained the price of crude antimony ore at £90 per ton; for English 99 per cent, £105, as reported on Sept. 1, 1945.

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APATITE

(Calcium Phosphate)

Properties. The mineral apatite varies widely in appearance, the crystals being colorless and transparent or white and opaque but usually green or brown in color. Its hardness is 5; its specific gravity, 3.2. In Canada, large apatite dikes occur in Laurentian limestone; in Norway, extensive deposits of chlorapatite occur in connection with gabbro.

Calcium phosphate is a salt of phosphoritic acid including various mineral substances that consist of salts of the acids of phosphorus. It occurs in large masses in Florida as the concretion known as caprolites and in certain islands of the Pacific. The acid salt is very soluble and constitutes, with calcium sulfate, the artificial manure "superphosphate of lime."

Apatite, the principal primary source of the element phosphorus, seldom forms a body large enough to have commercial value, although it is widely distributed as a minor mineral in igneous rocks. Commercial phosphate rock deposits are usually composed of animal remains and excreta. The value of a phosphate deposit is based on the phosphorus content, the material containing 20 to 23 per cent of P_2O_5 (tribasic phosphate 40 to 55 per cent). (P, atomic number, 15; atomic weight, 30.98; melting point, 44.2°C.) Phosphorus is one of the six nonmetallic or semimetallic elements used for alloying purposes.

Phosphate rock, the sole commercial source of phosphorus, occurs as a hard bed between sedimentary strata, as amorphous nodular pebbles in stream deposits, and as a residual deposit formed by the decomposition of phosphatic dolomite and other rocks containing phosphate. Phosphates are treated with sulfuric acid to produce phosphate or superphosphate for use as fertilizers. Triple superphosphate, ammonium phosphate, and other compounds are produced on an important scale.

Uses. A century ago, phosphatic materials were obtained largely from bones. The largest part of the phosphoric acid now required by agriculture is derived from phosphate rocks. War uses include the production of phosphine gases and smoke screens. The production of metallic phosphorus and ferrophosphates used in the making of steel has also been of strategic importance. Apatite is reported to have possibilities as an effective flux and

mineralizer with aluminosilicates and for ceramics. Apatite from Virginia is used in the preparation of refractories.

Many industries employ phosphorus as the element or as a component in a wide variety of salts and compounds. Various phosphates are used in the manufacture of ceramic ware, particularly as opacifying agents in glazes. Phosphate glass is being given intensive study in the light of modern chemistry, the chemical research director of Bausch & Lomb Optical Company reported in January, 1946. He predicted that glass containing little or no silica would be used on an increasing scale. Phosphate nonsilica glass has proved its value in the photographic field.

Other applications of phosphates include medicine, polishing powder, porcelain manufacture, and enameling. Elemental phosphorus, derived from phosphate rock, is used as a chlorinating agent in the production of sulfa drugs, vitamins, and other pharmaceuticals.

The manufacture of superphosphates required 70 per cent of the phosphate rock sold or produced in 1942. Phosphate rock includes several mineral phosphates employed as sources of fertilizer. Wider use is being made of finely ground phosphate rock for direct application to the soil. Greatly increased supplies are expected to be required for soil rehabilitation in the war-torn areas of Europe.

Domestic Sources of Supply and Production. Apatite-bearing titanium ore (nelsonite) is produced in open-cut mining at Piney River, Va., by Southern Mineral Products Corporation, subsidiary of Vanadium Corporation of America, for the recovery of apatite and ilmenite. Early in 1943, apatite was used in the production of monocalcium phosphate; after July, 1943, the apatite was used for making defluorinated phosphate. The Tennessee Valley Authority reported, in 1941, carrying on studies for improving several steps in large-scale processes for manufacturing calcium metaphosphate in the experimental fertilizer plant. In January, 1945, it was reported that a new TVA plant was nearing completion for producing defluorinated phosphate near Columbus, Tenn.

Elemental phosphorus, for the manufacture of war materials, was being produced in 1941 at Muscle Shoals, almost at capacity. In Peace Valley, Fla., the plant of International Minerals and Chemical Corporation was being supplied by the world's largest dragline excavator. In 1945, the same company was developing deposits at Garrison and Maxville, Powell County, Montana.

Three phosphate properties near Garrison are operated by Montana Phosphate Products Company, subsidiary of Consolidated Mining and Smelting Company of Canada. Since 1930, production has been secured from

a 3- to 4-ft. phosphate bed for shipment to Trail, British Columbia. There the phosphate is treated with sulfuric acid for conversion to phosphoric acid used for producing fertilizer. In the postwar period, the phosphate-rock industry of Florida, Tennessee, and Montana is expected to be extremely active.

Senate Bill 882, introduced in June, 1945, stated that Congress should hold phosphate in the public domain as a perpetual public trust, since "the Nation's soil resources have been depleted to an alarming degree." This bill would permit the TVA to build a phosphate fertilizer plant at Mobile, Ala., and acquire Florida phosphate lands with funds to be supplied by Congress. Two government plants would also be built in the Western states for making fertilizer with western phosphate.

Phosphate-rock deposits of Florida are of Tertiary age and extend in a belt 200 miles long and 20 miles wide along the west side of the state. Six classes of phosphates are recognized: hard rock, plate rock, land pebble, river pebble, soft phosphate, and phosphatic marl. The phosphate content ranges from 68 to 75 per cent. New production records were set in 1943 for the quantities of land pebble, soft rock, and total Florida phosphate rock sold or used.

International Minerals and Chemical Corporation reported in December, 1945, that a newly acquired phosphate-rock property near Bartow, Fla., was to be developed into the largest phosphate-mining operation in the United States. The operation will be highly mechanized for low-cost production. Reserves were reported to be adequate for a productive life of more than 25 years.

Demands of agriculture have stimulated a growing market for domestic phosphate rock since 1937. The peak demand was in 1920, stimulated by abnormally high prices. Consumption was nearly 50 per cent greater in 1941 than the average for 1935–1939.

In the west part of the central Tennessee basin, brown phosphate deposits have been formed as a residual product of the weathering and solution of Ordovician limestones. Tricalcium phosphate content varies up to 72 per cent in beds 6 to 10 ft. thick. Blue phosphate deposits are of Devonian and Mississippian age, similar to those occurring in Idaho, Montana, Utah, and Wyoming.

Commercial reserves of phosphate rock are shown in a preliminary estimate by Elmer W. Pehrson, U.S. Bureau of Mines, as adequate for more than 800 years, based on the annual rate of use and price, 1935–1939. More than 90 per cent of domestic reserves remained in 1944. Phosphate rock is one of eight major minerals that may be expected to last more than 100 years.

Production in 1941 was 4,689,652 long tons; in 1942, 4,644,240; in 1943, 5,126,232 tons valued at $18,962,021; in 1944, 5,500,000. The Florida phosphate-rock industry proposed to increase production, as reported on Mar. 8, 1946, by the Civilian Production Administration.

An investigation by the Federal Trade Commission disclosed that members of the Phosphate Export Association of New York had made agreements with groups of producers in French Africa, Curaçao, Egypt, and Great Britain. The agreements called for limited export quotas of nonmember producers as well as members in the United States. Member producers of the association were listed as American Agricultural Chemical Company, American Cyanamid Company, Coronet Phosphate Company, Phosphate Mining Company, Southern Phosphate Corporation, all of New York, and International Minerals and Chemicals Corporation and Swift & Co., both of Chicago. The members represent a major portion of the Florida land-pebble phosphate industry. The Florida Hard Rock Phosphate Export Association, Savannah, Ga., also investigated by the FTC, was found to be complying with recommendations. The Webb-Pomerene Export Trade Act required that such associations withdraw from cartel agreements, making clear to foreign traders that no arrangements that might involve restrictions on imports into the United States would be permitted and showing the determination of the United States to stamp out any apparent tendency toward cartelization.

The Phosphate Export Association, which was dissolved on Oct. 11, 1945, had entered into agreements with foreign producers. These agreements were found to be for the purpose of controlling sources of supply and deterring new producers and exporters from entering the business. The following practices were condemned by the FTC: (1) preventing the importation of phosphate rock into the United States from foreign sources, (2) restricting the right of members to withdraw from the association by requiring that their export trade continue to be handled by the association, (3) requiring members who dispose of mineral deposits to arrange for the successor to continue agreements with the Association, (4) restricting the licensing of patents to association members, and (5) restricting the use of the terminal at Fernandina, Fla., through an agreement with the Florida Hard Rock Phosphate Export Association.

World Production, Imports and Exports. Apatite imported by the United States, 1937–1941, was restricted to 2 tons valued at $5 (in 1938). Imports of apatite in 1942 amounted to 179 tons valued at $1,025; in 1943, 6,114 long tons valued at $61,890.

Small-scale production was reported for long-idle apatite mines in the Liévre River district of Quebec, Canada. Apatite produced in Buckingham

and Bowman townships, where it is recovered as a by-product of mica mining, amounted to 2,500 tons in 1941; in 1942, 930; in 1943, 1,451 tons valued at $18,385; in 1944, 482. All shipments were sold to the Electric Reduction Company, Buckingham, for the manufacture of elemental phosphorus and phosphorus compounds. In Frontenac County, Ontario, discovery of a large phosphate-rock deposit was reported in 1945.

No separate figures are issued for exports of phosphate rock and other phosphate materials (including bone ash, dust, and meal; animal carbon and fertilizer; basic slag, etc.; and sintered matrix). Of the 1938 output in the United States, 51.5 per cent was exported. Exports to Canada amount to about 300,000 tons a year, increasing in 1942 and 1943.

In 1938, the United States produced 26.1 per cent of world phosphate supplies, followed by U.S.S.R. with 13.8 per cent (in 1936). Next in importance as producers were Tunisia, French Morocco, and Germany. The United States and France (with colonies) have sufficient supplies for export; Britain and U.S.S.R. have supplies adequate to meet domestic requirements; Germany, Netherlands, and Japan have inadequate supplies to meet domestic demands; Belgium, Spain, Italy, and China are dependent almost entirely on foreign sources.

In Britain, the lean grade of phosphates has failed to meet competition with the product of North Africa. In Algeria and Tunisia, the hard, granular phosphate is of organic origin. The minimum average content of tricalcium phosphate is 58 per cent. In Morocco, the extensive deposits are soft and easily mined at prices lower than in Tunisia and Algeria. From the latter countries, shipments are made to France. The high-grade Moroccan product is shipped to other countries, and a prewar agreement had been entered into with American producers.

In U.S.S.R., the most important deposits are in the form of apatite, occurring in the Kola Peninsula. Apatite concentrates were shipped from prewar facilities at Murmansk to European markets in competition with North American phosphates. Production of apatite in 1941 was estimated at 2 million metric tons.

In the Pacific, Christmas, Makatea, and Angaur Islands and the Netherlands East Indies are important sources of high-grade phosphates. Nauru and Angaur Islands and other Japanese-held phosphate islands and the apatite workings near Laokay, French Indo-China, were bombed by the Allies in 1943 and 1944. Angaur, an island 30 miles square, has phosphate deposits estimated at 3 million tons. Japan, in 1939, secured from Angaur 25 per cent of the 1,500,000 tons of phosphates imported. Allied Headquarters in Tokyo on July 10, 1946, authorized the Japanese to return to Angaur to mine

phosphate rock and to make shipments at a daily rate of about 1,000 tons.

Imports of ammoniated superphosphates were higher in 1943 than in the previous two years. Imports of normal and concentrated superphosphates were lower in 1943. The U.S. Department of Agriculture announced on Aug. 4, 1946, that world production of phosphate rock was inadequate to meet demand by about 16 per cent; in the case of soluble phosphates, by 32 per cent.

Prices. Prices are not available for domestic apatite. In Canada, 80 per cent apatite sold at $16 per short ton; above or below 80 per cent, a penalty or premium of 20 cents per unit applied.

On Apr. 12, 1945, *E & M J Metal and Mineral Markets* quoted Florida land-pebble phosphate rock as follows: 77 to 76 per cent, $5.20 a long ton, f.o.b. mines; 75 to 74 per cent, $4.20; 72 to 70 per cent, $3.20; 70 to 68 per cent, $2.60; 68 to 66 per cent, $2.20.

The ceiling price of Florida and Tennessee brown-rock phosphate, in 1942 and 1943, ranged from $2 to $5 a long ton, bulk, f.o.b. mine, 66 to 77 per cent. Tennessee bone phosphate of lime, 66 to 72 per cent, was quoted at $4.30 to $5.50. Producers' ceilings were increased by the Office of Price Administration, effective June 19, 1946, 40 cents a ton for Florida pebble phosphate rock and 20 cents a ton for Tennessee brown phosphate rock. The producer's maximun prices of superphosphate were increased by OPA, on Aug. 23, 1946, an average of $1 a ton.

In Canada, phosphate rock of 75 per cent grade imported from the United States, laid down at east Canadian ports, was $14 to $19 per long ton in 1944.Phosphate rock and superphosphate for blending with other fertilizer ingredients both enter Canada duty free. Superphosphate imports from the United States are subject to a 5 per cent tariff, provided the United States imposes no restrictions on exports of either crude phosphate rock or superphosphate, in accordance with the United States-Canada trade agreement of 1938. Under the British preferential tariff, superphosphate imported for use as fertilizer is free of duty; under the intermediate tariff, 7½ per cent ad valorem; under the general tariff, 10 per cent.

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ARSENIC

(Crude, Trioxide, Speiss)

Properties. Arsenic is one of the 19 industrial nonferrous metals used essentially as alloying constituents. A grayish white, lustrous, brittle metallic element, arsenic has hardness of 3.5; its specific gravity is 5.63 to 5.78. (As, atomic number, 33; atomic weight, 74.91; melting point, 814°C.) Orpiment and stibnite are members of the same group (arsenic and antimony); they are soft and have low fusibility.

Realgar (arsenic monosulfide) and orpiment (arsenic trisulfide) are red to yellow in color; their hardness is 1.5 to 2; their specific gravity, 3.49 to 3.6. On long exposure, they disintegrate to powder. They occur commonly as minor constituents of certain ore veins associated with other arsenical minerals and stibnite. On exposure to light, realgar changes to orpiment and arsenolite.

"White arsenic," the poisonous oxide, is produced by the roasting of arsenical ores, usually as a by-product of copper, silver, gold, and tin. It is also recovered by sublimation from arsenopyrite (mispickel), which has hardness of 5.5 to 6 and specific gravity of 6.07. Loellingite, found with silver, gold, iron, and copper ores, is sometimes mined for arsenic. Its hardness is 5 to 5.5; its specific gravity, 7.4.

Uses. Shot metal is the chief alloy containing arsenic, up to 1 per cent being added to lead. Wartime uses increased in 1944, particularly in the glass industry and in insecticides (calcium arsenate and lead arsenate replacing pyrethrum and rotenone).

The most important metallurgical use of arsenic is in arsenical copper, where it increases the corrosion resistance, raises the annealing temperature, and perhaps serves as an oxidizer. In the making of automobile radiators and other manufactured objects that are assembled by soldering, arsenical copper containing 0.5 per cent or less of arsenic offers a higher annealing temperature; so no loss of strength results from heating during the soldering. Lead-base alloys containing up to 3 per cent of arsenic had war applications as substitutes for tin-base babbitt and solder.

Arsenious oxide, recovered as a by-product in certain smelters and in roasters at various gold mines, is employed in the manufacture of arsenic acid, pigments, wood preservatives, sheep dips, arsenical soaps, medicines, and the fixation of analine dyes and in printing cloth.

Uses in 1940 were apportioned in the United States as follows: insecticides, 68 per cent; weed killers, 19; opalescent and opal glass manufacture and enamels, 3; wood preservatives, 2; drugs and miscellaneous applications, 1. Consumption in 1940 declined 7 per cent, owing chiefly to the decrease in application of arsenicals as insecticides, including calcium arsenate, which is employed in destroying the cotton-boll weevil.

Of prewar production (about 45,000 tons a year), about 200 tons were used in metallic form.

Domestic Sources of Supply and Production. Maximum output was reached in 1944 in the United States, Mexico, and Canada. Domestic production of arsenious oxide in 1940 was increased 12 per cent as a result of diminishing competition from European sources of supply; in 1941, 32,481 short tons were reported valued at $1,119,320; in 1942, 28,681; in 1943, 31,202. Consumption established a new record in 1943, at 51,083 short tons; in 1942, 41,520; in 1940, 40,442.

Output from North America in 1926 amounted to about 16,000 tons compared with less than 12,000 tons produced in that year by Belgium, England, France, Germany, Greece, and Japan combined. The first commitment for the purchase of arsenic by the Metals Reserve Company was made in 1942. As of Oct. 31, 1944, the MRC reported that arsenic ranked twenty-ninth relative to the cost of deliveries to the government stockpile, amounting to $1,432,608. Inventories at that time were valued at $756,803.

In 1945, both Anaconda Copper and Rare Metals Products Company were marketing metallic arsenic and artificial red and yellow arsenic sulfide, which formerly had been imported from Europe. The Arsenical Insecticides Manufacturers Industry Committee of the War Production Board announced in September, 1944, that the over-all output of arsenic in 1945 was estimated at less than the 1944 total, as a result of curtailed production at certain mines. Any increase in postwar demand is expected to be supplied by imports from Sweden rather than by stimulating domestic output.

In the last 4 months of 1943, several thousand tons of arsenopyrite ore averaging about 23 per cent of arsenic were shipped to Midvale, Utah, from the United States mine at Gold Hill, Utah. This was the first production reported since 1925, when ore was mined in this country primarily for the arsenic content. Output to the end of 1943 was 114,510 short tons (1939–1943) of crude white arsenic, for which marketing arrangements were made with the MRC.

The MRC arranged, in June, 1943, with American Smelting & Refining Company for production of 10,000 tons of crude arsenic from flue dust supplied by Getchell Mine, Inc., Red House, Nev., and 1,568 tons from speiss

furnished by Richmond Eureka Mining Company, Eureka, Nev. A new recovery plant of Jardine Mining Company was to produce 5,000 tons of refined arsenic in 1944–1945. Ferro Enamel Supply Company, as MRC agent, contracted to deliver to E. I. du Pont de Nemours & Co., Inc., 4,125 tons of calcium arsenate to be derived from treatment of cobalt-nickel speiss imported from Burma before the Japanese invasion.

The WPB placed arsenic under allocation control on May 22, 19i42. Early in 1944, military contracts were canceled. Arsenic (As_2O_3) amounting to 4,225 short tons was held in government stocks by the Reconstructon Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration.

World Production, Imports and Exports. World arsenic production in 1936 amounted to 55,700 tons, distributed as follows: Sweden, 23,312 metric tons; France, 9,750; Mexico, 8,527; Australia, 3,650; Japan, 2,629; Germany (exports), 2,739. Belgium and Luxemburg exported a combined total of 2,731 tons.

Mexico, in 1941, produced 14,128 metric tons in refined, semirefined, and concentrate form. All but 236 tons was exported. Arsenic was one of 17 minerals included in the agreements negotiated by the MRC between Mexico and the Federal Loan Agency for purchase of the entire exportable surplus, as part of the foreign procurement program that was initiated late in 1940.

Sweden, the leading producing country, secures an excess of arsenic from gold ore of the Boliden mine. Part of the surplus has, formerly, been mixed with cement in large concrete blocks for disposal in the Atlantic at some distance from the shore.

Canada produced 7,484 tons in 1942; in 1943, 1,577 tons valued at $170,-360, mainly as a by-product of gold in Quebec and Ontario. In Brazil, the main source has long been the famous St. John del Rey mine in Minas Gerais, as a by-product of gold. Korea produced 250 tons of white arsenic in 1934, as reported by Samuel H. Dolbear. No record is available of subsequent output that was obtainable by Japan.

Prices. The New York price of white arsenic (arsenious oxide), Apr. 1, 1946, was 4 cents a pound, delivered, carload lots, in barrels; Sept. 30, 1946, 5 cents. This compared with the 1940 quotation of 3 to 3½ cents a pound, as reported by *E & M J Metal and Mineral Markets.*

The base price of lead arsenate, 11 to 11½ cents a pound in carlots, was set by the Office of Price Administration on Feb. 8, 1943. The base ceiling price of other insecticides was set by an amendment on Apr. 6, 1943, as fol-

lows: calcium arsenate, 7 to 7½ cents a pound, carload lots; Paris green, 20 to 25 cents; London purple, 7 to 8 cents.

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ASBESTOS

(African and Canadian)

Properties. The minerals having a crystalline fibrous structure recognized as asbestos are serpentine (or chrysotile, a hydrous-magnesium silicate) and the amphiboles (tremolite, actinolite, amosite, crocidolite, and anthophyllite), the latter being a silicate of lime and magnesia. The largest part of world output is from chrysotile, which is easily spun. It is highest in percentage of water of crystalization and lower in heat-resisting qualities than other varieties except crocidolite, which has a higher tensile strength. Of the world supply, about 90 per cent is derived from deposits of serpentine in dunite and peridotite, the three common forms being cross fiber, slip fiber, and mass fiber. Asbestos has excellent binding properties, low moisture absorption, and resistance to moderately high temperatures.

Paligorskite (mountain leather) has been described as a possible asbestos substitute. Crocidolite (blue asbestos) is lower than chrysotile in heat resistance and spinnability. Amosite fibers are harsher than chrysotile but not so good as an insulating material. Anthophyllite, fibrous tremolite, and fibrous actinolite have only limited uses. All three are marketed as amphibole asbestos. They have harsher and weaker fibers than those of chrysotile.

Uses. Military construction required large quantities of asbestos products; aircraft, tanks, army trucks, jeeps, mobile artillery, and other military equipment have needed large tonnages of asbestos. Chiefly of value for its spinning, insulating, and fireproof properties, asbestos is used for brake bands and clutch facings and for insulating electric conductors; its short fibers mixed with cement are used for building products (asbestos-cement shingles, siding, roofing, tile, and wallboard), various heat-insulation and fireproof materials, boiler lagging, pipe covering, gaskets, packing, and chemical filters. Woven asbestos belts convey cement clinker and other hot products. Large quantities of spinning fiber are used in the manufacture of gaskets consisting of asbestos cloth covered with rubber cement. Yarns impregnated with graphite and grease are used for steam and pipe packings.

Welding-rod coatings and heat-insulation material employ anthophyllite asbestos and actinolite. Blue asbestos is being obtained in small quantities of high-grade fiber. Glass wool has been developed as a substitute for some

grades of asbestos. The superior flexibility of asbestos and the high tensile strength of glass fiber have been combined in a glass-asbestos textile.

Many industries use asbestos for hundreds of minor purposes. It has no substitute for fireproofing and for various electrical and industrial applications. Stronger grades of anthophyllite are used for making acid filters, stoppings in combustion tubes, fireproof supports and protectors, and other chemical-laboratory equipment. The amphibole fibers have a higher resistance to acids than has chrysotile, the long harsh fibers being well adapted for use as an acid filter.

Military uses require three types of asbestos: chrysotile, amosite, and blue. More important uses of long fibers are in Navy cable, friction materials, packings and gaskets, cloth for the Maritime Commission and the Navy, laminated plastics, and aircraft tape. Navy cable construction, where electrical insulation is important, requires the low-iron Rhodesian fibers. Important military uses of amosite include woven insulation for shipwork, fireproof marine insulating board, and sprayed-asbestos insulation. Amosite has been recommended as a low-cost substitute for kapok in life jackets. Postwar uses of asbestos are expected to be close to the prewar level. Certain substitutes, originated under war conditions, may continue in use. Many new asbestos products, developed in recent years, include asbestos-cement materials and asbestos fabrics reinforced with glass fiber. Asbestos in combination with plastics was reported to have promising postwar applications. Asbestos paper as thin as cigarette paper has been announced as a new product.

Domestic Sources of Supply and Production. Asbestos was the third largest nonmetallic import (11 per cent of 1944 imported nonmetallics) rated as a war-essential mineral. The United States produces only 4 to 8 per cent of total requirements and less than 1 per cent of the needs for the essential long-fiber grades. In 1944, the discovery was reported of a large quantity of 6- to 12-in. slip-fiber chrysotile near Eden, Vt., where very short fibers were previously produced. Discoveries in Alaska were reported of slip-fiber chrysotile and tremolite asbestos.

Several states have a small output, the chief center of domestic production being the extensive deposits of slip fiber near Hyde Park, Vt. Domestic output increased 30 per cent in 1940 over the previous year and established a record of 20,060 short tons; in 1941, 24,391 tons valued at $725,753; in 1942, 15,317; in 1943, 3,945. Chrysotile asbestos is produced in limited quantity in Arizona and California. Oregon yields small tonnages of tremolite asbestos. Amphibole asbestos is produced in North Carolina and Georgia.

Domestic supplies were insufficient for requirements throughout the war

period; domestic production is estimated at a 3-year supply based on the annual rate of use 1935–1939, as reported by Elmer W. Pehrson, U.S. Bureau of Mines.

"We have less than a 35-year commercial supply of asbestos and twenty other minerals . . . which we shall have to import in larger and larger quantities," stated Harold L. Ickes, Secretary of the Interior, in December, 1945. "We cannot afford another prolonged war in 20 or 30 years. The prodigal harvest that we have reaped to win this war has bankrupted some of our most vital mineral resources."

Imports were accumulated in government stockpiles to the extent of 20,996 tons, as reported on July 17, 1944, by *The Wall Street Journal.* The first commitment of the Metals Reserve Company in stockpiling asbestos was made in 1941. As of Oct. 31, 1944, asbestos ranked eighteenth among materials purchased by the MRC, at a total cost of $8,389,332; on the same date, stockpiles had an inventory value of $2,780,951. On Oct. 31, 1945, government stocks of asbestos held in the United States and Canada by the Reconstruction Finance Corporation through the Office of Metals Reserve, were as follows (in short tons): C & G 1, 64; C & G 2, 716; C & G 3, 6,809; C & G 4, 5,499; Bl, etc., 1,411; Ml, 3,015; miscellaneous, 736.

Order M-283 was established to control and allocate supplies of asbestos textiles. Blue asbestos was tight early in 1943; but before the end of the year, adequate supplies were available.

Certain restrictions were placed on Canadian spinning fibers by Conservation Order M-72, as amended Oct. 1, 1943. This order also restricted the end uses of Rhodesian C & G 1 and C & G 2 and amosite grades B-1, B-3 or D-3 and 3/DM-1. It was stipulated that 1 ton of Rhodesian C & G 3 be used with every 5 tons of Canadian grade 3 R in textile manufacture, although Rhodesian C & G 3 had been classed as a shingle fiber unsuited for textile use. A threatened shortage of spinning fibers did not develop, owing in part to the large quantity of lower grade fiber employed.

In 1943 and 1944, the MRC purchased the entire supply of critical grades imported from South Africa and Rhodesia. Allocations were made to fill more urgent needs. The available supply of critical grades was distributed by Combined Raw Materials Board between the United States and England.

On Sept. 16, 1945, the War Production Board announced revisions of the new general inventory control regulation, lifting all inventory restrictions from asbestos building materials, friction materials, and textiles. The responsibility for maintaining asbestos supplies in balance with war demands was shared by the WPB and the CRMB. Asbestos-producing and asbestos-manufacturing industries cooperated efficiently with government agencies.

Asbestos is one of the strategic and critical materials required for essential war uses and for which stockpiling is deemed the only satisfactory means of ensuring an adequate supply for a future emergency. The stockpile bill passed by Congress in July, 1946, created a development and conservation program to acquire and guard domestic reserves of asbestos, as set up by the War, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated the Procurement Division of the U.S. Treasury to buy reserve supplies of asbestos and other strategic materials, aided by the OMR and other government agencies.

World Production, Imports and Exports. World production in 1939 was distributed as follows: Canada, 330,642 tons; U.S.S.R. (1938), 86,000; Southern Rhodesia, 52,900; South Africa, 52,900; United States 14,025; Cyprus (exports), 9,970; Swaziland, 7,233; Japan (approximate), 1,000.

In 1938, Canada produced 57.2 per cent of the world supply of long-fiber asbestos; U.S.S.R. ranked second with an estimated 18.7 per cent. Minor amounts were produced in Southern Rhodesia, South Africa, and the United States. The British Empire and Russia are the only world powers self-sufficient in asbestos.

The first asbestos fiber used commercially came from Italy in 1871; at present, the chief sources are Quebec, Canada; Rhodesia; South Africa; Ural Mountains, U.S.S.R. Western Australia now produces blue asbestos (crocidolite), which formerly came only from South Africa. Low-iron chrysotile asbestos is produced chiefly in Rhodesia. Increases in African output in recent years have competed on a basis of both quality and price with Canadian fibers, the latter supplying the United States for many years with requirements of both long and short fibers. Europe depends on imports for asbestos and mica and eight of the metals.

Amosite, crocidolite (blue asbestos), and spinning fibers (chrysotile) were imported in the war years because of industrial necessity. Longer and more essential grades were, in 1940, supplied to the extent of less than 8 per cent from domestic sources, which were limited to shorter grades.

Canada, in first place among asbestos-producing countries, in the war period achieved maximum output of 433,492 metric tons in 1941 compared with production in other war years as follows: in 1939, 330,642 metric tons; in 1940, 313,504; in 1942, 398,669; in 1943, 476,196 ($23,169,505); in 1944, 419,265 short tons valued at $20,619,516. In the first 9 months of 1945, Canada produced 357,863 tons. Over-all production of asbestos in Canada, Sept. 1, 1939, through Sept. 1, 1945, amounted to 2,590,100 short tons valued at $124,409,500. In 1944, Canada exported 1,541 tons of crude

asbestos; milled fibers, 181,668 tons; asbestos waste, refuse or shorts, 212,728 tons; asbestos roofing and other asbestos manufactures valued at $184,189. Exports are chiefly to the United States; minor shipments are made to Britain and Australia. Canadian production has been continuous since 1878 from the Thetford Mines area.

In peacetime, Canada and Africa are the principal sources; U.S.S.R., once a large producer, now uses its own output for domestic processing. In Venezuela, deposits of chrysotile in the Caracas serpentine belt have been under development since 1943. Chrysotile asbestos was first produced in Swaziland, at the Havelock mines, in 1939. Production in 1940 was about 18,000 tons.

All imported asbestos is delivered at ceiling prices or less. In 1944, the Foreign Economic Administration followed the policy of withdrawing from public purchase of asbestos when possible, returning the trade to former private channels if no impairment to the war effort resulted.

In Alaska, asbestos has not been brought into widespread commercial production, as reported on May 7, 1945, by the U.S. Geological Survey, but favorable possibilities have been indicated for important advances in the postwar period. The U.S. Bureau of Mines has proposed the development of a deposit of paligorskite for use in soundproofing, insulating, and shock-absorbing and in other products.

Prices. The price in United States funds of Canadian asbestos, f.o.b. Quebec mines, on Sept. 30, 1946, was $165 to $750 a ton for crude No. 1 and No. 2 and sundry grades; spinning fibers, $124 to $233; magnesia and compressed sheet fibers, $124 to $146.50; shingle stock, $26.50 to $85; paper stock, $44 to $49.50; cement stock, $28.50 to $33; floats and shorts, $14.50 to $26.50. The export of asbestos from Canada was under government control from Sept. 20, 1939, to 1945. The Quebec Asbestos Producers Association in 1942 adopted minor modifications in the classification of standard grades of Canadian asbestos.

Vermont asbestos was quoted by *E & M J Metal and Mineral Markets* on Sept. 30, 1946, f.o.b. Hyde Park, at $62.50 to $65 a ton for shingle stock; paper-stock fiber, waste and shorts, $14.50 to $53; floats, $19.50.

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BARITE AND LITHOPONE

Properties. Barite (barium sulfate), most abundant of the naturally occurring barium compounds, is a heavy, white, crystalline mineral, also called barytes and heavy spar. Its hardness is 2.5; its specific gravity, 4.3 to 4.6 (one of the heaviest of the nonmetallic minerals). Barite contains 65.7 per cent of barium oxide; lithopone is composed of 70 per cent of barium sulfate and 30 percent of zinc sulfide. (Ba, atomic number, 56; atomic weight, 137.36; melting point, 850°C.)

Witherite (natural barium carbonate), the only other important mineral of barium produced commercially, is white, gray, or yellow in color. Its hardness is 3 to 4; its specific gravity, 4.29 to 4.35. It is found in vein formations but is of rarer occurrence than barite. Barium, one of the most active metals, is an element having a specific gravity of 3.78.

Uses. Witherite is employed as a carbon carrier in the case-hardening of steels and in preventing efflorescence in structural bricks and as the raw material for the manufacture of various barium compounds. Barite is the raw material for the manufacture of various barium chemicals. Chemicals derived from either barite or witherite were used for many war and essential civilian purposes. Important military uses of barium carbonate and barium nitrate were in making shell primers, incendiary bombs, tracers, and green signal flares. The use of barium nitrate increased in 1944 in producing incendiary bombs used against Japan.

Important barium chemicals include synthetic carbonate and sulfate, chloride, dioxide, oxide, nitrate, hydroxide, and peroxide, the last being employed in the ceramic industry. The nitrate is used in green flares and explosives; the oxide in case-hardening steels; the peroxide in making hydrogen peroxide. Most important of the barium chemicals are the sulfate, nitrate, and carbonate. The carbonate and chloride are required for heat-treating metal parts, as a flux in producing magnesium alloys, and as an extender in titanium pigments. Both the chloride and the hydroxide are used in the purification of beet sugar.

Barium metal is used to a limited extent in special alloys. Milligrams of barium help to give radio tubes their present long life. Barium and strontium, alkaline-earth metals, are alloyed with aluminum and magnesium for use as "getters" in tubes for radios and other electronic devices. Several thousand pounds a year of barium metal are produced from barium oxide by Kemet

Laboratories Company, Inc., and King Laboratories, Inc. "Frary" metal (barium-lead-calcium alloy) is used for bearings. Nickel coated with barium oxide is a substitute for tungsten in cathodes for smaller types of electron tubes. Nickel-barium alloys are used for corrosion-resistant electrodes in spark plugs.

Ground barite, important in the chemical and processing industries, is applied as a heavy inert filler in many products, such as paints, rubber, paper, linoleum and oilcloth, asbestos products, plastics, and resins. It adds weight and volume to paper, textiles, and leather. It is used as a pigment (precipitated barium sulfate, or "permanent white") in paint, as a coating for photographic papers used by the armed services, and as an extender. Added to bentonite, barite is a heavy medium in mud used in oil-well drilling, which is the largest consumer of ground and crushed barite, followed by the glass and paint industries. Ground barite is used in the ceramic industry for glazing and enameling purposes. Barite is used as a batch-fluxing ingredient for molded flint glass.

Lithopone and barium chemicals accounted for about one-third of the domestic uses of barite in 1944. Lithopone is employed mainly as a white pigment in paint, enamel, and lacquer and also as a filler in floor coverings, textiles, rubber, and other products. Lithopone was an important war substitute for the more opaque titanium, zinc, and lead pigments. Of imported and domestic barite in the period 1930–1934, the production of lithopone used 58 per cent; crushed and ground barite used 19 per cent, the balance going into the manufacture of barium chemicals. More than 60 per cent of barite in 1938–1939 was used in the crushed and ground form.

Domestic Sources of Supply and Production. Domestic output of witherite comes only from California, chiefly from residual deposits of clays derived from the weathering of Cambrian and Ordovician dolomites. The U.S. Bureau of Mines reported several million tons of commercial barite available in 1944, in the extensive deposits near Magnet Cove, Ark. In Tennessee, the recovery of fluorite from Sweetwater barite is projected.

Primary barite is limited to ground barite produced at El Portal, Calif., and Malvern, Ark., and all crude, lump, and pebble barite except hand-mined. Depletion of deposits was cited by the U.S. Bureau of Mines as one reason for a serious shortage of barite in 1943.

Major production comes from weathered portions of deposits in three domestic regions: Missouri and Arkansas; Virginia, South Carolina, Tennessee, Kentucky, Georgia, and Alabama; and California, Arizona, and Nevada. In 1941, crude barite secured from these sources was 24 per cent higher than in 1940, at 483,391 short tons; domestic sales in 1941 reached the

peak figure of 503,156 tons valued at $3,134,234; in 1942, 429,484; in 1943, 420,343 tons valued at $2,796,776; in 1944, 518,617 tons valued at $3,558,489 as reported by the U.S. Bureau of Mines. Alaska produces minor quantities.

Ground or crushed barite sold or used by domestic producers in 1941 amounted to 234,877 short tons. Domestic-plant capacity for the production of lithopone was reported to total 181,600 tons. In 1944, output of crude barite increased 25 per cent over 1942, to 525,000 tons, for use in well-drilling muds, barium chemicals, and lithopone; in the first quarter of 1945, 145,277 tons.

Titanated lithopone, usually containing 15 per cent of TiO_2, produced in 1941 amounted to 10,800 tons containing 14,100 tons of ordinary lithopone. Lithopone sold or used by domestic producers amounted to 176,642 short tons in 1941; in 1942, 137,320; in 1943, 135,723; in 1944, 142,905.

Barite was designated on Mar. 1, 1944, by the War Production Board as a mineral sufficient for war uses plus essential demands. The first commitment for the purchase of barium by the Metals Reserve Company was made in 1944. This was the last to be designated of the 49 major stockpile items of the MRC. No barite remained in government stocks on Oct. 31, 1945, as reported by the Civilian Production Administration on Nov. 30, 1945.

In the postwar period, the demand for barite will depend on the volume of industrial production for stimulated output in relieving shortages of goods and services of many kinds. War uses of lithopone in the preparation of water paints for application to wallpaper may be continued after the war. Increasing production of titanium pigments was reported to be an unfavorable postwar prospect for lithopone. German crude barite, imported on a prewar scale of 40,000 tons a year, is expected to again enter the domestic market. The domestic paint industry reported in December, 1945, that no serious reconversion problems were being faced. Inventories were low for lithopone and other key materials.

DOMESTIC PRODUCTION OF WITHERITE, BARITE, AND BARIUM CHEMICALS, IN SHORT TONS
(After U.S. Bureau of Mines)

	1941	1942	1943	1944
Crude barite	483,391	449,873	429,298	515,136
Ground and crushed barite	234,877	178,765	208,252	344,757
Witherite	4,790	3,066	448	
Barium chemicals	71,319	70,610	77,869	73,470
Lithopone	176,642	137,320	135,723	142,905

World Production, Imports and Exports. Germany and the United States were leaders in barite production in the prewar period, high-grade

deposits and nearness to large markets making Germany the foremost source. Witherite is also mined in Thuringia. Less important sources of barite are reported in England. European production is also secured in Italy, France, and Spain. The Settlingstones mine in England is reported to be the world's chief source of witherite. Britain and Germany were the only sources of witherite up to the 1930's. Production in 1934 was 6,358 metric tons.

British barite production increased to about 100,000 long tons a year in the war period. In prewar years, Britain, Italy, Greece, France, and India supplied about 20 per cent of world output; the United States, 30 per cent; Germany, 50 per cent.

Because of economic advantage, barite was imported under war conditions from Canada and Cuba. Cuba exported 7,391 tons to the United States out of a total production of 16,105 tons in 1940; in the first 9 months of 1941, exports from Cuba dropped to 168 tons.

Canada increased production from 307 tons in 1940 to 6,043 metric tons in 1941, from the major deposits at Pembroke, Nova Scotia. Small shipments were made from British Columbia. Production has advanced rapidly as follows: in 1942, 19,667 tons; in 1943, 24,474 tons valued at $279,253; in 1944, 118,719 tons valued at $1,023,696. Canadian Industrial Minerals, Ltd., has doubled mill capacity to 400 tons a day and expected 1945 output to reach a value of about $1,300,000, the product being off-color and of use chiefly in well-drilling mud.

WORLD BARITE PRODUCTION, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Argentina	768	2,680	4,174	7,083	
Australia	4,205	4,725	4,990	5,916	
Canada	.....	307	6,250	17,842	22,202
Cuba	12,000	16,105	13,223		
Egypt	31	61	30	60	
Portugal	25	20	46		
Spain	8,856	9,936	8,125		
South Africa	439	891	1,390	745	1,745
United States	331,910	354,219	438,523	408,116	389,451

Considerable ground barite is exported from the United States, but data are not recorded. Imports in 1939 of crude, unground witherite from England amounted to 3,819 short tons valued at $64,106.

In Alaska, barite has not yet been brought into widespread commercial production, as reported on May 7, 1945, by the U.S. Geological Survey,

but favorable possibilities have been indicated for important advances in the postwar period.

Korea is reported by Samuel H. Dolbear to have 1 million tons of barite reserves, with output in 1938 amounting to 15,729 metric tons.

Prices. The price of Georgia and Tennessee crude, chemical grade barite ore, f.o.b. mines, on Sept. 30, 1946, was $8.50 to $9 a long ton. The price advanced in April, 1942, from the 1935–1942 quotation of $7.

The price of Missouri crude barite ore, chemical grade, 93 to 94 per cent, was $8.25 to $8.50 a short ton on Sept. 30, 1946, up from the following quotations of April, 1941: 95 per cent $BaSO_4$, less than 1 per cent of iron, $7 to $7.50; 93 per cent, $6.75 to $7.25. Water-ground and -floated, bleached Missouri barite, was quoted on Apr. 12, 1945, at $22.85 a ton, f.o.b. works.

Barium carbonate (witherite), precipitated, in 200-lb. bags, was quoted on Apr. 12, 1945, by *E & M J Metal and Mineral Markets* at $43 a ton, 90 per cent $BaCO_3$, 300-mesh. Prices are recorded by the U.S. Bureau of Mines as follows: 1941, $45 to $65; 1942, $55 to $65; 1943, $55 to $60.

Other barium chemical prices listed by the U.S. Bureau of Mines, 1943, are as follows: lithopone, ordinary domestic, in bags, 4¼ to 4¾ cents per pound; titanated, in bags, $0.056 per pound; barium chlorate, 112-lb. kegs, 36 cents per pound; barium chloride, barrels, $79 to $92 per short ton; barium dioxide (binoxide or peroxide), drums, 10 to 13 cents per pound; barium hydrate, 500-lb. barrels, at works 6 to 7 cents per pound; barium nitrate, in barrels, 11 to 12 cents per pound; blanc fixe (dry), direct process, in bags, $70 per short ton; by-product, in bags, $60 per short ton. In 1943, barium metal was quoted at $5 to $8 a pound by U.S. Bureau of Mines.

Crude barite is sold in the domestic market on a penalty-premium basis based on a standard of 95 per cent of $BaSO_4$ and 1 per cent of Fe_2O_3. Each percentage involves a penalty or premium of 25 cents per short ton, the same applying for each 0.1 per cent of Fe_2O_3 below or above 1 per cent. The United States tariff of $4 a ton applies to crude barite; ground or manufactured, $7.50 per ton.

Canada imports barite duty free under the British preferential tariff; barite imported from other countries is subject to 25 per cent ad valorem. The Canadian price of crude barite is $7 per short ton, f.o.b. mines. Domestic ground white barite for use in pigment and filler is quoted at $32 to $40 per ton, f.o.b. works according to quality; domestic ground off-color, $12.80 per short ton, f.o.b. Atlantic port; imported prime white barite in Canada, $50; off-color, $46.

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BAUXITE

Properties. Bauxite is used properly as a generic term for rocks rich in hydrous aluminum oxides of which the principal constituents are gibbsite, boehmite, and diaspore. Bauxite grades into laterite with increasing content of hydrous iron oxides. A nonplastic mineral of colloidal origin, bauxite is earthy and claylike, usually occurring in pisolitic masses, or porous to compact. Its hardness is 1 to 3.5; its specific gravity, 2.45 to 3.25. In Arkansas and Nyasaland, bauxite overlies decomposed syenite; in the Guianas, it is the weathering product of dolerite and epidiorite.

Grades acceptable either for metal production or for chemical use must contain more than 50 per cent of aluminum oxide. The common impurities, silica and iron, are undesirable for metal production and are generally held to less than 4.5 and 6.5 per cent, respectively. Alunite, clay, and leucite have been used for producing aluminum in the war emergency. Approximately 2 tons of bauxite are required to produce 1 ton of alumina, 2 tons of which produce 1 ton of aluminum. An abundance of cheap electric power is required for the reduction of bauxite.

Nepheline syenite and aluminum-rich clay or shale commonly weather to form bauxite. Rapid weathering and slow erosion are necessary to form the blankets or pockets of bauxite. Slow but thorough leaching of silica has been accomplished mainly by the organic compounds generated by vegetation in warm, humid areas.

Uses. Of total shipments of domestic bauxite in 1940, the aluminum industry used 48 per cent (in 1943, 89 per cent); aluminum abrasives and refractories manufactured in the United States and Canada used 28 per cent (in 1943, 7 per cent); the manufacture of alumina and aluminum salts by the chemical industry required 18 per cent (in 1943, 1 per cent).

Prewar uses (1936) gave second place to the manufacture of alumina (fused) cements, which are essential where strength is desired in a comparatively short time. No other hydraulic cement gives the early strength of that manufactured from aluminous cements, since they resist the action of salt water which is destructive to Portland cement.

Bauxite from the Eufaula district, Alabama, is being used extensively for chemical and other nonmetal purposes. The chemical industry employs bauxite for the preparation of aluminum hydroxide, sodium aluminate,

aluminum chloride for petroleum refining, and alum. Other uses are in the production of abrasives and refractories, the latter for linings in metallurgical furnaces and in kilns used in the manufacture of high-lime cements. A lower grade of bauxite is used for artificial abrasives than in producing aluminum. Bauxite is mixed with coke and iron borings and smelted in an arc furnace.

The dyeing and colormaking industries use sulfate of alumina, a colloid that absorbs other colloids to form a compound having great stability. Bauxite and alumina are used as catalysts in organic reactions involved in converting ethyl alcohol to ethylene, and bauxite is used in the manufacture of aluminum acetate, oleate, and stearate.

An order issued by the War Production Board on Sept. 1, 1942, forbids the use of bauxite except for the manufacture of aluminum, specifying lower grade materials such as kaolinite and halloysite for the manufacture of alum and aluminum sulfate, the latter for making paper.

Domestic Sources of Supply and Production. Output of domestic bauxite in 1940 advanced 17 per cent over 1939, based on increased shipments from mines in Arkansas. Apparent consumption amounted to 958,695 long tons, of which 437,595 tons came from Arkansas. Combined output of 11,603 tons was reported from Alabama, Georgia, and Virginia, the last producing for the first time.

Domestic output, in March, 1941, was 50 per cent above the monthly average in the previous year. The actual mine output in 1941 was 1,011,090 short tons; in 1942, 2,914,278; in 1943, 6,980,829, including 2,000,000 tons for Canada. Figures for 1944 represent a sharp decline to 3,344,800 tons valued at $16,680,000. Maximum monthly output was attained in August, 1943, representing an annual rate of more than 8,500,000 tons. Stockpiles at the end of 1943 amounted to 4,800,000 tons.

The Metals Reserve Company made its first commitment for bauxite in the stockpiling program in 1941; by the end of 1943, the government reserve exceeded 2 million tons. Bauxite ranked eleventh in cost of deliveries to stockpiles of the MRC, for a total cost of $22,589,044; inventories were valued at $14,023,783 on Oct. 31, 1944. Bauxite amounting to 2,712,688 long dry tons remained in government stocks held by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration. Total stocks, on Sept. 30, 1945, amounted to 2,794,173 long tons, of which 108,113 tons of bauxite were stored in Surinam. Government-owned reserves of 2,829,697 net tons were reported by *The Wall Street Journal* on July 17, 1944; at the end of the year, reserves of high-grade ore were reported to be adequate for 18

months' consumption, plus millions of tons of lower grade on stockpiles. The Office of War Information announced at the end of January, 1944, that bauxite production had been cut back by about 40 per cent. Bauxite stockpiles were to be made available to the Reynolds Metals Company to make up the possible deficit from commercial sources, it was reported on July 12, 1946, by John R. Steelman, OWMR chief.

The WPB modified the restrictions of General Preference Order M-1-h late in 1943, when controls on bauxite and alumina were relaxed. Restricted grades of bauxite could be delivered to alumina and abrasive manufacturers without authorization, and simplified procedure was set up to secure authorization for delivery to other industries.

Metallurgical and chemical processes have been developed to treat low-grade bauxite and other aluminous materials such as clay, anorthosite, alunite, and bauxitic shales. The standard Bayer process was combined with a lime-sintering operation at East St. Louis by Aluminum Company of America and at Hurricane Creek, Ark. This process is believed to have wider applications in peacetime than treating only high-silica low-grade ore.

Alumina was successfully produced in 1944 by the Salt Lake City plant of Kalunite, Inc., using alunite ore, with potassium sulfate as a by-product. Lime-soda sinter plants went into operation at Harleyville, S. C. (clay and marl), and at Laramie, Wyo. (anorthosite and limestone as raw materials). Columbia Metals Corporation, at Salem, Ore., was to start test runs in February, 1945, treating clay to produce alumina by the ammonium bisulfate process. The Harleyville plant was operated by Ancor Corporation, with a capacity of 50 tons of alumina daily, the residue being of possible use for fertilizer or cement manufacture. An effort was made to gain independence of foreign sources of bauxite through the use of acid and alkali processes in the production of alumina in domestic plants. The various processes for extracting alumina from clay were found to be too high cost, even in the war emergency, to be practical. These processes were selected by the National Academy of Sciences as being most likely to provide alumina from domestic nonbauxitic sources, of which vast quantities are available. Government cost for the construction of these four experimental plants was about $16,000,000.

Alcoa Mining Company (prior to Apr. 15, 1945, Republic Mining and Manufacturing Company) has been a wholly owned subsidiary of Aluminum Company of America since 1909 and was the first operator to mine bauxite in the United States. It has been active in Arkansas since 1899, and operations are also carried on in Georgia and Alabama. Production in 1944 was fifteen times the rate in 1939.

With the reopening of ocean shipping routes to British Guiana, all

exports of domestic ore to Canada were canceled in October, 1943. In spite of the large-scale production of domestic bauxite, a deficient mineral, exploration, in 1943, resulted in proving a larger tonnage than was produced and located in deeper and more scattered ore bodies. In an effort to expand reserves, the WPB sponsored the construction of four pilot plants for the production of alumina from clay and other nonbauxite aluminous materials.

GOVERNMENT-OWNED ALUMINA PLANTS

Operator	Location	Sources	Tons per year	Gov. invest.
Aluminum Company of America	Bauxite, Ark.	Bauxite	777,500	$39,300,000
Aluminum Company of America	Baton Rouge, La.	Bayer and sinter process	500,000	25,700,000
Columbia Metals Company	Salem, Ore.	Clay*	18,000	4,300,000
Ancor Corporation	Harleyville, S. C.	Clay*	18,250	3,200,000
Kalunite, Inc	Salt Lake City, Utah	Alunite*	36,000	4,900,000
Monolith Portland Mid-West Company	Laramie, Wyo.	Anorthosite*	18,000	3,300,000
Aluminum Ore Company.	Mobile, Ala.	Red mud	400,000	

* Experimental plant.

The alumina industry increased bauxite consumption 114 per cent in 1943 compared with the previous year; abrasive and refractory increased 10 per cent; and other uses 23 per cent. In 1943, there was a 30 per cent decline in bauxite used by the chemical industry. Ore shipments from Arkansas amounted to 97 per cent of domestic output.

Domestic production of bauxite has been too small to affect national requirements; commercial reserves are estimated at a 9-year supply based on the annual rate of consumption, 1935–1939. Submarginal and highly speculative domestic material is estimated by Elmer W. Pehrson, U.S. Bureau of Mines, adequate for 100 to 500 years in terms of prewar consumption, under emergency conditions and at a high price. Less than 35 per cent of domestic bauxite was still unmined in 1944. Greater dependence on foreign sources has been indicated for the postwar period.

Harold L. Ickes, Secretary of the Interior, stated in December, 1945:

> We have less than a 35-year commercial supply of bauxite and twenty other minerals . . . which we shall have to import in larger quantities. . . . We cannot afford another prolonged war in 20 or 30 years. The prodigal harvest that we have reaped to win this war has bankrupted some of our most vital mineral

resources. We no longer deserve to be listed with the British Empire and Russia as one of the "have" nations. We should be listed with the "have nots," such as Germany and Japan. Even more alarming than the fact that we are coming to the end of some of our known resources is the fact that we are uncovering few, if any, unknown deposits of minerals.

Bauxite amounting to 14,169,000 tons was mined between Jan. 1, 1940, and Jan. 1, 1945.

Potential reserves of bauxite are believed by another authority to be adequate for any future war, even without imports. The submarine blockade in 1942–1943 made high-grade ore from Surinam deposits less available than the domestic sources of low-grade bauxite, alunite, and clay.

A third estimate, by three members of the faculty, University of Washington, places total world reserves at 374 million metric tons of high-grade bauxite, of which the United States accounts for only 5 million tons.

Interior Secretary Ickes, in testimony submitted to the Senate small-business committee on May 14, 1945, recommended processing the 400,000-ton stockpile of bauxite in Arkansas. He stated that this should be done by private enterprise operating government plants under lease or management contract.

Bauxite was one of the strategic and critical materials required for essential war uses and for which stockpiling is deemed the only satisfactory means of ensuring an adequate supply for a future emergency. The stockpile bill passed by Congress in July, 1946, created a development and conservation program to acquire and guard domestic reserves of bauxite, as set up by the War, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated the Procurement Division of the U.S. Treasury to buy reserve supplies of bauxite and other strategic materials, aided by OMR and other government agencies.

World Production, Imports and Exports. In 1940, world output increased 7 per cent over the previous year to reach an estimated total of 4,627,000 metric tons. Production in 1941 was estimated by the U.S. Bureau of Mines at 6,296,000 long tons (in 1939, 4,238,000). Imported bauxite increased 21 per cent in 1940, compared with 1939, 75 per cent of the total ore being received from Surinam. In 1943, world production increased about 60 per cent. In 1942, output of bauxite and aluminum by the United Nations accounted for about 79 and 70 per cent, respectively, of the world total. Production in 1944 showed a decline.

Ore reserves, in general, are not abundant in the major aluminum-producing countries. In the postwar period, estimated annual bauxite re-

quirements indicate 4 million tons for the United States, 800,000 tons for Canada, and 6,420,000 tons for total world consumption. It is considered indispensable for world peace that a plan be adopted for allocating bauxite over a 60-year period to the various aluminum-producing countries.

Surinam, the major source of bauxite imported by the United States, has mines located at Moengo and Paranam.

Haiti and Jamaica, it is reported, have bauxite deposits that exceed the total proved reserves in the United States. A new, low-cost process is being perfected by Reynolds Metals Company for the treatment of ore from Haiti under long-term plans reported in November, 1944. These concessions are in addition to bauxite mines owned by Reynolds in Arkansas adjacent to Hurricane Creek.

Gold Coast production of bauxite, as reported by the U.S. Bureau of Mines, far exceeded previous expectations. Output jumped from 15,000 to 160,000 metric tons, 1941–1943, as shipping channels were opened for transporting the material to Britain.

In U.S.S.R., bauxite reserves were reported by the U.S. Bureau of Mines, in 1944, at an estimated 9,200,000 tons averaging about 56 per cent of Al_2O_3. A recent discovery in the Malofasensk area was reported to have reserves of about 10 million tons. The main deposits are located in the northern and central Urals, on the Vagram River at Krasnaya Shopochka.

In Brazil, bauxite deposits are perhaps the largest known, distributed in more than 80 localities where resources are estimated at well over 50 million tons. Deposits near Ouro Preto and in the Pocos de Caldas region of Minas Geraes are extensive and easily mined and have a high alumina content. Shipments amounting to about 35,000 tons a year are projected for 1945 from several simple roasting plants. Plans have been completed for locally converting bauxite to alumina and for final reduction to aluminum. This is reported to be the best Brazilian bauxite yet developed, with ore reserves of about 1½ million tons. Extensive ore areas have been explored in other yarts of Minas Geraes and in Espirito Santo. Development work in Brazil is rapidly leading to well-established operations, as reported in May, 1945, by James S. Baker, Foreign Economic Administration. In Brazil, bauxite was one of 10 minerals to be included in agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus as part of the foreign procurement program initiated late in 1940.

In the war period, German industry depended heavily on France and Dalmatia; and when these were lost soon after D-Day in 1944, domestic clay became the chief raw material available. Following the Russian advance through Silesia in January, 1945, the bauxite sources available to Germany

were reduced by about 75 per cent. Before September, 1939, Germany accumulated substantial stockpiles of aluminum and built large-capacity aluminum-reduction plants. Military and diplomatic pressure were both employed to secure adequate supplies of bauxite. Large bauxite deposits in Italy and Hungary support a domestic aluminum industry and produce ore for export.

The Palau and Caroline Islands, under Japanese mandate in the Pacific, were reported in March, 1945, by the Navy Department to have valuable deposits of bauxite of unknown extent. Japan, seriously short of bauxite, installed aluminum-reduction works capable of supplying more than 60 per cent of normal requirements, dependent on ore imported from the Netherlands East Indies.

With capital available from raw-material exports through loans from the Export-Import Bank for purchasing machinery and equipment in the United States, certain Latin-American countries are attempting to utilize raw-material products locally by erecting processing plants for bauxite.

No attempt has been made in this brief discussion of world bauxite resources to indicate the distribution of alunite. It is reported by Samuel H. Dolbear that reserves of alunite in Korea amount to 20 to 30 million tons, with an output of 149,000 metric tons produced in 1937 by the Japanese for conversion into aluminum.

WORLD PRODUCTION OF BAUXITE, IN METRIC TONS
(After U.S. Bureau of Mines)

Country*	1939	1940	1941	1942	1943
France	800,000	700,000	700,000	650,000	700,000
Gold Coast	.....	.....	15,000	45,000	160,000
British Guiana	483,653	634,510	1,089,833	1,175,000	1,930,000
Surinam	511,619	615,434	1,198,900	1,245,000	1,670,000
Hungary	485,000	647,000	1,000,000	1,200,000	1,200,000
Ireland	.....	.....	40,000	100,000	110,000
Italy	483,965	530,000	600,000	400,000	300,000
Netherlands Indies	230,668	274,345	171,821	160,000	250,000
U.S.S.R.	270,000	300,000	250,000	275,000	350,000
United States	381,331	445,958	908,525	2,511,385	6,120,315
Yugoslavia	318,840	290,000	400,000	200,000	120,000

* 13 other countries are established producers, with annual output of less than 100,000 tons.

France ranked first in 1938 as a producer of bauxite (17.7 per cent), followed by Hungary (14 per cent of world output) and Yugoslavia. The British Empire, France, the Netherlands, and Italy are self-sufficient in bauxite; United States, U.S.S.R., and Germany have supplies inadequate to

meet domestic demands; Belgium, Spain, China, and Japan are almost entirely dependent on foreign sources.

Prices. The price of crude bauxite (not dried), 50 to 52 per cent, f.o.b. Arkansas mines, remained at $5 a long ton through Sept. 30, 1946 (in 1941, the average selling price was $4.31). Domestic chemical grades (crushed and dried, f.o.b. Arkansas and Alabama mines), 55 to 58 per cent Al_2O_3, 1.5 to 2.5 per cent Fe_2O_3, were quoted at $7.50 to $8.50 a ton (in 1940, $6 to $8); other grades, f.o.b. Arkansas mines, 56 to 59 per cent Al_2O_3, 5 to 8 per cent SiO_2, $7.50 to $8.50; 8 to 12 per cent SiO_2, $14 to $16.

Domestic abrasive grades, crushed and calcined, f.o.b. Arkansas mines, 80 to 84 per cent Al_2O_3, were priced at $16.50 a ton (in 1940, $12 to $14); 56 to 59 per cent Al_2O_3, 5 to 8 per cent SiO_2, $7.50 to $8.50 a ton.

A duty of $1 per ton is charged on imported bauxite. There is no duty on bauxite imported into Canada. Present duty on imports of aluminum ingot from Canada is 3 cents a pound; semifabricated aluminum, 6 cents. Higher duties are charged on finished articles.

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BERYLLIUM

(Ore and Oxide)

Properties. A mineral silicate of beryllium and aluminum, beryl ore is the source of a metal that is lighter than aluminum. It is available only in limited quantity and in a questionable state of purity. Beryllium is one of the 19 industrial nonferrous metals used essentially as alloying constituents. Its favorable qualities of low density and permanence in the atmosphere are counteracted by its brittleness. One of the most difficult procedures in metallurgy is the production of beryllium metal and its alloys. (Be, atomic number, 4; atomic weight, 9.02.)

Beryllium is unique in having a much higher melting point (1280°C.), higher corrosion resistance, and greater hardness than either aluminum or magnesium. Beryllium-nickel (1.75 per cent of beryllium) has a tensile strength of 300,000 lb. compared with 90,000 lb. for nickel. The tensile strength of beryllium-copper (2.25 per cent of beryllium) is 190,000 lb. compared with 33,000 lb. for copper. The metal is very brittle at room temperature and shows no signs of ductility. Steel gray in color, the metal has specific gravity of 1.84. It can be sublimed or distilled rapidly at a temperature close to its melting point.

Beryl, containing a maximum of 14 per cent of beryllium oxide, is the only beryllium mineral utilized. It is found as irregular masses distributed through other minerals, not as a concentrated ore. Its occurrence is limited to pegmatites, the mineral being secured as a by-product of mining operations for the recovery of feldspar, mica, or lithium minerals. Beryl crystals sometimes reach a very large size. Beryllium with a purity of 99.5 per cent is obtained by means of electrolysis of the molten fluoride in a graphite crucible to which is added barium fluoride or sodium fluoride. Beryllium separates out on a water-cooled iron tube that serves as a cathode, slag inclusions being removed by remelting in contact with mixtures of alkaline-earth halides.

Uses. The critical place of beryllium in war industry was due largely to its use in relatively small percentages for the purpose of improving physical properties of certain alloys, particularly in springs, cams, gears, precision bearings and bushings, and contact brushes. Beryllium-steel and alloys with copper containing 0.1 to 3.5 per cent of beryllium are probably of major

importance. It also alloys with nickel, iron, aluminum, silver, and other metals, applications of which are being investigated. An aluminum-beryllium alloy containing 5 per cent of beryllium is used as a deoxidizer in making aluminum-magnesium products. Pistons and other uses in aircraft, where lightness, strength, wear resistance, high electrical conductivity, and corrosion resistance are essential, appear to be of primary commercial importance. Beryllium has no superior for resilience, particularly for small springs such as are used in small arms and munitions. It has various fabrication advantages associated with heat treatment or precipitation hardening.

Described as "the world's No. 1 metallurgical headache," owing to the metal's high fusion point and high vapor pressure at a temperature not much above the fusion point, beryllium can be hot-worked. Extreme lightness gives the metal a tendency to float on slags and on fused electrolytes. Treatment with zirconium or titanium is beneficial in producing thin hot-rolled beryllium strips for windows in X-ray tubes. Beryllium metal, transparent to rays, is essential for this application. Small quantities are added to aluminum-magnesium castings and extrusions. Platinum metals can be conserved by fractional beryllium additions.

The main application is in age-hardening copper-base alloys for increasing tensile strength—particularly the elastic limit, hardness, and fatigue strengths, of springs and diaphragms of delicate instruments and especially in sensitive fire-control mechanisms for large guns. The addition of 3 per cent or less of beryllium to copper makes an alloy that can be heat-treated.

Less than 1 per cent of beryllium and a small content of either copper or chromium are used in electrical alloys with copper. These are characterized by excellent hardness and tensile strengths of 60,000 to 190,000 lb. per sq. in., along with up to 70 per cent of the conductivity of copper. These properties make the alloy useful for the manufacture of valve guides for engines, pumps, and liquid meters and for gears, plastic molds, die-casting dies, and welding electrodes.

Beryllium-copper alloy is used as a setting for industrial diamonds. An essential use is in the hubs of adjustable steel aircraft propellers and in the motors and instrument panels of aircraft. Beryllium makes a nonsparking cutting tool that is used in gaseous coal mines and in some textile factories. The alloy is essential for switch blades and jaws and for electric-range switches. Beryllium-copper alloys are used in watch and camera parts and in fountain-pen clips, appliance-plug clips, fuse clips, optical alloys, vibrator arms, and gasoline and oil-pump parts. Beryllium-copper springs are employed for relays, brush holders, thermostatic controls, and leaf or helical, contact, and Bourdon pressure springs.

The war economy as well as peacetime industry have indicated many important applications of beryllium-copper alloys. Essential war uses include parts of aircraft, ships, tanks, guns, shells, instruments, engines, motors, radios, telephones, telegraphs, tools, and electrical-control equipment for machinery and fire protection. In certain aircraft instruments, the alloy is used because its properties make possible the employment of smaller parts than would be practical if other materials were applied.

In fluorescent lamps, beryllium oxide and carbonate—activated by uranium salts or rare earths—are used as a white phosphor in luminescent points. Greater demand is reported for the oxide as a coating for fluorescent lighting tubes and lamps and for fluorescent screens in the form of zinc-beryllium silicate. Ground beryl is employed to the extent of about 100 tons a year in the United States as a batch ingredient in spark plugs and other ceramic specialties and in cooking utensils.

War demands accounted for 99 per cent of the available beryllium, which is expected to find wider industrial applications in peacetime. About half the prewar output was utilized for ceramics and pottery.

Domestic Sources of Supply and Production. Not recovered in commercial quantity until the late 1920's, beryllium production in the United States increased to about 200 tons in 1940 (158 tons in 1941 valued at $7,300) and was considerably higher in 1944.

The War Metallurgy Committee, Beryllium, National Research Council, reported in April, 1943, that consumption of beryl was about 7 tons a day. Output was at the annual rate of 3 million pounds of beryllium-copper master alloy and 10,000 lb. of beryllium oxide for phosphorescent lamps. Beryllium metal was designated by the War Production Board on Mar. 1, 1944, as sufficient for war uses plus essential industrial demands. *The Wall Street Journal* reported on July 17, 1944, that government stockpiles contained 3,739 net tons of beryl ore. The first commitment for beryllium in the stockpiling program was made in 1941 by the Metals Reserve Company. It ranked thirty-fifth in cost of deliveries to the MRC ($682,311), the inventory of beryllium on Oct. 31, 1944, being $325,512. In 1943, the MRC increased beryl stocks from 725 to 2,513 tons. Government stocks held by the Office of Metals Reserve, on Oct. 31, 1945, amounted to 4,768 short tons.

The WPB placed beryllium in all forms under allocation on June 1, 1942, in Order M-160. This Order was amended on Dec. 16, 1943, to change allocation from a monthly to quarterly basis. Sales of material containing 2 lb. of beryllium or less were exempted from control.

Domestic production of beryl is as a by-product of feldspar, mica, and other pegmatite minerals. Mine shipments increased 40 per cent in 1943 com-

pared with 1942, the highest volume ever secured. The expanded industry is controlled by three operators: Beryllium Corporation of Pennsylvania, Brush Beryllium Company, and Clifton Products, Inc. Beryllium-copper master alloy, metal, and compounds are produced by these companies.

The beryllium situation had eased since the fall of 1944, as reported in May, 1945. Beryllium-copper scrap held by the MRC amounted to 850 tons. At the end of April, 1945, the WPB revoked Order M-160-A, freeing beryllium scrap. Users of small amounts had suffered a hardship under this restriction.

BERYLLIUM ORE SHIPPED FROM MINES IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

State	1939	1940	1941	1942	1943
Colorado	*	*	.....	3	68
Maine	*	*	*	45	2
New Hampshire	.....	.....	*	16	42
South Dakota	84	74	151	205	238
Other	11	47	7	.....	6
Total tons	95	121	158	269	356
Total value	$2,720	$3,721	$7,300	$24,188	$44,407

* Included in "Other."

The creation of a state or international monopoly of beryllium as one of the materials required in making atomic explosives was one of the technical difficulties brought under the authority of the Atomic Energy Commission which was to be established by the United Nations Organization, as voted on Jan. 24, 1946, by the UN Assembly in London.

Beryllium is one of the strategic and critical materials required for essential war uses and for which stockpiling is deemed the only satisfactory means of insuring an adequate supply for a future emergency. The stockpile bill passed by Congress in July, 1946, created a development and conservation program to acquire and guard domestic reserves of beryllium, as set up by the War, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated the Procurement Division of the U.S. Treasury to buy reserve supplies of beryllium and other strategic materials, aided by the OMR and other agencies.

World Production, Imports and Exports. World production in 1940 amounted to about 5,000 tons. Imports reached a new record, as follows: from Argentina, 422 tons; from Brazil, 377; from South Africa, 6. Beryl ore in Argentina was nearing exhaustion in 1945 (in 1942, production totaled 925

metric tons). Increased supplies were received from Brazil and India in 1940. Small output is secured in Canada and Portugal. In 1943, beryl imports more than doubled compared with 1942. Shipments were received from all continents. Exports amounted to 4,903 lb. of ore, 54,990 lb. of alloys and metal, and 3,915 lb. of compounds.

Beryllium ore imported into the United States was as follows: in 1939, 917,447 lb.; in 1940, 1,610,000; in 1941, 5,332,643 valued at $143,992.

WORLD PRODUCTION OF BERYL, IN METRIC TONS
(After U.S. Bureau of Mines)

Country*	1939	1940	1941	1942	1943
Argentina	299	520	1,986	925	1,054
Australia, Western	6	2	2	†	415
Brazil (exports)	276	1,472	1,703	1,634	2,027
Canada (estimated)	161	†	†	360	462
India, British	9	†	†	†	†
Madagascar (estimated exports)	†	†	†	†	67
South-West Africa	...	.....	20	18	36
United States (mine shipments)	86	110	143	244	323
South Africa (estimated)		5	†	34	76

* Production may be secured also in France, Italy, Norway, Rumania.
† Data not available.

In Australia, beryl is produced from the Wodgina tantalite district, Western Australia. Madagascar, in 1943, shipped beryl from the Fianarantsoa mine, about 100 miles inland from the port of Manakara. South-West Africa, in 1942, exported 77 metric tons of beryl to Britain.

In U.S.S.R., the chief source of beryl is reported by the U.S. Bureau of Mines to be the Sherlova Gora mine, located in Transbaikal. U.S.S.R. has some 25 other promising beryl deposits.

Brazil has become the principal source of beryl ore, production for war uses far exceeding normal requirements. Annual output amounting to 2,000 to 3,000 tons of 11 per cent BeO ore is obtained from pegmatites in the states of Paraiba and Rio Grande do Norte. Stimulated by war prices, production in increasing volume was secured from central and southern areas of the state of Ceara and from Minas Geraes. Imports of strategic beryl by air from South America were larger in 1944 than in 1943, as reported by the Foreign Economic Administration in April, 1945. All imported beryl is delivered at ceiling prices or less.

Beryl ore was one of 10 minerals produced in Brazil to be included under agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus as a part of the foreign procurement

program initiated late in 1940. In 1944, the FEA followed the policy of withdrawing from public purchase of foreign beryl when possible, returning the trade to former private channels if no impairment to the war effort resulted.

Prices. The price of beryl ore, 8 to 12 per cent BeO, f.o.b. mine, was $14.50 per unit, as reported on May 10, 1945, by *E & M J Metal and Mineral Markets.* The price on Apr. 1, 1946, was $8 to $10 per unit, which continued through Sept. 30. The quotation dropped on June 3, 1944, from $190 to $100 per short ton. The price in 1940 averaged $29.65 per ton; in 1941, $47.48; in 1943, $83 to $144; in 1944, $145 a ton for 10 per cent grade ($14.50 per unit).

The German product of the 1920's, having less purity, sold at $200 a pound compared with current prices of $45 to $50 a pound of contained beryllium in metallic beryllium and beryllium-aluminum. Beryllium-copper, 2.5 to 3 per cent of beryllium, was quoted on Aug. 1, 1946, at $15 a pound of contained beryllium. Beryllium-copper master alloy containing 4 per cent of beryllium, the balance copper, 40 lb. or more of contained beryllium, in the form of ingot, was priced at $17 per pound beryllium, plus the copper at market.

Beryllium iron, beryllium nickel, and beryllium aluminum were quoted on Jan. 1, 1945, at $50 per pound of contained beryllium, base metals at market. Prices on casting alloys are given on application. Beryllium nickel (2 per cent of beryllium, the balance nickel), strip and rod, was priced at $2 per pound.

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BISMUTH ORE

Properties. One of the arsenic group, based on chemical affinities, bismuth is a shiny, brittle, metallic element characterized by its silver streak, pinkish tinge, and arborescent structure. (Bi, atomic number, 83; atomic weight, 209; melting point, 271°C.) Its hardness is 2 to 2.5; its specific gravity, 9.7 to 9.83.

The most diagmagnetic of all metals, bismuth has low fusibility and expands on cooling. These properties are retained in a number of alloys. Thermal conductivity is less than in any other metal except mercury (18, compared with 1,000 for silver). Bismuth is one of the 19 industrial nonferrous metals used essentially as alloying constituents. Low-melting bismuth alloys are of high specific gravity, relatively soft, of low tensile strength, brittle to shock, yet subject to plastic flow. The wide industrial application of bismuth alloys is based chiefly on the low melting temperature and nonshrinking properties. Bismuth-lead-tin-cadmium alloys, the most widely used, have the property of expanding on cooling. Free-cutting aluminum alloys have small amounts of bismuth and lead.

Bismuth occurs as a native element and in a large variety of ores, in pegmatites and in hydrothermal veins accompanying various ores of cobalt, nickel, copper, lead, silver, and tin. Bismuthinite (bismuth trisulfide), closely resembling stibnite, has a hardness of 2; its specific gravity is 6.78. Other important ores are the oxide (bismite) and the carbonates (bismutite and bismutosphalerite). Its color and streak are lead-gray.

Flue dusts carrying lead and bismuth are usually treated by subjecting the dust to a partial reduction and concentrating the bismuth in the resulting metal. After selective oxidation, the molten bismuth is purified by treatment with chlorine. Lead bullion containing bismuth is treated either by the Betts electrolytic refining process or by the Kroll-Betterton (calcium) process.

Uses. The application of bismuth substitutes was encouraged in 1940 by war restrictions on imports and exports. Bismuth was employed on a larger scale in alloys. Thermoelectric properties of the metal render it valuable for the low melting point and nonshrinking properties, leading to increased consumption for machine tools and dies, aircraft, munitions, and automobiles. Solder having low bismuth content is used for special purposes. Solder containing 14 per cent or more of bismuth is an alternative of crimping for armor-piercing shells.

Alloys of 43 to 55 per cent of bismuth with lead, tin, and cadmium are used for pattern metal, assembly and checking fixtures, die and punch mounts, and filler for bending thin-walled tubing, particularly in the aircraft industry. Low-melting bismuth alloys serve as fuses in automatic sprinkler heads and safety plugs for fire detectors, as gas containers, and as coatings for selenium rectifiers.

Considerable bismuth and bismuth alloys were used in the production of atomic bombs, radar equipment, and other war uses not yet made public. Bismuth (cerrobase alloy) is used in aluminum alloys from which the forged cylinder heads of air-cooled aviation engines are made in order to increase machinability of the forgings. The property of increased machinability of castings is also secured by additions of bismuth to malleable irons, manganese steel, and stainless steel.

Bismuth alloys are employed in the production of spotting, checking, and erection fixtures for the aviation and automotive industries; in dies for drop hammer and press forming of thin sheet metals; as fusible cores in the manufacture of electroformed hollow articles; for anchoring fragile materials during machining, grinding, and testing; as a heat-transfer medium; and for molds and patterns in precision casting.

Prewar consumption of bismuth was reported to be 70 per cent in the manufacture of pharmaceutical compounds; in 1939, 85 to 90 per cent; in 1943, 49 per cent. These uses remain about as before; metallurgical applications account for increased requirements. Reduced quantities, in 1940, were used as salts in drug manufacture. Heavier purchases of bismuth pharmaceuticals (carbonates and nitrates) were made in 1941, by the Army and Navy. As a conservation measure, the consumption in cosmetics was reduced in 1943.

Domestic Sources of Supply and Production. Trade became subject to export license on July 2, 1941. The export of bismuth compounds and medicinals probably increased in 1940, when imports from Peru were cut 32 per cent and imports from Germany of compounds, mixtures, and salts of bismuth were terminated. Europe, normally using about half the total output, turned to Japan and Russia when cut off from sources in North and South America.

Bismuth production in the United States reached a record level in 1942, resulting in part from the cleaning up of residues collected over a period of years. Output dropped 44 per cent in 1943 to a level similar to prewar figures. The U.S. Bureau of Mines has not released domestic-production statistics. Domestic and imported lead and copper ores and Mexican bismuth-lead bullion bars are produced by three companies.

Anaconda Copper Mining Company produces bismuth-lead bullion at

Tooele, Utah, from Montana copper and Utah lead ores. The bullion is refined at East Chicago, Ind. American Smelting & Refining Company produces bismuth-lead alloys at plants located at Selby, Calif.; Perth Amboy, N. J.; and Monterrey, Mexico. The alloys are refined at Omaha, Neb. United States Smelting, Refining & Mining Company ships bismuth-lead bullion from Midvale, Utah, for refining at East Chicago. Cerro de Pasco Copper Corporation is the principal importer and consumer, using bismuth refined in Peru.

Bismuth and bismuth chemicals were included by the War Production Board in June, 1945, with a list of materials and products comprised of nine other minerals and certain ferroalloys that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and it was anticipated that further changes in controls would be announced. On Aug. 1, 1945, bismuth was grouped with tin, cadmium, and antimony as critical. Production in the United States is secured as a by-product in the electrolytic refining of lead.

The metal was designated on Mar. 1, 1944, by the WPB as insufficient for war uses plus essential industrial needs. *The Wall Street Journal* reported on July 17, 1944, that 453 tons of bismuth were held in government stockpiles. Bismuth ranked thirty-first in cost of deliveries ($1,150,910), and the Metals Reserve Company inventory on Oct. 31,1944, showed it valued at $1,084,115. The first commitment to purchase bismuth for stockpiling was made by the MRC in 1941. Bismuth amounting to 391 short tons remained in government stockpiles held by the Reconstruction Finance Corporation through the Office of Metals Reserve on Oct. 31, 1945, as reported by the Civilian Production Administration. The CPA froze the bismuth stockpile on May 6, 1946, and requested voluntary rationing, owing to an anticipated 90 per cent loss of production as a result of industrial disputes.

Bismuth is one of the strategic and critical materials required for essential war uses and for which stockpiling is deemed the only satisfactory means of ensuring an adequate supply for a future emergency. The stockpile bill passed by Congress in July, 1946, created a development and conservation program to acquire and guard domestic reserves of bismuth, as set up by the War, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated the Procurement Division of the U.S. Treasury to buy reserve supplies of bismuth and other strategic materials, aided by the OMR and other government agencies.

World Production, Imports and Exports. Peru normally supplies about half of world requirements as a by-product of the smelting and refining of

lead and lead-silver ores of the Cerro de Pasco Corporation. This by-product is available in excess of world consumption, which was about 3 million pounds in 1940 and in 1943. The Peruvian Trade Agreement, effective on July 29, 1942, provided a 50 per cent reduction in duty for bismuth imported into the United States. Refined metallic bismuth imported from Peru in 1943 amounted to 430,874 lb.; in 1941, 223,477; in 1940, 123,880.

Bolivia is reported to have the most productive deposits of bismuth and bismuthinite, in the states of La Paz and Potosi and associated with cassiterite in veins at Uncia-Llallagua. Bolivia exported 68,600 lb. to the United States in 1943, the ore containing 36.3 per cent of bismuth. The Foreign Economic Administration reported that a potential annual output of 600,000 lb. of bismuth could be secured for a few years from Patino and other operators in Bolivia.

Canada recovered bismuth as a smelter by-product, in 1944 producing 62 tons valued at $154,750; in 1943, 203; in 1942, 173; in 1941, 3; in 1940, 29; in 1939, 205, as reported by Dominion Bureau of Statistics.

Mexico, in 1941, produced 108 metric tons in the form of semirefined and concentrate; 70 tons were exported. Recovery is from flue dusts of smelters treating copper and copper-silver ores. Bismuthinite is reported at Guanajuato. The entire Mexican bismuth output is imported in the form of bismuth-lead bars for refining in the United States. Bismuth was one of 17 minerals produced in Mexico to be included in the agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus as part of the foreign procurement program initiated late in 1940.

In Alaska, bismuth has not yet been brought into widespread commercial production, as reported on May 7, 1945, by the U.S. Geological Survey, but favorable possibilities have been indicated for important advances in the post-war period.

WORLD PRODUCTION OF BISMUTH, IN KILOGRAMS
(After U.S. Bureau of Mines)

Country*	1940	1941	1942	1943
Mexico (impure bars)	185,433	97,971	128,041	175,055
Peru:				
Refined metal	387,479	276,907	373,942	482,916
Bismuth-lead (alloy)	56,314	78,138	16,913	
Bolivia (exports)	18,700	22,604	8,896	12,419
China	40,000			
Argentina	4,880	10,040		20,900
Canada	18,479	6	156,605	180,347

* Other producing countries are Spain, Japan, Yugoslavia, Sweden, Belgium, U.S.S.R., Australia, Germany, France, and South Africa.

In Europe, the Trepca lead mines of Yugoslavia have a substantial by-product output of bismuth; large stocks of the metal are believed to have been available to Germany when France was conquered. Small supplies were probably secured from Spain and Sweden. In 1940, limited output was reported from China, South Africa, and Australia.

In China, bismuth oxide ores are the only sources of the metal other than by-product recovery.

Prices. The price of bismuth metal in ton lots on Jan. 1, 1946, was quoted at $1.25 a pound, which has continued in effect since 1940, as reported by *E & M J Metal and Mineral Markets;* on Sept. 30, 1946, $1.60.

Compounds used by the oil, paint, and drug trades sold at the following prices, 1940 through 1943: bismuth subcarbonate, $1.73 a pound (in 1943, $1.50); subnitrate, $1.48 (in 1943, $1.20); subgallate, $1.68 (in 1943, $1.40); subsalicylate, $2.50.

Metal duties set by the tariff act of 1930 and the revenue bill effective on June 21, 1932, corrected to Feb. 1, 1943, embracing revisions resulting from all reciprocal trade agreements, provided 7½ per cent for bismuth metal and 35 per cent for bismuth salts and compounds.

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CADMIUM

Properties. "The rarest of the common metals," cadmium is a metallic element closely related to zinc, with which it is usually found associated and which it resembles in color. It is the most plastic of the common hexagonal close-packed metals. Cadmium is one of the 16 industrial nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. Cadmium is white, capable of taking a high polish, easily fusible, ductile, and malleable. Fusible alloys of cadmium have the advantage of low melting point. (Cd, atomic number, 48; atomic weight, 112.41; melting point, 320.9°C.) Its specific gravity is 8.56.

The sulfide greenockite, or cadmium blende, occurs as an earthy coating on zinc minerals. Its color includes various shades of yellow and orange. Its hardness is 3 to 3.5; its specific gravity, 4.9. Cadmium oxide, a secondary oxidation product, is assigned to the periclase group of minerals.

Uses. In filling military orders, cadmium was required in an increasing quantity as a corrosion resistant in surface-plating metals, its uses limited only by price and supplies available. About half the total world supply had prewar application as a corrosion-resisting plating on iron. It is finding large application as a metal surface capable of high polish and as an alloy with copper, adding strength without sacrificing conductivity.

Greater demand has been indicated, since 1941, for cadmium-plated bolts and nuts for aircraft, plated wire cloth, plated shoe nails, and cadmium bearings and other alloys. Its principal value for bearing metals in aircraft is due to the low coefficient of friction; corrosion properties are improved by the addition of indium. Cadmium lowers the melting point of solders and of fuse metal. Copper alloyed with small quantities of cadmium is fabricated into trolley wire and welding rods. Bearings are made for heavy-duty applications, utilizing over 95 per cent of cadmium and small quantities of nickel, silver, and copper. The War Production Board reported 53 per cent of the cadmium allotted for bearings in part of 1943 was for civilian use, 21 per cent for ships, 8 per cent for aircraft, 7 per cent for ordnance, 8 per cent for other military purposes, and 3 per cent for export.

Cadmium compounds have various strategic uses. The sulfate is employed for making standard electric cells. The oxide, hydrate, and chloride are used in electroplating solutions. The halides are used in photography, and the

carbonate in ceramics. For luminizing maps and aircraft dials, cadmium-zinc sulfide is an important phosphor. Sulfide and sulfoselinide are standard agents for yellow and red colors, respectively, used in paints, ceramics, inks, rubber, and leather.

Luminescent paint made by mixing small quantities of cadmium sulfide with ordinary pigments is used on walls, ceiling, and floor of an operating room. This reduces danger from the sudden failure of lights during an operation, when light appears to pass through the solid walls and ceiling. The luminescent paint is activated by a mercury-vapor lamp with a black reflector.

Electroplating protective coatings on steel articles and parts consumed 90 per cent of the cadmium used in the United States in 1943. The WPB reported that 39 per cent of the cadmium required for this purpose was for aircraft frames, 17 per cent for aircraft engines, 14 per cent for ammunition, 6 per cent for other ordnance, 10 per cent for communications, 5 per cent for ships, 6 per cent for other military equipment and 3 per cent for civilian use. Cadmium plating was being replaced, where possible, by zinc and lead coatings.

A low-melting point alloy for use as solder is formed of lead with 10 per cent of cadmium and 10 per cent of tin. In dentistry, fillings for teeth are made from cadmium-mercury amalgam. Paint manufacturers have made increasing use of cadmium since 1941 for a wide range of colors, including reds, maroons, and yellows.

The cadmium ray has been used as a standard of measurement in lens grinding and in various other work that requires precise measurements. The cadmium line over a platinum-iridium meter bar offers a standard that can be reproduced, the measurements being made by means of an interferometer to calculate interference of light waves. Substitution of the mercury ray was announced in April, 1946, by Dr. Jacob H. Wiens, staff engineer of the Navy Electronics Research Laboratory at Berkeley, Calif. Mercury atoms are heavier and can be made to glow like a neon bulb at lower temperatures than cadmium atoms, producing a green ray. This new standard of measurement is capable of accuracy to within a billionth of a centimeter, or about ten times the accuracy of the cadmium ray.

Domestic Sources of Supply and Production. A license for exports was specified by proclamation of the President on Mar. 4, 1941. In that year, the Metals Reserve Company made its first commitment to acquire cadmium for stockpiling. It ranked twenty-seventh in cost of deliveries of stockpile items ($1,809,977), the cadmium inventory was $1,873,800 on Oct. 31, 1944. Designated by the WPB on Mar. 1, 1944, as insufficient for war uses plus essential demands, cadmium amounting to 836 tons was reported in govern-

ment stockpiles by *The Wall Street Journal* on July 17, 1944. The Office of Metals Reserve reported the stockpile at 6,013 short tons of cadmium on Oct. 31, 1945.

Stocks were reported in 1944 by the WPB to have been reduced one-third in spite of increased production. The vital importance of this metal was again stated in January, 1945, when the War Department urged greater production. Amended Conservation Order M-65 was issued by the WPB, taking effect on Apr. 13, 1945. This placed new restrictions on the use of cadmium because of increased military requirements. All purchasers were required to certify that the metal would be used for permissive purposes only.

Cadmium was included in June, 1945, by the WPB in a list of materials and products with nine other minerals and certain ferroalloys that were expected to continue in short supply for an indefinite period. WPB controls were removed from other materials, and it was anticipated that further changes in controls would be avoided. The WPB continued on Aug. 1, 1945, to list cadmium as critical; on Aug. 20, Order M-65 was revived to free this metal of all controls. The Civilian Production Administration included cadmium on Nov. 30, 1945, with those materials still in short supply. Monthly output was averaging about 50 tons under consumption. Cadmium Order M-389 was revoked by the Office of Price Administration on Mar. 22, 1946, when a specific list of products was issued on which CC ratings might be used to obtain cadmium.

The government stockpile was frozen on May 3, 1946, by the CPA in order to meet an anticipated loss of 45 per cent of cadmium production because of work stoppages due to strikes. Producers and distributors of cadmium were requested to put into effect voluntary rationing measures in order to spread the available supply. Strikes at smelters were stated to have cut production of cadmium from 662,000 to 350,000 lb. a month. The government-owned stockpile amounted to 685,472 lb. on Mar. 31, 1946. The OPA reported that releases would be made for emergency uses only.

In 1940, exports of metallic cadmium totaled 64 tons, and consumption increased 23 per cent. Metallic cadmium imported and sold by producers amounted to a total of 3,333 tons compared with 2,036 tons in 1938. Production, derived chiefly from zinc ores, was secured from 15 plants in the United States in 1940. Domestic production of cadmium metal in 1941 was 6,937,931 lb. valued at $5,498,404; cadmium in compounds, 295,600 lb. valued at $207,246, as reported by the U.S. Bureau of Mines.

Domestic output is based on ore reserves estimated at a 16-year supply computed from the annual rate of use in 1935–1939. Large submarginal domestic resources of cadmium, a deficient mineral, are available in terms of

prewar consumption, but greater dependence on foreign sources has been indicated for the postwar period.

The shortage of cadmium was cited by the WPB on July 11, 1945, as creating an engineering problem in finding a substitute for that metal in the manufacture of automobiles, the latter to be removed from rationing early in 1946.

CADMIUM INDUSTRY IN THE UNITED STATES, IN POUNDS
(After U.S. Bureau of Mines)

	1939	1940	1941	1942	1943
Production (primary)	4,790,500	6,363,600	7,233,500	7,370,969	8,466,963
Imports (metal)	309,874	27,491	147,378	53,298	48,891
Exports	*	387,118	171,858	283,630	169,265
Consumption†	5,900,000	6,178,000	7,766,000	7,659,000	7,381,000
Stocks (year-end)	*	2,844,200	2,610,643	2,408,992	3,466,635

* Data not published.
† Apparent consumption.

We have less than a 35-year peacetime commercial supply of cadmium and twenty other minerals . . . which we shall have to import in larger and larger quantities. . . . We cannot afford another prolonged war in 20 or 30 years. The prodigal harvest that we have reaped to win this war has bankrupted some of our most vital mineral resources. We no longer deserve to be listed with the British Empire and Russia as one of the "have" nations. We should be listed with the "have nots," such as Germany and Japan. Even more alarming than the fact that we are coming to the end of some of our known resources is the fact that we are uncovering few, if any, unknown deposits of minerals.

This was stated by Harold L. Ickes, Secretary of the Interior, in December, 1945.

Cadmium is one of the strategic and critical materials required for essential war uses and for which stockpiling is deemed the only satisfactory means of ensuring an adequate supply for a future emergency. The stockpile bill passed by Congress in July, 1946, created a development and conservation program to acquire and guard domestic reserves of cadmium, as set up by the War, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated the Procurement Division of the U.S. Treasury to buy reserve supplies of cadmium and other strategic materials, aided by the OMR and other government agencies.

World Production, Imports and Exports. World production, in 1938, amounted to 9,138,860 lb., half of which came from the United States. Canada produced 317,122 lb. in 1938; in 1942, 1,148,963; in 1943, 786,611; in

1944, 547,944 lb. valued at $602,738. In 1938, Germany produced 432,000 lb.; Poland, 244,000; Norway, 207,667.

The United States imports about 30 per cent of its supply from Mexico, cadmium being recovered from flue dust at Monterrey and Rosita and shipped for treatment to Denver, Colo. In 1941, Mexico produced semi-refined cadmium and concentrate amounting to 997 tons, all but 5 tons being exported. Cadmium was one of 17 minerals included in agreements negotiated with Mexico by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus as part of the foreign procurement program initiated in 1940.

WORLD PRODUCTION OF CADMIUM, IN KILOGRAMS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Australia (Tasmania)	175,150	‡	‡	165,821	‡
Belgian Congo	.....	.....	3,086	27,387	24,000
Canada	426,234	411,917	567,573	521,158	352,186
Mexico*	816,584	815,734	906,577	854,264	801,992
Peru	.....	.....	.....	2,000	3,653
United States†	2,172,926	2,886,484	3,280,976	3,343,397	3,840,474

* Cadmium content of flue dust.
† Metallic cadmium and cadmium content of compounds.
‡ Data not available.

Consumption of cadmium in Britain, as reported by the Directorate of Nonferrous Metals in December, 1945, was 377 tons, in 1944; in the first 9 months of 1945, 336 tons.

Prices. The producers' price for commercial sticks of cadmium, f.o.b. New York, on Apr. 1, 1946, was 90 cents a pound in wholesale quantities. This price was in effect from 1942. *E & M J Metal and Mineral Markets* reported the average price for 1941 at 88.443 cents; in 1940, 79.92 cents; in 1939, 59.16 cents. The average producers' and platers' quotation on Apr. 1, 1946, was 92.5 cents a pound; anodes and patented shapes sold to platers for 95 cents; in 1941, 93.43 cents; in 1940, 84.91 cents; and 1939, 68.87 cents. On Sept. 30, 1946, the price of commercial sticks was $1.25 a pound.

Prices in 1943 for compounds, as reported by the U.S. Bureau of Mines, were as follows: cadmium bromide, $1.65 to $1.91 a pound; cadmium lithopone red, 85 cents to $1; cadmium lithopone yellow, 55 to 65 cents; cadmium sulfide, $1.10.

The London price for commercial sticks of cadmium on May 10, 1945, was 5s. 4d. for a minimum of 1 ton.

The Canadian Agreement effective on Jan. 1, 1939, made a 50 per cent

reduction in the duty on cadmium. A duty of 7½ cents a pound applied on cadmium sticks, bars, and shapes, according to the tariff act of 1930 and the revenue bill effective on June 21, 1932, as corrected to Feb. 1, 1943, with revisions resulting from trade agreements.

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CALCIUM AND CALCITE (OPTICAL)

Properties. Calcium, a soft, lustrous, metallic element, is the fifth most abundant constituent of the earth's crust. Calcium represents about 3.63 per cent of the composition of the outer 10 miles of the earth's crust. It is one of the 19 industrial nonferrous metals used essentially as alloying constituents. It does not occur naturally in the free state. Similar chemical properties are shown by strontium and barium which, together with magnesium, constitute the "alkaline earths." Calcium is malleable and can be drawn into wire. Its specific gravity is 1.5. (Ca, atomic number, 20; atomic weight, 40.08; melting point, 810°C.) Its strong affinity for oxygen is one of the characteristics that has made calcium a commercial material.

Optical calcite (Iceland spar) is calcium carbonate, characterized by its purity, transparency, and perfection of crystalline structure. Its hardness is 3; its specific gravity, 2.71. Crystals suitable for optical uses must be clear and transparent; if in the form of rhombs, crystals must measure at least ⅞ in. on each edge and be free from cracks along cleavage planes and from twinning other than parallel to the base. Some color and a few inclusions in the calcite are allowable.

Uses. Calcite spar of optical grade represents only a small part of the material recovered from the few known deposits of Iceland spar. A minor quantity of chemically pure calcium carbonate is used by chemists in preparation of standardizing solutions for making volumetric analyses. Strong double refraction is utilized in the nicol prism to transform ordinary light rays into plane-polarized light. The petrographic microscope uses two nicol prisms of optical calcite, which are also essential parts of polariscopes, colorimeters, photometers, dischroscopes, and saccharimeters. The Polaroid Corporation, in 1943, used as much as 500 bl. a day of spar in making newly developed optical devices that had important military application.

In 1943 and early in 1944, optical calcite was in large demand for use in gun sights; however, toward the end of 1944, calcite was no longer required in approved equipment. Normal demand continued for small quantities of high-grade spar.

Metallic calcium, calcium-silicon, and other calcium alloys are employed in deoxidizing and scavenging steel. Additions up to 0.35 per cent of calcium in some magnesium castings reduce the heat-treating time and give an improved surface.

Calcium lead, containing 0.1 to 0.4 per cent of calcium, is employed in making cable sheaths, storage-battery grids, and bearings. In magnesium bearings, calcium improves the grain structure, workability, and corrosion resistance.

The calcium alloy "Frary" metal has been extensively used as a substitute for babbitt and other bearing-metal alloys that contain substantial percentages of tin. Calcium metasilicate (wollastonite) is used as a welding-rod coating, and other applications were reported to be in prospect in February, 1945. Calcium carbonate and calcium fluoride are employed as welding fluxes. Calcium is having increased application as a purifier in the refining of other metals, and as a medicine. The traditional method of making glass combines silica with oxides of calcium and sodium.

The main use of calcium chloride is in road stabilization, concrete mixing, coal cleaning, and airfield stabilization. The salines calcium chloride and calcium-magnesium chloride are derived from sea-water bitterns, well brines, and by-product liquors of the ammonia-soda process. The amount recovered depends on the market from year to year. Calcium chloride salt was used in stabilizing rolled sand fill on the Adak airfield in the Aleutians campaign. Calcium chloride is added directly to concrete mixes in order to obtain early strength, to prevent freezing, and to provide greater strength than ordinary cement. Postwar prospects show good demand in roadwork and construction projects.

Domestic Sources of Supply and Production. Calcium-silicon was placed by the Office of Production Management under direct allocation on July 29, 1941; the order was extended indefinitely on May 30, 1942. Calcium metal was placed informally under government allocation control early in 1943 and officially on Apr. 1, 1943, in Order M-303. The order was suspended on Aug. 18, owing to a balance of supply and demand.

The United States, principal consumer of calcium, has been a producing country only since 1936. Calcium metal, in 1942, was supplied chiefly by Electro Metallurgical Company, which expanded capacity. In 1944, production of 100 tons of wollastonite was reported at Willsboro, Essex County, New York.

Calcium-magnesium chloride (75 per cent of $CaCl_2$) production in 1941 was 165,932 short tons; in 1942, 224,527; in 1943, 199,796 tons valued at $1,549,565; in 1944, 200,964 valued at $1,621,227.

The first domestic deposit of optical calcite was opened near Taos, N. M., in 1939; since that year, there has been sustained output of high-quality material, including rhombs weighing up to 17 lb. In Park County, Montana, production started in 1943, followed by the opening of promising deposits in

Archuleta and Hindsdale counties, Colorado. Before 1937, consumption of optical calcite in the United States was limited to less than 300 lb. a year. In 1943, Polaroid Corporation started to search for a source of supply in Montana and California.

CALCIUM METAL AND CALCIUM SILICON IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN POUNDS
(After U.S. Bureau of Mines)

	1939	1940	1941	1942	1943
Calcium metal	41,719	11,900			
Calcium silicon	3,972,571	2,131,758	11,994	60,300	

CALCIUM CHLORIDE AND CALCIUM-MAGNESIUM CHLORIDE SOLD BY PRODUCERS IN THE UNITED STATES, IN SHORT TONS [75 PER CENT $(Ca, Mg)Cl_2$]
(After U.S. Bureau of Mines)

1940	1941	1942	1943	1944
99,536	165,932	224,527	199,796	200,964

The first commitment for the purchase of optical calcite by the MRC was made in 1943. The stockpile held relative rank in thirty-ninth place among the strategic minerals, based on delivery cost of $204,009. This value remained unchanged on the inventory of Oct. 31, 1944, with the notation that final details of sales to the Navy Department, where delivery was made at cost, had not been arranged. Optical calcite, 1 and 2 grades, amounting to 520 lb. was held in government stocks by the Reconstruction Finance Corporation through the OMR on Oct. 31, 1945, as reported by the CPA. Ceiling control on calcium was removed by the OPA in October, 1945.

Continuous production in Montana and California was maintained by the MRC from December, 1943, to September, 1944. In Montana, the calcite veins occur in Park, Sweetgrass, and Stillwater counties, cutting andesite and andesitic sandstone and shale. Calcite crystals of acceptable quality and size for optical use are found lining the sides of vugs. The largest crystal reported weighed 300 lb. and produced 30 lb. of acceptable material.

World Production, Imports and Exports. Iceland spar was produced in Iceland for many years from deposits that, apparently, are now exhausted. New deposits have been opened in Mexico. Small amounts are being imported from Spain and South Africa, but no records of shipments are available.

Calcium-silicon was imported from France (111,994 lb. in 1941) and from Canada (60,000 lb. in 1942). France is the main producer of calcium.

Prices. The price of calcium metal, 97 to 98 per cent, in ton lots, cast in slabs and small pieces, continued to be quoted at $1.85 a pound on Sept. 30, 1946, as reported by *E & M J Metal and Mineral Markets.* Prices in 1918 were upward of $20 a pound.

Calcium-silicon, 1942–1943, was 16½ cents a pound, f.o.b. Welland, Ontario.

The price of Iceland spar has fluctuated from $10 to $25 a pound, as reported in 1937 by the U.S. Bureau of Mines.

The following prices of calcium chloride were in effect, 1942–1943, as listed by *Oil, Paint, and Drug Reporter:* flake, 77 to 80 per cent, carlots, delivered, $18.50 to $35 a ton according to zone; solid, 73 to 75 per cent, $18 to $31.50 (in 1943, $34.50); 40 per cent solutions, $7.50 a ton, tank cars at works.

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CHALK

(English)

Properties. Largely calcium carbonate in the form of calcite, chalk is a white or grayish, soft, friable limestone composed mainly of the calcareous remains of marine organisms (coccolithphores). It is difficult to determine where, through consolidation and crystallization, chalk grades into marl or stone. All chalks have abundant cryptocrystalline material.

English and stratigraphically related French and North American chalks were deposited during part of the Upper Cretaceous period. Marl, occurring in unconsolidated deposits high in calcareous material, is rarely pure enough to be used in the preparation of whiting. Whiting is made from white limestone, white marble, marl, or lime or from the waste calcium carbonate sludge resulting from the manufacture of caustic soda. This whiting substitute differs from whiting made of chalk in that the substitute is whiter and has low capacity for absorbing oil and the individual particles are subangular rather than rounded. Whiting substitute made from marl usually has greater oil-absorptive capacity than that of whiting made from chalk, the two products being about the same in physical characteristics.

Uses. Chalk, as "Paris white," enters the manufacture of rubber goods, oilcloth, and wallpaper. Other important applications include the manufacture of fertilizer, plaster, Portland cement, mortar, and quicklime and as a writing material in the form of white and colored crayons.

Whiting (finely ground, pulverized, powdered, or chemically precipitated calcium carbonate) is important in wartime in the manufacture of explosives, medicines, calking compounds, and insecticides and in numerous chemical and industrial processes. Calcium carbonate powders of a color darker than whiting are employed as rock dust in coal mines in order to prevent dust explosions.

The rubber industry, in prewar years, consumed about 35 per cent of imported whiting (nearly pure calcium carbonate); the putty trade used about 10 per cent. Other applications are in the manufacture of paper as a filler for loading and coating, in the ceramic industry as a constituent of glazes and enamels, as a mineral filler and "extender" in paints, and in the manufacture of oilcloth and linoleum.

Domestic Sources of Supply and Production. True chalk formations occur in well-defined bands in the Central and Southern states. The Niobrara chalk is found in South Dakota, Wyoming, Nebraska, and Kansas; Austin chalk beds extend across Texas; Selma chalk, in Tennessee, Mississippi, and Alabama; and the Annona chalk in Arkansas. These beds resemble soft limestone of Florida, Georgia, and Alabama.

Negligible production on a commercial scale was reported before the war, and strategic applications continue to be dependent on material from sources in England.

World Production, Imports and Exports. English chalk is quarried in Kent, Surrey, Sussex, and other areas in Britain. Annual output is normally about 5 million tons. In 1940, imports of crude chalk amounted to 61,477 tons valued at $83,083; of whiting, 5,500 tons valued at $43,555; of precipitated whiting, 2,131 tons valued at $63,109. Prewar imports were also received from France, Belgium, Japan, and nine other countries.

In Canada, whiting substitute is produced by one operator each in Quebec and British Columbia and by four operators in Ontario. The new material used is white marble. Improvements in grinding equipment and maintenance of close technical control has produced a material that is consistent in chemical and physical properties, replacing the whiting formerly imported. Chalk whiting is required for certain uses. Canada imported whiting, crude chalk, and prepared chalk valued in 1944 at $334,744; in 1943, $303,190.

Prices. The price of crude imported chalk in 1940 was $1.35 per long ton; chalk manufactures (including some chalk crayons), $22.10 per 100 lb.; precipitated whiting, $1.48 per 100 lb.; other whiting, $8.95 a long ton; putty, $2.63 per 100 lb. Domestic whiting, 300-mesh, f.o.b. Georgia, was quoted at $7 to $8 a ton by *E & M J Metal and Mineral Markets* on Apr. 12, 1945.

In Canada, whiting substitute sells at $8 to $15 a ton, bagged and in carload lots, f.o.b. plants.

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CHINA CLAY (ENGLISH), BENTONITE, FIRE CLAY

Properties. Produced by the decomposition of various rocks, plastic earths consisting essentially of hydrated silicate of alumina are classified as china clay (kaolin or kaolinite), bentonite, and fire clay. These are secondary minerals formed at low temperatures by percolating solutions, causing decomposition of feldspar. In order to remedy the lack of uniformity in classifying clays, a series of 58 definitions was recommended in 1939 by the American Ceramic Society.

Bentonite is a claylike substance formed by the weathering or alteration of volcanic ash deposited in salt seas, salt and alkaline waters having dissolved fragments of other minerals. Of the two types, the northern, or true, bentonite is characterized by its unique swelling and gelation properties; the metabentonites show less marked swelling in water.

Natural bonded molding sand is composed of fairly pure silica sand with 3 to 30 per cent of plastic refractory clay. Mechanically prepared molding sand is made by the addition of bonding clay to silica. When moist, a molding sand can be formed into molds from which metal castings can be made.

Uses. Production of military equipment required greatly expanded production of certain clays, particularly for factories and housing. Both new and old uses of kaolin, ball clay, fuller's earth, molding sand, and bentonite gave these materials strategic importance. Completion of building programs for metal, power, and glass industries resulted in lower demand in 1943–1944. Demand for refractories continued strong, greater requirements being shown for bentonite and fuller's earth. With the exception of English ball clay and china clay, all needs were met from domestic sources.

The Army and Navy Munitions Board included English kaolin on the list of strategic raw materials because of its essential use in the production of high-quality ultramarine blue pigment, which represents only a small part of the total tonnage of kaolin or china clay consumed.

High-grade kaolin for ceramic use (low in iron and with only a trace of titanium) is gaining increased application for various filters and in special products. Georgia kaolins are employed as special paper coatings, the coarser fractions being sold to the ceramic industries. In the manufacture of earthenware, china clay gives added whiteness to the body and is more plastic than flint, which is used for the same purpose. Hard porcelain for the electrical

trade must be rich in sillimanite. There is no known substitute for china clay in the manufacture of electrical insulators. The use of substitutes in the manufacture of chinaware and paper results in the production of inferior grades.

South Carolina output consists largely of paper-filler and rubber clays; Georgia kaolin ranges from low-grade refractory material to the highest grade paper-coating clays. White high-silica kaolinite clays are used in white cements, as rubber filler, and as foundry clay. Insulating parts for high-power transmission lines and transformer stations are made of china clay.

Bentonite, produced principally in the United States, was first recovered commercially in 1888; but until 1927, output remained on a small scale. True swelling-type bentonite (type 1, alkali and alkali-earth bentonites) is increasing in importance for a variety of special uses, largely based on its adhesive or cementing properties, which are retained at high temperatures. When added to clays and refractory materials, it imparts plasticity. Purified ground alkali bentonite is useful as fillers, binders, and plastics. Other applications include sealing dams and reservoirs, surfacing highways, increasing strength and making a smoother texture and as a waterproof agent in Portland cement, and increasing plasticity and strength of clay mixtures in the ceramic industry. Clay of the "filtrol" type is used for bleaching purposes in oil refineries and packing houses.

Foundries and steelworks used about one-third of the total output in 1939 as a conditioning agent for rebonding synthetic molding sands. Bentonite-bonded sand requires about one-third the amount of fire-clay-bonded sand for equivalent results in making molds, cores, and washes. Other applications of alkali bentonite include deinking old newspapers, the preparation of insecticides, and the manufacture of paint, ink, and enamel. In 1943, 85 per cent of domestic production of bentonite was used as a bonding ingredient in foundry sands, for bleaching or decolorizing and filtering of mineral and vegetable oils and packing-house products, and to control the viscosity of oil-well drilling muds. Other applications of the colloidal or swelling type of bentonite include the following: as an emulsifying agent in asphaltic and resinous compounds, in soaps and detergents, and in clarifying wines and vinegar.

Metabentonite (type 2, alkali and alkali-earth subbentonites, nonswelling) is employed largely in the manufacture of acid-treated bleaching clays for oil bleaching and other purposes; as a coagulant in the white water at paper mills; as a filler for paper, oilcloth, curtain cloth, linoleum, and cordage; in foundries; and in preparing rotary-oil-well drilling muds, largely based on dehydrating and coagulating effects. Metabentonite in considerable amount is used in refining mineral and vegetable oils and in the treatment of fats and greases.

Fire clay is used chiefly for refractories. Prewar imported Klingenberg clay from Bavaria was employed in making graphite crucibles. Other uses of fire clay include heavy-duty products, chemicals, fillers, and pottery. English (Dorset) bond clay (bondite) and various fire clays were used as substitutes during the war years. Several industries made large demands for nonclay

CLAY SOLD OR USED BY PRODUCERS IN THE UNITED STATES, IN SHORT TONS, 1943
(After U.S. Bureau of Mines)

Use	Kaolin	Ball clay	Fire clay and Stone-ware clay	Benton-ite	Slip clay and others	Total
Pottery and stoneware	86,921	133,337	47,500	.....	13,699	281,457
Tile, high-grade	9,282	6,720	6,936	.....	.....	22,938
Kiln furniture, wads, saggers, pins, stilts	1,732	.....	36,550	.....	.....	38,282
Terra cotta	.....	.....	3,842	.....	.....	3,842
Paper filler, paper coating	545,186	750	389	.....	.....	546,325
Rubber	50,964	.....	10,259	.....	.....	61,223
Linoleum and oilcloth	4,468	1,400	5,474	.....	.....	11,342
Paints:						
Filler	16,242	57	284	.....	.....	16,583
Calcimine	490	.....	3,089	.....	.....	3,579
Cement	12,674	177	450	3,136	202,428	218,865
Refractories:						
Firebrick and block	136,793	1,668	2,926,683	.....	.....	3,070,364
Bauxite, high-alumina brick	154	.....	65,767	.....	.....	65,921
Fire-clay mortar	2,812	.....	334,237	.....	.....	337,049
Clay crucibles	1,120	.....	17,368	.....	.....	18,488
Glass refractories	220	.....	17,407	.....	.....	17,627
Zinc retorts	.....	.....	58,076	.....	.....	58,076
Foundries and steelworks	6,626	.....	813,819	181,412	23,970	1,025,827
Miscellaneous:						
Rotary drilling mud	.....	.....	787	68,841	185,097	254,735
Filtering oils	.....	.....	.....	158,671	237,852	396,523
Other filters	.....	.....	.....	836	5,016	5,852
Artificial abrasives	480	.....	1,594	.....	2,172	4,246
Asbestos products	3,768	1,500	1,332	.....	15,520	22,120
Chemicals	8,638	.....	80,796	1,237	.....	90,671
Enameling	.....	750	.....	.....	.....	750
Fillers (other than paper or paint)	2,068	.....	.....	2,830	80	4,978
Plaster	8,472	.....	.....	.....	210	8,682
Concrete admixture	.....	.....	.....	1,494	.....	1,494
Heavy-clay products	.....	.....	249,644	.....	377,670	627,314
Other uses	30,327	1,426	18,861	61,745	53,120	165,479
Total, 1943	929,437	147,785	4,701,144	480,202	1,122,064	7,380,632
Total, 1942	946,588	162,295	4,839,332	374,967	1,223,907	7,547,087

refractories, but no substitutes have been reported for the essential uses of fire clay in steelmaking, for high-temperature cements, or for plastic refractories. Semifire clay or stoneware clay is used in the manufacture of stoneware, pottery, tableware, and sewer pipe.

Ball clay of high bond strength is employed in a number of products, such as linoleum, refractories, and asbestos. More than 90 per cent of the output in the war years was used for pottery, and 5 per cent went into the manufacture of high-grade tile.

Postwar construction projects are expected to increase the demand for heavy clay products. New or improved products were being designed in 1944 in order to increase the economy of building-brick and tile construction by the use of common clay. Larger acceptance of bentonite and fuller's earth in new uses is expected to continue a large part of the increased output for war purposes. Kaolin and ball clay are in a position to hold the market in spite of high-grade materials which will be available from foreign sources. Among producers of building brick, tunnel kilns were reported to be receiving more attention as a postwar market. Of great benefit in war production was the progress made in quality and methods of processing. The brick and tile industry was ready to meet all reconversion needs, after overcoming postwar production difficulties and reconversion problems, it was reported on Oct. 23, 1946, by J. Ernest Fender, president of the Structural Clay Products Institute.

Domestic Sources of Supply and Production. The United States has become increasingly independent of foreign clay supplies in recent years owing to improved processes in the preparation of domestic materials. Froth flotation is used with sandy kaolins to yield a purified kaolinite that is free enough from grit for application as a paper filler. Georgia kaolin is now being dewatered continuously with "panel-type" Oliver filters. Both Georgia and North Carolina clays are reported to have a wider range of usefulness if the free silica content is removed, separation in the dry state being accomplished.

Georgia, the major kaolin-producing state, reported 512,214 short tons in 1939 valued at $4,135,727; output from South Carolina amounted to 158,629 tons worth $1,297,813; and a total domestic production from 15 states was 780,804 tons valued at $6,200,606. Domestic output of kaolin, china clay, ball clay, fire clay and stoneware clay, bentonite, fuller's earth, and miscellaneous clays increased from 4,847,519 short tons in 1940 to 7,380,632 in 1943. Maximum output in the war years was secured in 1942.

Principal occurrences of kaolin in the United States are located in Florida, South Carolina, Pennsylvania, Delaware, New Jersey, and Maryland. The deposits are sedimentary clays formed by the weathering of feldspar.

The United States produces and uses most of the world output of bentonite. Capacity production was reported in 1944, particularly for foundry, drilling, and filtering use; no cutbacks were made by the War Production Board. Bentonite deposits, from a few inches to several feet in thickness, occur in beds of Upper Cretaceous, Mesozoic, and Paleozoic age in many parts of the United States and Canada. Production is secured mainly from Wyoming, California, New Mexico, South Dakota, and Texas. Eight other states have deposits, chiefly of metabentonite, and some production is reported; twelve other states and Alaska have widely scattered deposits. Production increased 28 per cent in volume in 1943 over the previous year, to 480,202 tons valued at almost $3,000,000.

Fire-clay demand was strong in 1944 owing to the high level of activity of metallurgical furnaces. Production was secured in 31 states, led by Pennsylvania, Missouri, and Ohio. Production of fire clay and stoneware clay increased from 2,222,295 short tons in 1939 to 4,839,332 tons in 1942, the peak year.

Clay products, other than refractories and pottery, reached a maximum value of $102,740,000 in 1942, when raw clay sold by producers amounted to 7,342,843 short tons, as reported by the U.S. Bureau of Mines.

English china clay and bentonite were added to the list of materials exempted from all inventory controls by an order of the WPB on Sept. 30, 1945. The conservation division of the WPB had retained both materials in Group II as being sufficient for war uses plus essential industrial demands. A second revision of the WPB Inventory Control Regulation 32 placed English china clay and bentonite in Group III as readily available for essential uses.

World Production, Imports and Exports. Imports in 1939 consisted largely of high-grade china clay and other types having special applications in the pottery trade; exports were fire clays and bleaching clays. Imports of china clay (kaolin) decreased from the average of 140,888 short tons per year, 1930–1934, to 114,696 tons in 1939, when blue and Gross-Almerode glass-pot clays amounted to 20,404 tons. Imports were reduced to 71,478 tons in 1943, lower than in the previous year. Exports in 1943 were 163,539 tons.

English sources of kaolin and other clays were reported in January, 1946, to be reaching exhaustion as a result of wasteful methods of mining and utilization.

Brazil is stated to have what are probably the world's major deposits of kaolin. The clay is reported to be similar in quality to North Carolina kaolins.

China is normally the largest producer of china clay. The center of operations is in the Kingtehchen district of Kiangsi province, where the produc-

tion of chinaware started about 1,700 years ago. "Bone" clay (kaolin) gives strength and brittleness to the ware, which receives toughness and resilience from "flesh" clay, a mixture of feldspar and quartz. The Chimen district, Anhwei province, produces high-grade kaolins employed in the porcelain industry; good quality clays are also found in five other provinces of China.

In Japan, two-thirds of domestic pottery production takes place at Nagoya, where china-clay deposits have been formed by the decomposition of granite and the weathering of certain lavas.

Malaya, the Netherlands East Indies, Chosen, British India, Australia, and South Africa are sources of china clay. In Europe, kaolin deposits have long been developed for producing high-grade china and porcelain ware in Germany, France, Italy, Sweden, Czechoslovakia, and other Balkan countries.

German reparations to U.S.S.R. and Poland, Edwin W. Pauley stated on Oct. 11, 1945, were to be taken out of the eastern zone of occupation. U.S.S.R. and Poland were also to receive 25 per cent of the industrial equipment of the western zone, which was under control of the United States, Britain, and France. In exchange for this equipment, U.S.S.R. and Poland were to deliver various commodities including clay products, potash, and zinc equal in value to three-fifths of the amount received from the western zone. The United States had limited her reparations claims, to patents, samples of specialized machinery, "know-how," and German foreign-exchange assets.

Bentonite deposits are reported in Mexico, South Africa, New Zealand, U.S.S.R., Poland, Italy, France, Germany, and Japan. In Canada, the Morden deposit in southern Manitoba is the source of about 98 per cent of production, which increased from $4,122 in 1937 to $163,174 in 1944, including natural crude clay and activated material. Over-all production of clay products and other structural materials in Canada from Sept. 1, 1939, to Sept. 1, 1945, was valued at $259,000,000. Canada, in 1944, produced structural clay products made from domestic clays valued at $4,438,501; stoneware articles produced from domestic clays, $1,803,276; refractories produced from domestic fire clays, $386,088. Sales of clay products made from domestic clays in Canada during 1945 reached a total value of $8,305,000 compared with $6,760,000 in 1944, as reported by the Dominion Bureau of Statistics.

Prices. The price of domestic china clay (kaolin), f.o.b. South Carolina and Georgia mines, as reported on Sept. 30, 1946, by *E & M J Metal and Mineral Markets*, was as follows:

Sagger clays, $2.50 to $3.50 a ton; tailings, $4.50 to $5; No. 2 grades, $5.50 to $6; intermediate grades, $6 to $7.50; No. 1 grades, air-floated, crude, $6.75 to $8; No. 1 washed, $8.

Ceramic clays, air-floated, crude, $7.50 to $8; washed, $8.50; selected specialties, $9.50 to $10; coating clays, $11 to $22.50; special coating clays, $20 to $30 a ton.

Washed and crushed clays in bulk, f.o.b. Florida mines, $11.75 a ton; washed and air-floated, $14 to $15; enamel-grade air-floated, $18 to $20.

Virginia and North Carolina, f.o.b. mines: tailings, $4.50; crude, washed and air-floated, $7 and upward; ceramic grades, $14 to $15. Delaware No. 1, washed, $15 and upward.

Kentucky and Tennessee ball clay, $7; air-floated, in bags, $14 and upward. Maryland ball clays, shredded, in bulk, $3 to $7; air-floated, in paper bags, $10 to $18.25. Ball clays averaged $8.49 a ton in 1942; 1943–1945, $8.60.

New Jersey plastic kaolin, pulverized, in paper bags, $10.25 to $10.75; insecticide clay, $11.50 to $16.50. Pennsylvania crude clay, $6 to $7 a ton.

Under war conditions the price of kaolins varied widely, from $2.50 a ton for crude to $60 a ton for special products. The average for domestic kaolin in 1942 was $8.49 a ton; in 1943, $8.68. English china clay, lump in bulk, was $19 to $28 a ton; air-floated, $40 to $60, c. & f. United States port.

Number 1 fire clay imported from Klingenberg, delivered at Atlantic ports, was $38.50 a ton in 1939. Missouri, Kentucky, and Pennsylvania fire-clay brick, first quality, was priced at $51.30 per thousand; second quality, $46.55. Ohio fire-clay brick, first quality, was $43; intermediate grade, $36.10; second quality, $36.

Maximum Price Regulation 188 controlled prices of fire clay and common-clays. Maximum Price Regulation 327 was applied to kaolin, bentonite, and fuller's earth on Feb. 16, 1943; an amendment was later adopted to include ball, slip, and stoneware clays under the ceiling prices, in which some adjustments were later made for individual companies.

Bentonite, dried and crushed, f.o.b. Wyoming mines, in bulk, carload lots, was quoted at $7.50 a ton on Apr. 12, 1945; pulverized, 200-mesh, in 100-lb. bags, $9.50 to $11 a ton; 325-mesh, bagged, $16; crushed, in bulk, $7. California bentonite sold at an average of $12 a ton in 1939, as reported by the U.S. Bureau of Mines. Mine-run material is valued at $2 to $5 a ton; special pulverized products, up to $35 a ton.

In Canada, standard Wyoming-type bentonite sold at $27 to $30 per ton in 1944. Activated bentonite for bleaching use, delivered in eastern Canada, was quoted at $66 to $68 per ton, carload lots. Crude bentonite, f.o.b. mine, was $5. Alberta drilling bentonite, in bags, f.o.b. Calgary, was $38 per ton; f.o.b. Turner Valley, $40, the price being reduced to $35 in December, 1944.

Fuller's earth had an average value in 1942 of $10.42 a ton; in 1943, $10.56.

The Georgia-Florida district averaged $13.68; Illinois, $9; Texas, $7.73, in 1943. The price, f.o.b. Georgia or Florida, was $7 to $14 a ton on Aug. 1, 1946. Slip clay and rotary drilling mud were quoted from $4 to over $10 a ton; miscellaneous clays, less than $1.

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CHROMIUM ORE

(Chemical, Metallurgical, Refractory)

Properties. Having blue-white metallic luster, chromium is a hard, brittle, light gray, fairly ductile metal. It ranks sixteenth among the elements in primary abundance, forming 0.5 per cent of the lithosphere. (Cr, atomic number, 24; atomic weight, 52.01; melting point, 1830°C.)

Chromium is one of the 19 industrial nonferrous metals used essentially as alloying constituents. In the pure state, the element is used as an electrodeposited coating on other metals. Chromium in the periodic system is one of the oxygen group which also includes molybdenum, tungsten, and uranium. Cast chromium has a hardness of 4 to 5; chromium plating has a hardness of 9; its specific gravity is 6.92 at 20°C. It oxidizes at 1200°C.; but at temperatures up to 300°C., chromium is not affected by air, oxygen, or chlorine.

When sufficiently pure, it can be cold-rolled or drawn; it is freely plastic when prepared in the pure state. Widely adaptable in the stainless iron-base alloys, chrome-nickel steels are tough and withstand punishment at high temperatures. Chromium is resistant to corrosion from molten zinc, tin, brass, ammonia, lactic and acetic acids, and other industrial organic acids except oxalic acid. It is also resistant to corrosion from the atmosphere and sea water and from sulfur compounds. Chromium alloys can be bent while cold or welded to iron to form either a hard surface or a core that is impenetrable to the finest drilling tools.

Chromium metal is produced in electric furnaces through the agency of silicon as the reducing agent. For metallurgical use, chromium is converted into the high-chromium alloy known as ferrochromium, in which silica is a most objectionable impurity. The chrome-iron ratio desired for metallurgical use is 2 to 1; for refractory use, the ratio should be even higher. In wartime, low-grade domestic chromite has been crushed, washed, and mechanically concentrated into a much higher grade product.

When ferrochromium of very low carbon content is required, the thermic process is employed for reducing the ore. Chromic oxide is reduced by powdered aluminum. Oxidation of the aluminum and reduction of the chromic oxide generate an extremely high temperature.

Chromite, the important mineral of chromium, is assigned to one of three

divisions of the spinel group. It occurs principally in massive form in such basic rocks as peridotite and serpentine. Its hardness is 5.5; its specific gravity, 4.5 to 4.8. It has metallic luster, black color, and brown streak.

Uses. In classifying stockpile reserves, chromium, an essential steel alloy, is one of four minerals forming the first priority class. It was used in relatively small quantities in the First World War, but consumption has increased about ten times. Chromium salts (chromates and dichromates) have long been applied to refractories and chemicals and in dyeing, tanning, and pigment industries. Only recently has chromium been adapted as an alloying metal. The pure metal is used for electroplating on steel as a protection from oxidation and wear.

The great increase in the use of chromium in steelmaking is due largely to its high-strength and resistance to abrasion and corrosion. When added to steel, it increases hardness, toughness, susceptibility to magnetism, and resistance to acids. The most important use of chromium is in the manufacture of ferrochrome. All stainless (rustless) steels contain more than 11 per cent of chromium, some of it as high as 35 per cent. There is no known substitute for chrome in treating steel and in other alloys. The entire output in the United States has been utilized for war production.

In low-chromium steels, from 0.5 to 4 per cent of chromium is required to harden and strengthen the steel used in projectiles, armor plates, and cutting tools and for transmission parts of aircraft, tanks, and motor vehicles. Armor plate, armor-piercing projectiles, and machinery subject to abrasive action are fabricated from the intermediate chromium steels containing from 3 to 12 per cent of chromium either alone or as an alloy with such metals as nickel, vanadium, tungsten, and manganese. The military value of chrome metal applies to ordnance, transportation, and all steel parts that are subjected to hard usage.

"Rustless" steels, containing 12 to 18 per cent of chromium, and "superstainless" steels, containing from 12 to 30 per cent and generally 7 to 10 per cent of nickel, are used in the manufacture of exhaust valves, turbine blades, pump rods, rollers for bearings, electric heating stoves, and cooking utensiles.

High-speed tool steel, known as "stellite," contains 20 to 35 per cent of chromium with cobalt, tungsten, or molybdenum. These alloys give steel a hardness and cutting edge retained at high temperatures; under similar conditions, ordinary carbon tool steel would be softened.

In 1940, greater demands for steel production created a market for 75 per cent of the domestic chrome supply. Normally, three-eighths of the chromite used in the United States is employed in the manufacture of refractories for furnace linings. Chromite in the form of bricks and special shapes has come

into general use. Chromite bricks retain their shape under furnace temperatures. However, magnesite is a suitable material for furnace linings, but no known substitute is available for the manufacture of certain steels. No satisfactory substitute has been found for chrome in tanning chrome leather. Chromates for pigments (yellow, green and red) are widely used, and substitutes are more expensive. Chrome ore has largely replaced magnesite as a refractory for furnace linings. The postwar period will introduce applications in various industries, including food processing equipment, hospital and household supplies, transportation and chemical-plant equipment.

Domestic Sources of Supply and Production. War demand led not only to greater domestic use but also to heavy export requirements for aluminum alloys and chemicals, because of supplying ferroalloys to the British market and those chromium chemicals which formerly were produced in Germany to both Britain and Latin America.

Of the commodities purchased by the Metals Reserve Company, chrome ore was one of the first seven on which a commitment was made, in 1940. Chromium ranked eighth in cost of deliveries of stockpile items, and the chromium inventory held by the MRC on Oct. 31, 1944, was valued at $24,700,653 compared with total deliveries valued at $50,794,768. Government stocks held by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, included the following: chemical chromite, 51,595 long dry tons; refractory chromite, 236,855; low-grade domestic metallurgical chromite, 111,861; medium- and low-grade, 159,875; high-grade Russian, 236,297. Supplies of refractory chrome were estimated by the Civilian Production Administration to be adequate for the needs of industry, on Nov. 30, 1945. The Office of Metals Reserve held 703,097 long tons of chrome ore and concentrates on June 1, 1946.

Chrome represents one of the earliest strategic-metal problems to face war industry, with domestic production normally supplying only 3 per cent or less of requirements. In 1943, up to 60 per cent of the greatly expanded war demand could be supplied from two domestic low-grade areas. It was reported by the War Production Board at the close of 1943 that available chrome amounted to 1,100,000 tons. Government stockpiles of chrome ore were reported by *The Wall Street Journal* on July 17, 1944, at 1,051,651 tons.

The major development in chromite in 1943, as reported by the U.S. Bureau of Mines, "was the transition of the supply situation from one of anxiety to a comfortable working margin." Foreign supplies were maintained, and domestic production attained the all-time record of 160,120 short tons, in contrast to the critical supply conditions resulting from submarine warfare on shipping, 1941–1942.

The WPB applied complete allocation of chrome chemicals in September, 1943. A critically short supply for war needs affected primary chrome chemicals for use in pigments, chromic acids, surface treatment of metals, plating, tanning, textile processing, and dyes. In the manufacture of high-carbon ferrochromium, the WPB ordered a decrease in the quality of chromite used, in April, 1943. The WPB also ordered a reduction in ferrochromium consumption in stainless steel, 30 to 40 per cent of the chrome to be secured from scrap and ore. Early in 1944, the supply situation for chromium metal again became critical, the free-delivery allowance for smaller consumers being reduced from 3,000 to 250 lb. Chrome ore was removed by the WPB from import controls on Sept. 17, 1945. Consumption controls were also revoked on chromium and ferrochrome. The Office of Price Administration on June 12, 1946, suspended price controls from all products subject to chrome-ore price administration and the ferrochromium- and chromium-metal regulation.

Methods making possible the production of high-grade concentrate from domestic chrome ore have been developed to make the United States self-sufficient for a long war, even though no foreign ore should be available. However, Elmer W. Pehrson, U.S. Bureau of Mines, reported that domestic production of chrome has been too small to affect national requirements, and he estimates commercial reserves limited to a one-year supply based on the annual rate of use in 1935–1939; submarginal chromite resources (excluding commercial reserves) are assumed to be adequate for 5 to 25 years. The submarginal domestic resources of chromite, a deficient mineral, are available in terms of prewar consumption under emergency conditions and at a high price. For the postwar period, greater dependence on foreign sources has been indicated, as reported by Mr. Pehrson.

> We have less than a 35-year commercial supply of chromite and twenty other minerals . . . which we shall have to import in larger and larger quantities. . . .

This is according to Harold L. Ickes, Secretary of the Interior, in December, 1945.

Chromite is one of the strategic and critical materials required for essential war uses and for which stockpiling is deemed the only satisfactory means of ensuring an adequate supply for a future emergency. The stockpile bill passed by Congress in July, 1946, created a development and conservation program to acquire and guard domestic reserves of chrome, as set up by the War, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated the

Procurement Division of the U.S. Treasury to buy reserve supplies of chrome and other strategic materials, aided by the OMR and other government agencies.

The shortage of chromic acid was cited by the WPB on July 11, 1945, as creating an engineering problem in finding a substitute for that metal in making automobiles, the latter to be removed from rationing early in 1946. Refractory chrome was reported to be in adequate supply for industrial needs.

Low-grade domestic chromite ore is usually treated by gravity-concentration methods, although flotation may also be adapted to this problem. Domestic ore contains too much iron to yield a standard ferrochromium alloy, with the result that several methods have been developed for changing the chromium-iron ratio. Most steel manufacturers see no reason for changing to a process for making stainless steel from low-ratio domestic chromite ore while imported high-ratio ore is cheap and abundant.

Low chromium-to-iron-ratio chromite ore of the Stillwater Complex, Sweetgrass County, Montana, is used for making Chrom-X, an exothermic ferrochromium alloy used in the manufacture of low-chromium alloy steels. Montana chromite is reported to be suitable for the manufacturing of chromium metal products, as well as for making stainless steel by the process employed by Rustless Iron and Steel Corporation. The lack of a substantial market for chrome ore in Western states and the adverse effect of the high freight rates to Eastern manufacturing centers are conditions preventing utilization of large bodies of chromite ore developed in Montana.

A pilot plant for treating low-grade Montana chromite ore was operated at Boulder City, Nev., by the U.S. Bureau of Mines in an effort to increase the consumption of domestic ore for wartime requirements. The Benbow and Mouat-Sampson mines at Columbus, Mont., were operated by Anaconda Copper Mining Company, as agent for the MRC. At both of these low-grade properties, work started in 1941 and was suspended in 1943. The two mills had combined annual capacity of 1,080,000 tons and were built with approximately $12,116,000 of government funds. The chromite concentrator built by the Defense Plant Corporation at Marshfield, Oreg., at a cost of $581,000, had annual capacity of 144,000 tons and was operated by the Southwestern Engineering Company.

Increased supplies of foreign chrome ore and the improved alloy situation were given as reasons for the 30 per cent reduction in domestic output in 1944 (about 40,000 net tons shipped from domestic mines) as compared with 160,120 tons in 1943; in 1942, 112,876; in 1941, 14,259 tons valued at $274,062. Production in 1943 was from three states and Alaska; in 1942, from

six states; in 1941, from two states. Mining operations at two properties in Oregon and at one each in California and Alaska shut down in 1943–1944, when operations were also suspended at four mills or concentrators in Montana, three in California, and one (beach sands) in Oregon.

The Bureau of Mines examined several hundred chromite showings in many states, 1940–1944. Of these, 20 properties (8 in California; 4 in Montana; 3 in Oregon; 1 each in Georgia, Pennsylvania, and Wyoming; and 2 in Alaska) were explored and found to include 5,370,000 tons averaging 19 to 25 per cent of chromic oxide. In California, a major part of the ore was mined by Rustless Mining Company. In Montana, operations were terminated in 1944 but production of electrolytic chromium will be possible when cheap electric power is made available by the Missouri Valley Authority. In Oregon, a considerable part of the better ore has been mined, the balance consisting of low-grade beach sands. In Pennsylvania and Georgia, unsatisfactory results were secured. In Wyoming, the 575,000 tons averaging 8.7 per cent of chromic oxide are classified as an emergency reserve.

Chrome-alloy steel output, in 1939, amounted to 170,000 tons, increasing to 341,000 tons in 1942. Electric-furnace capacity for the manufacture of ferrochromium has been increased far above prewar capacities. Chrome refractories were in strong demand in 1944 because of the increase in activity of metallurgical furnaces.

World Production, Imports and Exports. World output in 1939 exceeded the record 1937 figures, at 1,167,000 metric tons. The major supply was derived from the following countries: Turkey, 191,083 tons; South Africa, 160,014; South Rhodesia, 139,083; Cuba, 67,061; Yugoslavia, 59,527; Greece, 57,091; New Caledonia, 52,000.

In 1938, Turkey was the major chromite producer, accounting for 19.4 per cent of world supply. Deposits are located along the Aegean coast and inland several hundred miles, near Erganimaden. These are reported to be the world's largest and richest deposits. Turkey usually produces about the same amount of chrome as Rhodesia. Germany was the largest customer, followed by the United States and France.

U.S.S.R. ranked second in 1938, with an estimated 18.2 per cent of world output, followed by Southern Rhodesia and South Africa. Russia is the only steel-producing country not dependent on imported chrome, Britain being dependent on imports from Africa. South Africa was the fourth largest producer after 1935, with half the production going to the United States. The British Empire is self-sufficient in chromite; United States and Japan have inadequate supplies; and other world powers depend almost entirely on foreign sources. The dependence of Europe on foreign sources of supply

is illustrated by the need for importing by far the greater part of chrome ore consumed.

The following table (see "World Minerals and World Peace") shows the origin and distribution of the 774,000 metric tons of chromite (figures in thousands of metric tons) exported in 1938 (shipments of less than 2,000 tons not shown).

1. *Southern Rhodesia*	
To: United States	105.4
Norway	28.4
France	24.4
United Kingdom	16.0
Germany	13.7
Belgium	9.5
Total	199.7
2. *Turkey*	
To: Germany	52.6
Sweden	41.0
Italy	32.2
United States	17.1
France	14.3
Norway	12.9
Hungary	3.9
United Kingdom	3.5
Finland	2.4
Czechoslovakia	2.4
Total	183.8
3. *Union of South Africa*	
To: United States	65.0
Germany	59.7
United Kingdom	9.3
Canada	7.5
Sweden	7.1
Australia	4.0
Total	157.7
4. *Philippine Islands*	
To: United States	54.1
Canada	4.7
Germany	2.2
Total	64.5
5. *New Caledonia*	
To: United States	29.0
Germany	7.3
France	3.3
Australia	3.2
Total	42.9
6. *Cuba*	
To: United States	40.2
Total	40.2

7. *Greece*	
To: Germany	14.0
United States	10.2
United Kingdom	2.3
Total	30.3
8. *British India*	
To: Norway	8.7
United Kingdom	5.1
Germany	4.3
United States	4.1
Poland	2.9
Total	25.2
9. *Yugoslavia*	
To: Germany	12.7
United States	3.0
Finland	2.9
Total	20.4
10. *Cyprus*	
To: Germany	7.5
Total	7.5

In the Philippine Islands, production started about 1930 and increased to 74,000 tons in 1938; in 1939, 126,749; in 1940, 194,393. Most of the ore was shipped to the United States, with minor amounts going to Canada and Japan. New Caledonia had a prewar output of more than 50,000 tons a year, chiefly for export to the United States. Canada, in 1944, produced 27,720 tons valued at $761,229; in 1943, 29,595; in 1942, 11,456.

Cuba, the principal source from 1941 through 1944 of refractory chromite for United States industry, has extensive ore reserves owned by United States corporations and capable of supplying domestic requirements for many years, contingent on favorable wage scales and prices. The main sources (grade averaging 35 per cent of Cr_2O_3) are the Camaguey, Moa-Baracoa, and Mayari districts. In 1941, production was 160,000 tons (prewar rate averaged 60,000 tons a year); in 1943, 340,000; in 1944, 170,000. In Venezuela, chromite deposits have been reported but are undeveloped.

Brazil, second largest producer in the Western Hemisphere, is followed by Canada and Guatemala. Refractory chromite, amounting to about 500 tons monthly in 1944, was produced from small, low-grade reserves in Campo Formoso and Santa Luzia, Bahia. Under normal conditions, this ore is undesirable for ferroalloy production, grading 35 to 48 per cent of chromic oxide and having a low chromium-iron ratio of 2.4 to 2.8 to 1. A smaller deposit is reported in Minas Geraes, which has exported limited tonnage. Chromite was one of 10 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for purchases from Brazil of

the entire exportable surplus as part of the foreign procurement program initiated late in 1940.

Chromite production in Canada, as a war project, secured ore from deposits in the asbestos district of Quebec, near the Vermont border. The Dominion Bureau of Statistics reported output as follows: in 1940, 335 short tons; in 1941, 2,372; in 1942, 11,456; in 1943, 29,595. Total production of chromite in Canada, Sept. 1, 1939, to Sept. 1, 1945, amounted to 71,000 short tons valued at $2,061,000.

In Alaska, total mineral production to the end of 1944 represented gold (70 per cent), copper (25 per cent), and eight other minerals including chromite (5 per cent). Postwar expansion in the output of chrome can be secured through systematic development, as reported on May 7, 1945, by the U.S. Geological Survey. In Kenai Peninsula, the U.S. Bureau of Mines developed 128,000 tons averaging nearly 20 per cent of chromic oxide, with a high chromium-iron ratio. Part of the area was in production in the summer of 1944. Chrome ore remaining in stockpiles of the MRC at Fairbanks, Anchorage, Seldovia, and Nome depots was sold to private industry in June, 1945. The disposal included stocks of four other minerals, as reported by the Territorial Commissioner of Mines.

Large chrome deposits are reported in the Selukwe district of Southern Rhodesia, where proved reserves are larger than those in Turkey.

Southern Rhodesia, following U.S.S.R. in volume of output in prewar years, supplied 15 to 25 per cent of world requirements, more than half going to the United States.

The United States imported 49 per cent of Southern Rhodesia's exports in 1939 (58,256 tons), increasing, in 1944, to 64 per cent, or 190,711 tons. In 1944, exports included 73,734 tons to Britain and 30,820 tons to Canada. Many small deposits in Yugoslavia, Greece, and Bulgaria made a substantial part of world output, chiefly for export to Germany. Russia and New Caledonia were sources of chrome ore imported by the United States in 1945.

All sources of Turkish and Balkan chrome available to Germany were cut off early in 1944, when Germany was seriously short, as reported by the Batelle Memorial Institute; Japan was believed to have a substantial stockpile. In Turkey, preclusive-buying operations by the United Kingdom Commercial Company and the U.S. Commercial Company succeeded in eliminating German purchases. The method followed was to force German purchasing agents out of the open market by bidding the price up to a point where German credits were exhausted.

Government foreign procurement combined with private purchases, in February, 1945, was at a yearly rate of more than 750,000 tons of chrome ore,

all imports being delivered at ceiling prices or less. In 1944, the Foreign Economic Administration followed the policy of withdrawing from public purchase of foreign refractory chrome when possible, returning the trade to former private channels if no impairment to the war effort resulted.

Purchases of foreign chrome amounted to 1 per cent of foreign metal and mineral procurement, valued at $51,000,000, as reported by Leo T. Crowley, Foreign Economic Administrator. These purchases were made from July 1, 1940, through Mar. 31, 1945, when uncompleted contracts amounted to $9,000,000.

Postwar supplies were expected by the FEA to continue adequate, including chemical and refractory ore and metallurgical chrome. An exception to this condition may apply for high-grade lump ore. Higher consumption is expected, particularly in the reconversion period. The speed of reconversion and postwar financing problems of private industry will be important factors affecting demand for chrome ore.

The Second World War demonstrated that such raw materials as bauxite, chromium, copper, high-grade iron ores, manganese, nitrates, tin, and uranium were among those imports essential to our national economy, it was reported on Oct. 25, 1946, by William L. Clayton, Under Secretary of State for Economic Affairs. The United States should give greater support to foreign investments of its nationals in strategic minerals that are in short domestic supply. It should be possible for America to back up the overseas investments of its nationals, in the case of minerals essential to national security, at least to the extent of the British tradition. The nation's dependence upon these foreign sources of supply controlled by our investments has now become a matter of national welfare.

Prices. The price of 97 per cent chromium was 89 cents a pound, spot, on Sept. 30, 1946; contract, 84 cents (usually sold as chrome-metal). *E & M J Metal and Mineral Markets* quoted the following prices:

Indian and African chrome ore, $43.50 a ton, 3 to 1 ratio, 48 per cent of Cr_2O_3; $41, f.o.b. cars at Atlantic ports, 2.8 to 1 ratio; $31, no ratio. Transvaal ore, 44 to 50 per cent, no ratio, $27.40 to $32.80. Brazilian ore, 44 per cent, 2.5 to 1 ratio, $33.65; 48 per cent, 3 to 1 ratio, $43.50. Rhodesian ore, 45 to 48 per cent, no ratio, $28.50 to $31; 48 per cent, 3 to 1 ratio, $43.50.

Domestic ore, 48 per cent, 3 to 1 ratio, $43.50, less $7 freight allowance. High-carbon standard-grade ferrochrome, 65 to 70 per cent, 13 to 14½ cents a pound of contained chromium, according to crushed size. Low-carbon standard rate, 19½ to 54 cents a pound. Chrome brick, $54 per thousand, f.o.b. shipping point; $36.50 for refractory ore, f.o.b. Chester, Pa.

Ferrochrome duty was fixed by the tariff act of 1930, corrected to Feb. 1, 1943, 3 per cent or more of carbon, 1.25 cents per pound of contained

chromium. Chromium metal was 25 per cent, according to the revenue bill effective on June 21, 1932, after revisions resulting from reciprocal trade agreements.

Effective Jan. 1 to June 30, 1945, both contract and small-lot purchases of domestic chrome ores containing a minimum of 10 long tons and for purchases of 500 to 3,000 long tons per contract were being made at the following depots of the MRC: Phoenix, Ariz.; Batesville, Ark.; Butte and Philipsburg, Mont.; Grants Pass and Seneca, Oreg.; and at seven points in California. In May, 1945, John W. Snyder, Federal Loan Administrator, announced that purchases of chrome ore by the MRC would be continued through Dec. 31 on premium lots of 50 tons per contract, at prices to be specified later. Although other depots would close on June 30, purchases would continue to be made at Batesville, Ark., and Grants Pass, Oreg. The MRC would pay freight charges to the nearest open stockpile or to the nearest sales point designated. In the first 4 months of 1945 the average deliveries at MRC depots did not exceed 125 tons. The Metals Reserve Division, WPB, announced in September, 1945, that chrome ore produced in Siskiyou County, California, would be accepted for purchase at Yreka for the Grants Pass stockpile. The ore was to be graded before shipment by a Federal engineer.

On Jan. 1, 1945, the base price was $52.80 per long ton of 2,240 lb. for ores analyzing 48 per cent of chromic oxide, chromium-iron ratio of 3 to 1; premium of $1.10 a ton for each 1 per cent of chromic oxide above 48 per cent. The premium was $1.50 a ton for each tenth increase in the chromium-iron ratio up to, but not exceeding, 3.5 to 1. Penalties were being charged at the same rate for grades down to a minimum of 42 per cent of chromic oxide and a chromium-iron ratio of 2 to 1.

Price stability of chrome and other alloy materials has been a notable achievement since 1941, in contrast to the inflation that marked purchases in the First World War.

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COBALT

(Ore and Oxide)

Properties. A silver-white metal slightly harder than iron or nickel, cobalt is magnetic at temperatures up to 1150°C., when it becomes nonmagnetic. The boiling point (1415°C.) is intermediate between corresponding temperatures for nickel and iron. Its density is 8.8. (Co, atomic number, 27; atomic weight, 58.94; melting point, 1480°C.) Cobalt is one of the 19 industrial nonferrous metals used essentially as alloying constituents.

The cobaltite group, including gersdorffite and ullmannite, has a hardness of 5 to 5.5; specific gravity, 5.819 to 6.65. These two minerals occur in high-temperature deposits and in veins, with other cobalt and nickel sulfides and arsenides. Nickel-cobalt minerals include skutterudite and smaltite.

Cobalt strongly resembles nickel in its appearance and properties, notably in its resistance to corrosion. Cobalt-nickel alloys have properties distinct from cobalt alloys with other metals.

Uses. The major use of metallic cobalt is in the manufacture of ferrous and nonferrous alloys, many of which are employed directly or indirectly in fabricating munitions. The metal goes into the manufacture of heat-resisting and corrosion-resisting alloys for cutting tools, drills, welding rod, stock for tipping tools, dies, valve steel, electroplating, and dental restorations. Cobalt speiss is smelted directly to yield ferronickel-cobalt alloy for the manufacture of special high-speed steels.

In 1943, 43 per cent of the cobalt used in the United States was in stellite or stellite-type alloys, containing up to 55 per cent of cobalt. The second largest use was in magnets and magnet steels (23 per cent of total consumption). About 14 per cent went into high-speed steels and other cutting-tool materials, valve steel, welding rod, and carbide-type alloys. The preparation of driers accounted for 13 per cent; ceramics, 3 per cent; electroplating, catalyst, and other uses, 4 per cent.

Cobalt, with a beryllium-copper alloy, is used for the hubs of aircraft propellers. No substitute has been found for the metal in permanent magnets for generators in gasoline engines of aircraft and tanks.

Telephone and radio magnets are made of cobalt-tungsten steel. High-speed cutting tools, including those made of stellite, which retain hardness at a red heat, are made of nonferrous alloys containing over 50 per cent of

cobalt, with tungsten, chromium, and molybdenum. One application of these special alloys is for electrical heating elements.

Stellite, cobalt-chromium-tungsten alloys, was first used commercially in 1917. The use of stellite tools has increased to include turning, milling, boring, and other operations on cast iron, steel, bronze, and other alloys in shops engaged in the mass production of duplicate parts. At temperatures above 600°C., these alloys are harder than any steel, recovering their original hardness after being heated to any temperature up to 1000°C. Cobalt alone has the property of retaining hardness under high temperatures. Stellite has an exceptional resistance to corrosion when subjected to many acids and chemicals. In wear resistance, stellite outlasts steel from four to thirty times.

In the manufacture of magnetic materials, iron-cobalt alloys show remarkable properties. Greater electrical conductivity than that of either component characterizes iron-cobalt alloys containing about 50 per cent of cobalt. Desirable magnetic properties are developed by precipitation-hardening treatments in iron-cobalt-molybdenum and iron-cobalt-tungsten alloys. A new type of small but powerful magnet, believed to be the lightest ever developed, was reported by General Electric Company in December, 1945. The magnet is fabricated of iron oxide and cobalt oxide, in powder form, which are molded and heated into solid form. The magnet is a nonconductor and is not easily demagnetized. It is adapted for use in high-frequency magnetic fields. In war service, this magnet was used in highly sensitive aircraft meters and other essential equipment.

A nickel-cobalt alloy containing 7.4 per cent of iron and 2.8 per cent of titanium replaces platinum in oxide-coated thermionic cathodes. An electrical-resistance material, composed of cobalt-chromium-aluminum, is used to operate furnaces at high temperatures.

In 1943, cobalt used in stellite and stellite-type alloys and in magnets and magnet steels increased greatly and accounted for two-thirds of consumption in that year. Although supplies declined for use in high-speed steel, there was a 5 per cent increase in consumption of cobalt in alloy ore and speiss. Imports increased, mainly from the Belgian Congo.

Cobalt salts are employed as a catalyst for pigments; in Germany, these catalysts have been used in the coal-oil industry. Cobalt compounds are used as "driers" in the paint and varnish industry and for linoleum, as blue and yellow pigments; cobalt oxide produces these colors and also red and purple, which are employed in ceramics.

Domestic Sources of Supply and Production. The principal North American source of cobalt is the silver area of Cobalt, Ontario, Canada,

which stopped production on Feb. 21, 1944, after termination of purchases by the Metals Reserve Company.

Domestic production of cobalt ore was chiefly from the magnetite mine at Cornwall, Pa., operated by Bethlehem Steel Company; cobalt content of the ore averages 1.34 per cent. Small by-product recovery was secured by Eastern Magnesia Talc Company, Burlington, Vt., and Sullivan Mining Company, Kellogg, Idaho, the latter processing zinc residues. St. Louis Smelting and Refining Company in 1944 started the recovery of cobalt near Fredericktown, Mo. The production of cobalt oxide was started in November, 1943, at the cobalt-nickel plant of Ferro Enamel Supply Company, Cleveland, Ohio. No figures are available on domestic production.

The U.S. Bureau of Mines has explored cobalt showings that extend over a large area in the Blackbird district, Lemhi County, Idaho. Deposits amounting to about 1,100,000 tons have been indicated by drilling and underground exploration, the grade estimated at about 0.6 per cent of cobalt and 1 to 1.5 per cent of copper. Production would involve difficult metallurgical problems.

Commitments for the purchase of cobalt were first made by the MRC in 1941. Cobalt ranked twenty-fifth among stockpile items purchased by the MRC, and the cobalt inventory on Oct. 31, 1944, was valued at $1,193,101 compared with a total cost of deliveries of $2,489,303. Government stockpiles of cobalt ore and oxide were reported by *The Wall Street Journal* on July 17, 1944, at 1,113 tons and 45 tons of cobalt-nickel compound. The Office of Metals Reserve reported the government stockpile of cobalt at 1,648 short tons. Some of the cobalt stocks are stored in Canada.

Restrictions on the delivery and sale of cobalt were removed by the War Production Board on Dec. 30, 1943, when vendors of more than 1,000 lb. in any one month were required to report to WPB. Cobalt was placed under complete allocation by General Preference Order M-39, as amended by the WPB on Mar. 9, 1943.

Supplies were ample in 1943 to meet the controlled requirements. Consumption of metal, oxide, salts, and driers was 32 per cent greater than in 1942. Cobalt adequate for industrial needs was reported by the Civilian Production Administration on Nov. 30, 1945. The Office of Price Administration on June 12, 1946, suspended price controls from all products subject to cobalt and certain other alloys and metals regulation.

Cobalt is one of the strategic and critical materials required for essential war uses and for which stockpiling is deemed the only satisfactory means of ensuring an adequate supply for a future emergency. The stockpile bill passed by Congress in July, 1946, created a development and conservation

program to acquire and guard domestic reserves of cobalt, as set up by the War, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated the Procurement Division of the U.S. Treasury to buy reserve supplies of cobalt and other strategic materials, aided by the OMR and other government agencies.

World Production, Imports and Exports. More than 75 per cent of world output is supplied by the small cobalt content of copper ores of Rhodesia, French Morocco, and the Belgian Congo. Annual production of about 5,000 tons was reported in 1938 and 1939 from 14 countries. The following origin and tonnage were reported in 1939: Northern Rhodesia, 1,502 tons; French Morocco, 720; Burma, 228; Canada, 208.

WORLD PRODUCTION OF COBALT, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Belgian Congo*	§	1,423	1,844	1,900	1,976
Bolivia (exports)†	.....	2	2	28	189
Canada†‡	332	360	119	38	80
French Morocco†	719	700	700	400	§
Northern Rhodesia*	1,598	§	§	§	§

* Cobalt alloy.
† Cobalt ore.
‡ Oxide and metal.
§ Data not available. Australia and Burma are minor producers.

COBALT IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN POUNDS
(After U.S. Bureau of Mines)

Product	1939	1940	1941	1942	1943
Metal	2,130,296	130,321	554,030	148,304	256,670
Ore	611,083	2,653,891	2,443,725	834,797	10,566,681
Alloy	.....	7,843,828	9,970,589	10,313,867	10,110,879
Oxide	680,644	756,759	38,002	.....	58,928
Sulfate	75,290	11,468	4,480		
Other salts and compounds	1,374	.....	500	200	56

The United States imported 5,692 tons in 1940, including 3,922 tons of ore from the Congo and 1,326 from Canada, 50 tons of metal from Belgium and 15 tons from Canada, 244 tons of oxide from Belgium and 89 tons from Canada.

Canada, ranking as third largest producer, in 1944 recovered 18 short tons valued at $34,106; in 1945, 55. The Deloro plant in Ontario, formerly

treating Canadian ore, has been used under war conditions mainly for treating imported ore from Africa. Canadian ore has been stockpiled.

Brazil has extensive cobalt deposits, as reported by M. L. Cooke, and had produced 1,200 tons of ore up to March, 1942; 700 tons had been shipped to Japan, and the balance was in stock. In an emergency, it was estimated that 20 tons a day could be mined and shipped by plane to supply urgent needs in the United States. Ore reserves are estimated at 50,000 tons, but additional deposits located in the state of Minas Geraes are available where reserves have not been indicated. At Sao José do Tocantins, state of Goiaz, oxidized nickel-cobalt ore deposits are among the important known concentrations of this nature in the world. Lack of rail and water transportation makes this inaccessible at present.

The Belgian Congo, the chief source of supply for the United States in 1943, shipped 4,357,335 lb. of cobalt in the form of alloy; French Morocco supplied 1,098,228 lb. of cobalt in ore. Canada shipped 256,670 lb. of cobalt contained in ore.

In the Belgian Congo, production is secured from straight cobalt ore and from high-grade copper-cobalt ore. The United States imported an average of 1,786 tons a year, 1940–1943. Following the Nazi invasion of Belgium, these imports represented the entire Congo production. Northern Rhodesia, ranking second as a cobalt source, secures production from copper-cobalt ores.

Germany, in 1943, had an estimated 250 tons of cobalt available, of which Finland supplied 150 tons, as reported by the Foreign Economic Administration. In December, 1944, Germany was reported to be reduced to a domestic output of about 100 tons a year. The dependence of Europe on foreign sources of supply is illustrated by the need for importing by far the greater part of the cobalt consumed.

In Mexico, cobalt was one of 17 minerals included in agreements negotiated by the Federal Loan Agency through the MRC for purchase of the entire exportable surplus as part of the foreign procurement program initiated late in 1940.

In 1944, the FEA followed the policy of withdrawing from public purchase of foreign cobalt when possible, returning the trade to former private channels if no impairment to the war effort resulted. Supplies from foreign sources are believed to be adequate for the postwar period.

The consumption of cobalt in Britain, as reported by the Directorate of Nonferrous Metals in December, 1945, amounted to 787 tons in 1944; in the first 9 months of 1945, 521 tons.

Prices. The price of cobalt remained unchanged from 1940 through Sept. 30, 1946, at $1.52 a pound for 97 to 99 per cent metal, in 100-lb. (case) lots; under 100 lb., $1.57; in 550-lb. (barrel) lots, $1.50, as reported by *E & M J Metal and Mineral Markets.*

Prices of black cobalt oxide for the ceramic industry ($1.84 a pound, 70 to 71 per cent grade, in 350-lb. lots) and for metallurgical plants ($1.06) have been in effect since October, 1939.

Cobalt ore, f.o.b. Cobalt, Ontario, was quoted at $1.10 (Canadian funds) per pound of cobalt, 10 per cent or more of cobalt contained, on Aug. 10, 1944.

Maximum prices for cobalt metal, fines, powder, oxides, and other alloys and compounds of cobalt were established on Nov. 2, 1943, by the Office of Price Administration. Cobalt ores, concentrates, and crudes were exempt from the price regulation.

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COLUMBITE

Properties. Columbite (also known as iron niobate) occurs in black, opaque crystals, frequently tarnished iridescent with submetallic luster. Its hardness is 6; its specific gravity, 5.2. Minerals of the columbite-tantalite series occur as crystals and compact masses in granite and pegmatite.

The metallic element columbium (called niobium in Great Britain) has an attractive yellowish color. Its specific gravity is 7.06; its hardness is almost equal to wrought iron. (Cb, atomic number, 41; atomic weight, 92.91.) It is malleable, may be welded, and has great resistance to corrosion by mineral acids and other chemicals and a high melting point (1950°C.). Ferroalloys may be made directly from the concentrate and the pure metal by electrolytic means or by alkali-metal reduction. Columbium is one of the 19 industrial nonferrous metals used essentially as alloying constituents.

Uses. Columbium, classified a few years ago as rare and having no industrial use before 1928, has become widely employed in steel for various war materials. One of the most critical metals of the Second World War, columbium is applied indirectly on a larger scale and directly to a minor degree. Employed in increasing quantity to prevent intergranular corrosion of stainless steel, columbium is important for inhibiting the air-hardening property in 4 to 6 per cent chromium steels of low carbon content. Corrosion-resistant steels containing 0.5 to 0.8 per cent of columbium are used in aircraft exhaust systems, supercharger systems, and engine parts exposed to temperatures exceeding 800°F. and subject to severe corrosion or conditions likely to result in fatigue failures. Columbium is reported to offer the most satisfactory solution to the problem of intergranular deterioration of stainless steels.

Small additions of ferrocolumbium make stainless steel more weldable, prevent "weld decay," and give resistance to excessive heat. An iron containing 3 per cent of columbium is used by General Electric in preparing a new precipitation-hardening alloy having remarkable qualities that may lead to substitution for expensive steels where it is necessary to boost the operating temperatures of steel turbines about 1000°F.

Columbium is much used in making chemical equipment and in welding rods for welding stainless steel. It is superior to titanium and to other substitutes as an alloy in the manufacture of stainless steel. Postwar use for jewelry

and tableware has been indicated, in addition to various new applications developed during the war.

Domestic Sources of Supply and Production. The more desirable occurrences of the mineral are either as columbite with a small tantalum content or as tantalite with a small columbium content. Unlike the ore produced in Nigeria, domestic and Australian ores are both mixtures of columbite and tantalite. The United States produced 2,470 lb. of columbium ore from New Mexico in the years 1938, 1939, and 1943. In the last year, as reported by the U.S. Bureau of Mines, production was also secured from Colorado (1,225 lb.), North Carolina (4,219), and South Dakota (137).

Output in 1944 was lower than in 1943, but the quantity has not been made public. Domestic production of columbium ore has been secured from the McKinney mines of Carolina Mineral Company and Whitehall Company, Inc., Spruce Pine area, North Carolina. Shipments were made by Robert A. Shipley, Canon City, Colo. Ferrocolumbium is produced by Electro Metallurgical Company, Niagara Falls, N. Y.

The first commitment for the purchase of columbium by the Metals Reserve Company was made in 1943. This metal held forty-first place among the stockpile items of the MRC, and the total cost of delivery was $23,772 compared with a value of $12 shown in the inventory of Oct. 31, 1944, Government stocks of columbium amounting to 33,991 lb. were held by the Reconstruction Finance Corporation through the Office of Metals Reserve, as of Oct. 31, 1945. The War Production Board revoked all controls on ferrocolumbium in September, 1945.

The WPB designated columbium on Mar. 1, 1944, as a ferroalloy insufficient for war uses plus essential industrial demands. Columbite amounting to 10 tons was reported in the government stockpile by *The Wall Street Journal* on July 17, 1944. There was no government inventory of columbite in 1943. The government stockpile held by the MRC at the end of 1943 held 11,371 lb. of columbite and 1,050 short tons of columbite-bearing slag. Columbium adequate for industrial needs was reported on Nov. 30, 1945, by the Civilian Production Administration.

Columbite is one of the strategic and critical materials required for essential war uses and for which stockpiling is deemed the only satisfactory means of ensuring an adequate supply for a future emergency. The stockpile bill passed by Congress in July, 1946, created a development and conservation program to acquire and guard domestic reserves of columbite, as set up by the War, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated by the Procurement Division of the U.S. Treasury to buy reserve sup-

plies of columbite and other strategic materials, aided by the OMR and other government agencies.

World Production, Imports and Exports. Imports in 1940 amounted to 595,220 lb., the chief source being Nigeria. This figure was more than five times the total amount imported in 1939. The best Australian tantalite carries a few per cent of Cb_2O_5 and upward of 70 per cent of Ta_2O_5.

In Brazil, columbite production has been increasing, stimulated by war prices. Output is secured from the central and southern areas of the state of Ceara.

Exports in 1943 were reported by the U.S. Bureau of Mines at 27 lb. of ferrocolumbium valued at $37. Imports are shown in the following table:

COLUMBIUM ORE IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN POUNDS
(After U.S. Bureau of Mines)

Country	1941	1942	1943
Argentina	2,914	.....	2,685
Belgian Congo	.....	36,422	
Brazil	2,229	1,133	
India	.....	.....	21,600
Nigeria	1,435,312	1,724,800	2,350,329
Uganda	.....	.....	3,111
South Africa	.....	.....	4,325
Total:			
Pounds	1,440,455	1,762,355	2,382,050
Value	$504,537	$608,917	$844,544

Nigeria, the principal world source of columbium ore, placed government license control over prospecting and developing the mineral. The discovery of columbite in British Guiana was reported. Argentina, in 1942, exported 5 metric tons of columbium-tantalum ore. Before the Nigerian deposits were brought into production in the early 1930's, only one producing property, in West Australia, was operated for columbite-tantalite ores.

In 1944, the Foreign Economic Administration followed the policy of withdrawing from public purchase of foreign columbite when possible, returning the trade to former private channels if no impairment to the war effort resulted.

In U.S.S.R., the discovery of rich deposits of columbium ore in the middle Ural Mountains was reported on June 16, 1946.

Prices. The price of columbium metal through June 1, 1945, was $560 a kilo for rod and $500 for sheet ($227 to $254 a pound). These prices were in effect from 1940, as reported by *E & M J Metal and Mineral Markets.*

Columbium ore was purchased at 25 cents a pound (gross weight, no payment for Ta_2O_5 content).

The price of ferrocolumbium, 50 to 55 per cent, was $2.25 to $2.30 a pound of contained columbium, f.o.b. producer's plant.

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COPPER

(Ore, Matte, Refined)

Properties. One of the six great nonferrous metals, copper ranks seventh in value of the domestic minerals produced. "No other metal has rendered such dependable service for so many uses, for so long a time." It is the most abundant and most important of the base metals. Copper is one of the 16 nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. (Cu, atomic number, 29; atomic weight, 63.57; melting point, 1083°C.)

Copper-type atomic structure is common to gold, silver, and lead native metals, which are similar in physical properties. Copper and gold show complete mutual solubility, whereas copper and silver are mutually insoluble. Copper takes about 4 per cent of arsenic. The metal is highly ductile and malleable; it is an excellent conductor of heat and has a higher electrical volume conductivity than any other metal except silver, 39 per cent greater than aluminum, although the latter has double the mass conductivity.

Copper is of primary importance in the electrical industry, due to its tensile strength and resistance to corrosion, in addition to its qualities as a conductor. Its hardness is 2.5 to 3; its specific gravity, 8.95. Properties found only in copper or its alloys are superior ability to carry electric current and to transfer heat, freedom from rust and resistance to corrosion, ready workability, bearing and spring qualities, strength and durability.

Chalcopyrite, the most widely occurring copper mineral, alters to chalcocite, covellite, chrysocolla, malachite, melaconite, and iron oxides. Commercial ores also contain native copper, cuprite, bornite, azurite, and enargite. Chalcopyrite is brittle and has a metallic luster and a brass-yellow color, often tarnished and iridescent. Its hardness is 3.5 to 4; its specific gravity, 4.1 to 4.3. Ores produced in the United States have an average copper content of about 1.4 per cent from the 20 per cent average treated in 1851. Accessory metals recovered by electrolytic refining include zinc, selenium, tellurium, arsenic, antimony, bismuth, molybdenum, and platinum.

Copper ore is first treated in a concentrator, and the resulting concentrate, together with other ores, are treated in furnaces for reduction as matte, having 25 to 55 per cent copper content. This is again treated in converters and reduced to blister copper. After refining, copper is cast into standard

marketable shapes. Electrolytic refining is necessary before copper is converted into finished products. The treatment process from ore to refined metal requires a period of about four months.

The four major copper areas are (1) United States (Rocky Mountains and Great Basin), (2) United States and Canada (Precambrian Shield of Michigan, Manitoba, Ontario, and Quebec), (3) Peru and Chile (west slope of the Andes), and (4) Northern Rhodesia and the Belgian Congo (central African plateau).

Casting copper, made from ore and scrap, usually analyzes 99.50 to 99.75 per cent. Copper smelted in Chile (known as Chile bars) grades 95 to 99 per cent pure. British grades include (1) best selected (99.75 per cent for brass trades), (2) tough (99.25 per cent for casting, rolling, and drawing), and (3) standard (94 per cent and upward).

In 1942, copper was classed by the U.S. Bureau of Mines as "probably the outstanding critical metal."

Uses. As strategic materials, copper and iron are equally indispensable. Hundreds of essential war functions, particularly in transportation and communications, have been performed with copper, brass, bronze, and special copper alloys, in the fabricated forms of wire, sheet, tube, etc. Copper's unique value in the manufacture of cartridge cases from copper-zinc alloy, the broad application in fabricating other war equipment, and the major use as an electrical conductor, all contribute to the indispensable place held by this metal. "An army without copper would be an army without speed, maneuverability, communications, or fire power," said Secretary of War Patterson.

The incendiaries M-69 and M-74, the most effective weapons used against Japan before the atomic bomb, were made by General Electric Company. Copper brazing metal was thrown into each casting, which then entered electric furnaces for roasting at a temperature of 2050°F. The copper closed all joints, forming an alloy with the steel casting to make resistant joints that protected the inflammable gell gas.

Copper averages more than 80 per cent of the alloy with zinc in readily workable brass and with tin to make bronze having strength, flexibility, and resistance to wear and corrosion. Of domestic consumption, more than one-third goes into electrical uses, with copper used in the manufacture of generators, motors, electrical locomotives, and switchboards. Rod and wire, in 1940, required 120,000 tons; automobiles, 103,000; buildings, 102,000; light and power lines, 74,000; telephones and telegraphs, 49,000.

In the nonferrous-alloy industries, copper accounts for one-third of the metals used. Bronze welding rod is employed for building up worn surfaces and making repairs to cast iron, malleable iron, steel, or copper-alloy parts.

Phosphor-bronze welding rod produces welds of high tensile strength. Phosphor bronze, an alloy of copper, tin, and phosphorus, is highly resistant to corrosion, fatigue, abrasion, and friction; this alloy is used in making springs. Fine bronze wire is used for Fourndrinier machines in papermaking. Brass is the material on which the type founder carves the original type designs. Smaller brass plates become the molds, or matrices, in which the type is cast. Large-diameter seamless copper tubes are used for pulp lines in paper mills, where phosphor bronze forms Jordan bars and doctor blades and where screen plates and pans are made of copper-silicon alloy.

Copper is employed in powder metallurgy for producing intricate gears and parts. Cuprous oxide has special application in antifouling paints for ship bottoms. Copper paint is one of the most durable surface finishes.

Scrap supplies will probably be absorbed by postwar reconstruction, particularly in the electrical industry which normally has taken about half the annual output of copper. In peacetime, a large part of the copper supply is returned as secondary, or scrap, metal for refabrication. Expansion in the electrical power, automobile, housing, and railroads industries may be expected to utilize substantial copper supplies; however, it appears that postwar requirements will be considerably lower than the greatly expanded demand for war materials.

The wide range of substitutes for copper indicates that new applications may be developed if warranted by price differential. In 1942, steel shell cases gave generally satisfactory service at a time when critical needs for copper affected many war plants; thus, millions of pounds of copper were released for other uses. In prewar Europe, aluminum was used to replace copper in high-tension transmission lines, and zinc replaced, in part, other essential uses.

Domestic Sources of Supply and Production. Copper, although formerly available from domestic sources for all requirements, was supplemented by large imports to meet heavy war requirements. Domestic production exceeded output in the First World War to only a limited extent, mainly owing to depleted ore reserves. Between 1929 and 1939, domestic production dropped 28 per cent, according to the American Bureau of Metal Statistics. Proved and inferred reserves in 1944, estimated at 1 million tons of recoverable metal and an additional 10 million tons available from submarginal resources, indicate dependence on imported copper within the next 10 years.

Domestic ore reserves adequate for 34 years, in terms of the average rate of consumption, 1935–1939, were reported in April, 1945, by Elmer W. Pehrson, U.S. Bureau of Mines. Of total reserves of copper ore, only 40 per cent remains unmined. This figure indicates only the quantitative significance

of estimated reserves and does not imply that reserves could sustain consumption at the assumed rate for the full period. A 25-year supply is calculated for submarginal copper-bearing material, of which the availability is highly speculative or remote because of uncertainties in basic estimates, high costs of recovery, or technologic problems involved. Harold L. Ickes, Secretary of the Interior, in December, 1945, reported:

> We have less than a 35-year peacetime commercial supply of copper and twenty other minerals . . . which we shall have to import in larger and larger quantities. . . . We cannot afford another prolonged war in 20 or 30 years. The prodigal harvest that we have reaped to win this war has bankrupted some of our most vital mineral resources.

Copper amounting to 5 million tons was mined between Jan. 1, 1940, and Jan. 1, 1945.

Domestic output is mined and smelted chiefly in Arizona, Utah, Montana, New Mexico, and Nevada, where ore reserves are estimated, by an authority independent of the U.S. Bureau of Mines, to be good for production only until 1955. This calculation had been published prior to the report by Mr. Pehrson. Arizona and Utah have combined output representing two-thirds of the United States total, the decrease in 1944 in both states amounting to about 12 per cent. Utah Copper Company, the major producer, treated a daily average of about 80,000 tons in 1944; in 1943, 96,920. In Arizona, the Morenci mine of Phelps Dodge Corporation held second place in 1944, increasing concentrator and smelter capacity from 25,000 to 45,000 tons of ore daily. Total capacity of the six copper smelters located in Arizona is 4,750,000 tons a year, as reported in 1945.

Copper refining and fabrication take place on or near the Atlantic seaboard. In 1943, mines, mills, smelters, and refineries employed more than 50,000 people. Consumption, in 1940, at 1,070,000 short tons, was 41 per cent higher than the 801,000 tons consumed in 1939, 13 per cent above the previous record of 1929. The U.S. Bureau of Mines reported copper production at primary plants from domestic ore, in 1940, at 927,239 tons; in 1941, 975,408; in 1942, 1,064,792; in 1943, 1,082,079; in 1944, 973,852 tons valued at $260,496,000 (exclusive of premium payments to the mines). The 8 per cent reduction in 1944 was reported to be due largely to the labor shortage. The American Bureau of Metal Statistics reported domestic refined copper, in 1944, including secondary metal plus refined copper from abrood, at 1,803,-200 tons; copper contained in ores and metallurgically recoverable, 968,191 tons.

Preliminary figures for domestic production in the first 10 months of 1945 show 651,151 short tons, with output in August representing a low for many

years. In 1944, total domestic output included 14,831 tons from Eastern states (6,146 in the first half of 1945), 45,369 from Central states (19,153), 909,585 from Western states (386,308), 4 from Alaska. Consumption of new copper in 1944, as estimated by the U.S. Bureau of Mines, was 1,587,000 tons. Consumption, including imports, was reported by the Copper Institute at 1,643,955 tons in 1943; in 1942, 1,635,236.

UNITED STATES CONSUMPTION* OF COPPER, IN SHORT TONS
(After U.S. Bureau of Mines)

Year	Tons
1939	714,873
1940	1,008,785
1941	1,641,550
1942	1,678,091
1943	1,621,666
1944	1,632,709
1945	1,527,500

* Including primary or virgin copper and some refined secondary metal exports not determined separately, but excluding exported copper wire, sheets, etc.

Works	Location	1942*	1944*
American Smelting and Refining Co....	Barber, N. J.	168,000	174,000
American Smelting and Refining Co....	Tacoma, Wash.	126,000	126,000
Anaconda Copper Mining Co.....	Great Falls, Mont.	180,000	180,000
Inspiration Consolidated Copper Co....	Inspiration, Ariz.	39,000	39,000
Lewin-Mathes Co.....	East St. Louis, Ill.	30,000	30,000
Phelps Dodge Refining Corp.....	El Paso, Tex.	158,000	220,000
Phelps Dodge Refining Corp.....	Laurel Hill, N. Y.	138,000	138,000
International Smelting and Refining Co. (Rariton Copper Works).....	Carteret, N. J.	190,000	190,000
Canadian Copper Refiners.....	Montreal East, Quebec	112,000	112,000
International Nickel Co. of Canada.....	Copper Cliff, Ontario	168,000	168,000
Total.....	.....	1,873,000	1,905,000

* In short tons at end of year; 1943 and 1944 identical.

Copper stocks held by fabricators at the end of 1943 decreased sharply to an estimated 360,000 tons, as a result of cutbacks for armament. The apparent deficit between supply and needs was reported at 230,324 tons at the end of August, 1944, compared with an apparent deficit of 245,215 tons at the end of February, 1945, when stocks on hand plus orders with producers made a combined total of 401,308 tons.

Fabricators' stocks of refined copper were 333,250 tons at the end of February, 1945; at the end of October, 368,042. Copper content of finished

and semifinished fabricated products shipped in February totaled 165,387 tons, an all-time monthly record. In addition to the large government-owned stockpile, stocks of refined copper at primary smelting and refining plants at the end of 1940 amounted to 91,500 tons; in 1941, 77,500; in 1942, 84,000; in 1943, 68,500; in 1944, 80,000. Stocks in producers' hands at the end of March were 51,861 tons; at the end of February, 57,142; at the end of November, 74,425. Primary production in March, 1945, was reported by the Copper Institute at 76,234 tons; in February, 67,496. Refinery production of copper from domestic sources in 1945 was 776,000 tons plus 324,500 tons from foreign sources. Domestic output in 1944 was 973,582 tons.

UNITED STATES SMELTER PRODUCTION OF COPPER FROM DOMESTIC ORES, IN SHORT TONS
(After U.S. Bureau of Mines)

	1939	1940	1941	1942	1943	1944
Alaska	152	64	95	33	31	4
Arizona	234,856	287,267	328,550	388,394	397,434	368,549
California	4,245	6,546	4,015	1,019	8,522	13,200
Colorado	12,774	13,186	6,483	1,249	1,134	1,257
Idaho	2,316	3,690	3,551	3,889	2,330	1,440
Michigan	44,702	45,743	46,752	47,470	45,498	42,334
Montana	101,756	129,071	128,712	140,465	138,295	117,856
Nevada	92,271	78,621	80,518	83,434	71,553	61,109
New Mexico	37,042	70,484	73,848	79,598	78,804	70,267
Utah	163,059	248,732	270,647	317,717	325,961	301,676
Other states	19,502	25,680	22,901	24,723	23,377	25,691
Total	712,675	909,084	966,072	1,087,991	1,092,939	1,003,379

It was reported late in 1943 that copper supplies were available equal to total requirements of the United States, Canada, and the United Kingdom. These three countries appointed representatives who formed the Combined Copper Committee on Feb. 10, 1943; and since that time, the committee has functioned in assembling and reviewing data relating to supply and consumption.

Early in May, 1943, the Combined Raw Materials Board urged that production from all sources be maintained as far as practicable. The Office of War Information announced on Jan. 1, 1944, that copper was in plentiful supply after having been desperately short in the previous 6 months.

The Combined Materials Plan, under which copper, aluminum, and steel were allocated, came to an end on Sept. 30, 1945. With the termination

of priority ratings, minor preferences were adopted to allow for military needs and to overcome reconversion difficulties caused by bottlenecks of raw materials and equipment. Cancellation of armament orders after VJ-Day led to further reduction in copper requirements below the figure for July.

The CRMB was expected to continue its functions after VJ-Day. The U.S. Treasury was reported, in August, 1945, to be purchasing 15,000 tons of copper for France and 4,000 tons for Italy.

Before the beginning of 1942, complete priority control was placed on copper, copper-base alloys, and copper scrap. War Production Board orders were issued through 1945 concerning restrictions on various uses. In September, 1942, the supply situation had become so tight that the Army and Navy and the Maritime Commission agreed to rigid restrictions confining copper consumption to vital war uses. In the third quarter of 1942, the Production Requirements Plan (PRP) was put into operation for the purpose of providing stricter controls on distribution. This was replaced in the second quarter of 1943 by the Controlled Materials Plan (CMP), under which the WPB gave authorization to individual firms for material.

In September, 1943, the new copper supply and its actual consumption by the United Nations had reached a rough balance, as reported by the CRMB and Combined Production and Resources Board. Shipments of copper from Africa to England had been speeded by the opening of the Mediterranean to Allied shipping. This state of balance could be continued, it was reported, by maintaining production rates of new copper, the collection of scrap, and the acceptance of steel cartridge cases.

Expanded output for 1944 was announced by Charles E. Wilson of the WPB, in December, 1943. The projected over-all total was 80 per cent higher than 1942 production. Small-arms ammunition was to be 142 per cent higher in 1943; in 1944, the rate was to be only 60 per cent of the 1943 rate; but for artillery ammunition, the 1943 output was 70 per cent above 1942 and 120 per cent above that level in December, 1943. A further 25 per cent increase was required in 1944. Other war construction that involved larger copper demands in 1944 included aircraft production (235 per cent greater than in 1942), merchant-ship construction (145 per cent above 1942), and big-truck production (100 per cent above 1942).

Within the year following VE-Day (May 8, 1945), copper requirements were estimated by the WPB at 2,350,000 a year, compared with 1,516,000 tons a year estimated by the Copper Producers' Advisory Committee on Sept. 19, 1944. Consumption in 1937 was 1,750,000 tons. In May, 1945, the copper division of the WPB stated that military uses of copper would be reduced about 15 per cent after VE-Day, representing a cutback of 250,000 tons of

copper per quarter from the level scheduled for the second quarter of 1945. The increase in the capacity of brass production led to abandoning the program for substituting steel for brass in cartridge-case manufacture at the end of 1943. In terms of refined copper content, a saving in actual use of 74,000 tons resulted in the first 3 months of 1945. It was reported in June, 1945, that copper would continue in short supply for nonessential uses.

Government stockpiles reported by *The Wall Street Journal* on July 17, 1944, amounted to 263,959 tons of refined and blister copper, 1,780 tons of anode scrap, and 155,367 tons of copper ore. At the end of March, 1945, stockpiles were estimated at 285,000 tons; on Dec. 31, 1945, the Office of Metals Reserve held 570,190 tons of which 321,363 was refined and the balance was in process. The Truman Committee investigating the war-production program in March, 1944, announced that surplus copper output at the end of the year would exceed 7,000 tons compared with earlier indications of a 163-ton surplus. Surplus copper held in August, 1945, in the government stockpile was estimated at 400,000 tons, in addition to 385,000 tons held by fabricators and 70,000 tons held by refiners. These supplies did not include copper in the form of military scrap. A large part of world requirements for several years can be supplied from military scrap. The large supply of scrap will serve as a postwar threat to the copper industry, even though surplus tonnage is now placed in government stockpiles.

Copper is one of the strategic and critical materials required for essential war uses and for which stockpiling is deemed the only satisfactory means of ensuring an adequate supply for a future emergency. The stockpile bill passed by Congress in July, 1946, created a development and conservation program to acquire and guard domestic reserves of copper, as set up by the War, Navy, and Interior Departments. Stockpiling policy is directed by the three-man Army and Navy Munitions Board. The stockpile bill designated the Procurement Division of the U.S. Treasury to buy reserve supplies of copper and other strategic materials, aided by the OMR and other government agencies.

The Metals Reserve Company was paying premiums on about 17 per cent of domestic copper output, as reported in March, 1945. Premiums totaling $53,609,000 had been paid through Oct. 31, 1944, on 495,019 tons produced in excess of established quotas. Premiums amounting to $262,500,000 were paid on 246,908 tons produced in 1944, when bonus payments were made on 25 per cent of total output; in 1943, on 23 per cent; in 1942, on 11 per cent of tonnage produced. Bonus payments in 1945 covered 25 to 30 per cent of domestic-produced copper. Of the commodities purchased by the MRC, copper was one of the first among all stockpile items; total copper purchases were

valued at $567,188,110 (not including payments under the premium price plan). Inventory on Oct. 31, 1944, was valued at $111,680,135, as reported by the president of the MRC. Government stocks of refined copper amounting to 498,406 short tons were held by the Reconstruction Finance Corporation through the OMR, on Oct. 31, 1945, as reported by the CPA. This compares MRC holdings on Sept. 31 of 508,726 tons in the United States and Canada and 35,159 tons in South America, ore, blister, and refined. Some of the copper stocks were stored in Canada. The MRC stockpile was reduced to 471,778 tons on Nov. 30. Foreign allocations by the MRC amounted to 644,922 tons in the first 11 months of 1945; 469,296 tons in the same period of 1944. The MRC allocated 45,000 tons for domestic consumption in January, 1946.

The emergency stockpile was considerably reduced late in 1944, although large shipments had been received from Latin America, consisting of about 305,500 tons, on Sept. 1, 1944. The MRC was releasing the metal at the rate of about 60,000 tons a month, increasing to 135,812 tons in March, 1945, the highest figure reported for any month. MRC deliveries reduced the government stockpile to about 225,000 tons on Apr. 1. Working stocks of 293,701 tons, plus unfilled orders, indicated total copper requirements at the end of January, 1945, of 596,604 tons. Against this were stocks of 330,397 tons at the end of January compared with an apparent deficit of 187,259 tons at the end of Dec., 1944.

Removed by the WPB from the list of critical materials, in January, 1944, copper was again placed in the critical category before the end of the year, in spite of record imports of copper in 1944. Battlefield scrap began to be returned to the United States from foreign areas. Military reverses in France, in the final quarter of the year, resulted in greatly increased production of small-arms and heavy-artillery ammunition and in other manufactures requiring large copper supplies. Larger copper supplies than ever before were required at the end of 1944.

The "open-ending" of the CMP resulted in making copper available, in July, 1945, for the production of civilian goods. The MRC stated that copper in the government stockpile would be available for purchase by companies that could not find the metal in normal trade channels. Manufacturers and warehouses would be eligible to purchase the metal without certification, preference rating, or authorization number.

Copper was designated by the WPB on Mar. 1, 1944, as a metal sufficient for war uses plus essential industrial demands. In October, it was stated that cancellation of nearly all government production controls would follow VE-Day, when an estimated 28,500 tons per quarter would be available to

ingot makers for civilian use. The WPB reported on Nov. 1, 1944, that relaxation of controls on refined copper for civilian-goods manufacturers could not be expected in the near future, although restrictions were removed for the use of copper and copper-base alloys in the manufacture of 17 commercial and civilian items.

A warning that civilian production in 1945 might be further curtailed was given by the WPB on Dec. 17, 1944. The German offensive in northern France led to greatly increased demands by the U.S. Army for bullets and artillery shells. These requirements were expected to result in orders for the Office of Civilian Requirements to give back half of the tonnage of copper and brass mill products allotted to it for the manufacture of civilian goods in the first quarter of 1945, when available supplies were estimated at 494,000 tons. Consumption was estimated at 457,000 tons, and requirements for the second quarter were anticipated at a larger figure.

Scrap-copper requirements in the first half of 1945 were calculated at 720,000 tons compared with total consumption for 1944 of 1,371,200 tons. As the copper-supply-requirement situation tightened in 1945, the possibility for easing civilian consumption allowances in the near future was limited.

Inventories were reported on Jan. 18, 1945, by J. A. Krug, of the WPB, to be about as low as at any time since 1942. Lowest domestic production for any month in the war period was the 66,037 tons reported in February compared with 67,681 in January, 1945, as reported by the U.S. Bureau of Mines. Refined output of 777,051 tons was reported in the first 11 months of 1945 compared with 1,016,139 for the same period of 1944. The Copper Institute reported a record high level in February, 1945, for shipments of refined copper to domestic users, aided by peak delivery of 100,062 tons of foreign metal. Shipments in the first 11 months of 1945 were 1,414,328 tons compared with 1,477,495 in the same period of 1944. In December, 1945, domestic shipments were 103,464 tons including 39,489 tons of foreign-mined ores.

Michael Schwarz, director of the copper division of the WPB, stated in April, 1945, in the fourteenth *Supply-requirements Report*, that refined copper for all 1945 had an estimated deficit of 189,000 tons compared with the March estimate of 208,000 tons. This reflected a reduction of 61,000 tons in estimated demand. Trade estimates at the end of March showed a 236,443-ton deficit, at the end of February, 245,215. Fabricator receipts, in March, of new and refined copper from domestic and foreign producers were reported at 218,012 tons. The total for unfilled orders was 679,889 tons.

In the postwar period, the copper industry in the United States is expected by W. R. Ingalls, of the American Bureau of Metal Statistics, to be protected

in much the same way that the lead and zinc industries have experienced for many years; it was assumed that a higher general price would be maintained, supported by the 4 cents tariff. Postwar industry may absorb 1 million tons of copper a year, including manufactures for export, according to a statement by Philip D. Wilson, vice-chairman for metals and mining of the WPB, in November, 1944. Imported copper is expected to form a larger part of domestic fabricated metal. The subsidized domestic output of copper in 1944 represented about 75 per cent of the 1 million tons consumed.

For 1945, domestic output was estimated at 936,000 tons, about 11 per cent below 1944; an effort was made to secure imports amounting to 1 million tons for the full year. The WPB estimated requirements for the first half of the year at 940,800 tons. On May 10, 1945, J. A. Krug announced the release of copper on July 1 without allotment orders where delivery did not interfere with war-production or priority-consumer requirements. Until more supplies were obtainable, large quantities of copper would not be available for "hard goods" such as automobiles, furniture, trucks, refrigerators, and stoves. Brass-scrap production, in the first quarter of 1945, averaged 156,785 tons a month compared with 144,000 tons estimated by the WPB as required for a one-front war against Japan. VE-Day resulted in reduced need for the stockpiled copper held by the MRC. Ninety-day furloughs had been granted 2,173 enlisted reserves for work in copper mines, it was reported on Apr. 1, 1945, by the War Department.

The CMP was applied, in April, 1945, for the purpose of dealing with the problem of completing war work. General Order M-21 gave the Period I Planning Board of the WPB sole control over copper and certain other metals in the transition period of about six months following VE-Day, the order providing that producers could sell metal only to those manufacturers who held allocation "tickets" issued for war or civilian uses. General Order M-9 revoked all controls on copper, effective on Aug. 20, 1945.

The WPB released copper and brass mills on July 1, 1945, to deliver metal to nonpriority manufacturers of civilian goods. This relaxed allocation of copper and certain other metals included under the CMP made possible the resumption of peacetime production within a few months. Action by producers was to be dependent on retooling their plants and securing materials and labor. The CMP was to be terminated on Dec. 31, 1945, when it was planned to end rationing to authorized users. Relaxing the plan on July 1 permitted delivery of copper and certain other metals after priority users had secured all supplies required.

The War Assets Corporation authorized government agencies on Mar. 8, 1946, to make direct sales of scrap containing copper and copper-base alloys

at ceiling prices without declaring its supply for strategic stockpile purposes. The Civilian Production Administration on Mar. 7, 1946, tightened inventory controls on copper products in an effort to check hoarding or preemptive buying. Priorities Regulation 32 was revised to lower the maximum inventory limit on all supplies of copper and copper-base alloys to a 45-day level rather than the former 60-day supply. Copper magnet wire had been on the 45-day level since Feb. 8, the new ruling embracing ingots, castings, refinery shapes, scrap, and brass mill and wire mill products.

Demand for copper and brass, 1945–1955, was expected to amount to a record peacetime boom, as announced in September, 1945, by B. B. Caddle, secretary of the Copper and Brass Research Association. The industry was expected to employ 15 per cent more men than in prewar years. Automobile manufacturers were expected to require 150,000 tons of copper in 1946 compared with 120,000 tons in 1940. Electrical manufacture was expected to increase requirements more than 25 per cent above the 1940 levels.

The shortage of domestic copper supplies became serious by the end of May, 1946, as a result of strikes. New wage agreements and higher operating costs made it necessary to secure a higher price. The OPA assured producers in April that an increase in the ceiling price would be granted. During the 3 months of labor unsettlement in the industry, copper consumers were able to fill requirements from foreign sources. After contracts expired, it was expected that an increased price would be necessary in order to maintain imports in competition with foreign prices around 14 cents a pound. All imports in the war period and to the end of May, 1946, were for the account of the government, which paid no duty.

World Production, Imports and Exports. Since the First World War, foreign copper output has shown a steady increase, as follows: Chile had doubled output by 1924; South America, Africa, and Canada had made large increases by 1930. In the period 1909–1929, United States copper accounted for more than 55 per cent of the world total. In the First World War, the United States accounted for 60 per cent. After 1928, the United States became an importer of copper with net imports amounting to 48,000 tons in 1932, when legislation was enacted setting up a 4 cent copper duty. In 1938, 53.1 per cent of domestic production of refined copper was exported; and in December, 1944, imported copper for the first time exceeded domestic output. The production peak of copper was not reached in the United States until 1929, although predepression peaks of foreign production were exceeded in 1939.

World output of copper (1929, 1938, 1939) amounted to 2,099,000, 2,250,000, and 2,443,000 short tons, respectively. In the United States, cop-

per output in the same three years compares as follows: 1,001,400; 562,300; and 712,700 short tons.

World trade in minerals in 1938, as shown in "World Minerals and World Peace," indicates the movement of copper ore, matte, and concentrates, in thousands of metric tons, as follows:

1. *Canada*	
To: United States	26.5
Japan	13.8
Germany	9.5
Total	49.8
2. *Cyprus*	
To: Germany	34.5
Total	34.5
3. *Belgian Congo*	
To: Belgium (matte)	50.2
Total	50.2
4. *Chile*	
To: Japan	10.2
United States	3.1
Germany	0.3
Total	13.6
5. *Newfoundland*	
To: United States	11.1
Total	11.1
6. *South-West Africa*	
To: Belgium	7.5
Germany	1.3
Total	8.8
7. *France*	
To: Belgium	7.3
Total	7.3
8. *Norway*	
To: Germany	6.6
Total	6.6
9. *Cuba*	
To: United States	5.5
Total	5.5
10. *Bolivia*	
To: United States	2.7
Belgium	0.1
Japan	0.1
Total	2.9
11. *Mexico*	
To: United States	2.8
Total	2.8
12. *Philippine Islands*	
To: Japan	2.8
Total	2.8

13. *Australia*

To: United States	2.1
Belgium	0.1
Total	2.2

14. *Peru*

To: United States	1.1
Japan	0.4
Total	1.5

15. *Spain*

To: Germany	1.3
Total	1.3

16. *Sweden*

To: Germany	0.5
Belgium	0.3
United States	0.2
Total	1.0

World exports of smelter copper (including refined), as shown below, include all shipments amounting to 3,000 metric tons or more, in 1938.

1. *Chile*

To: Britain	100.3
United States	57.3
Germany	45.9
France	36.7
Italy	29.6
Belgium	22.3
Sweden	19.5
Poland	9.6
Czechoslovakia	3.5
Switzerland	3.5
Total	329.0

2. *United States*

To: Japan	94.9
Germany	74.0
Sweden	23.9
Czechoslovakia	22.5
France	20.7
Italy	15.8
Britain	14.7
Poland	10.7
Switzerland	7.7
Netherlands	3.1
Total	322.7

3. *Northern Rhodesia*

To: Germany	73.4
Britain	66.3
Italy	21.6
Belgium	10.2
United States	3.1
Total	200.6

4. *Canada*	
To: Britain	71.9
Germany	20.8
United States	15.8
Czechoslovakia	9.2
France	6.5
Sweden	5.2
Poland	3.5
Total	170.8
5. *Belgium*	
To: Russia	36.1
France	31.2
Germany	21.9
Rumania	4.8
Switzerland	4.5
Italy	3.2
Netherlands	3.1
Total	113.0
6. *Belgian Congo*	
To: Belgium	39.9
Germany	38.5
Total	78.7
7. *Mexico*	
To: United States	31.0
Total	36.1
8. *Peru*	
To: United States	34.3
Total	36.0
9. *Yugoslavia*	
To: United States	11.7
Belgium	10.8
Total	30.3
10. *Norway*	
To: Belgium	16.8
Total	20.4
11. *Finland*	
To: Germany	12.5
Total	12.5
12. *Union of South Africa*	
To: United States	4.4
Italy	3.3
Total	10.3
13. *Great Britain*	
To: France	3.8
Total	10.2
14. *Sweden*	
To: Germany	6.3
Total	8.5

Of total world capacity for refining copper (more than 3,298,000 metric tons a year), the Axis powers held 356,000 tons plus 232,000 tons in countries occupied or controlled by the Axis. Refining capacity controlled by the United Nations and trade associates amounted to 2,710,000 tons. The dependence of Europe on foreign sources of copper is illustrated by the need for importing 80 per cent of the crude copper consumed in 1935.

Foreign mining and smelting capacity of about 1,800,000 short tons and refining capacity of 1,500,000 tons, in 1934–1936, expanded considerably after 1939 to meet war demands. Domestic refining capacity at the end of 1943 amounted to 1,595,000 tons for new copper plus secondary metal, as estimated by the American Bureau of Metal Statistics.

WORLD SMELTER PRODUCTION OF COPPER IN 1934, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	Production
Australia	8,098
Austria	597
Belgian Congo	110,085
Belgium (blister copper)	61,110
Canada (blister copper)	151,818
Chile	247,721
Chosen	1,434
Czechoslovakia	633
France	1,000
Germany*	53,000
British India	6,400
Italy	303
Japan	67,002
Mexico	47,100
Norway	7,989
Peru	28,033
Northern Rhodesia	140,110
Rumania	202
Spain	13,777
Sweden*	7,854
South Africa	8,328
U.S.S.R.	53,600
United Kingdom	11,380
United States*†	251,225
Yugoslavia	44,390
Total	1,323,000

* Not including scrap.
† Includes imported ore.

In 1944, imported copper reached a new peak; exports declined steadily, 1941–1944. Insulated wire and cable exceeded all other classes of copper

exported, including refined copper, which had been the chief form of export copper for more than 45 years.

Imports of refined copper reached a new record figure of 530,000 tons in 1945, of which 60,000 tons were supplied by Northern Rhodesia. Imports from Chile were considerably lower.

Certain competitive factors are expressed in the following table:

AVERAGE GRADE, LABOR AND PRODUCTION COSTS OF COPPER ORE†

	Pounds per ton*	Cost per ton,* cents	Miners' average day wages†
United States	32	6.97–12.4	$7.50–$8.25‡
Chile, Chuquicamata	43	.....	$2.50§
Rhodesia	80	5.76	0.50‖
Canada, Frood	88		
Congo, Katanga	128	.....	0.75§

* Report by U.S. Tariff Commission, 1931.

† Brief filed on behalf of nine U.S. copper producers with Congressional Committee on Ways and Means, Washington, May, 1935.

‡ Wage scale based on copper price; does not include "fringe" benefits.

§ Reported by U.S. Department of Labor; includes allowance for various benefits.

‖ Rate of Grade A workers, about $16 a month.

World production in 1939 was 2,216,000 metric tons distributed as follows: United States, 698,323; Chile, 324,591; Canada, 229,370; Northern Rhodesia, 215,035; U.S.S.R., 144,000; Belgian Congo, 122,649; Japan, 104,000. In 1938, copper-ore production in the United States represented 24.5 per cent of the world total, and smelter output was 29.1 per cent of the total. Chile held second place, as a producer of 17 per cent of the world supply of ore and 17.2 per cent of smelter output. In 1943, world production of 3,070,557 was estimated by the American Bureau of Metal Statistics.

The United States, Britain, Belgium, and Spain are self-sufficient in copper. It is available in quantity inadequate for domestic demands in U.S.S.R., Germany, and Japan. France, the Netherlands, Italy, and China are almost entirely dependent on foreign sources.

Copper procured by nonmilitary agencies from foreign countries from July 1, 1940, through Mar. 31, 1945, had a total value of $681,000,000, which was 16 per cent of the metal and mineral procured from foreign sources. Agreements to purchase foreign copper on uncompleted contracts, as of Mar. 31, 1945, had a total value of $118,000,000.

Copper from South America has been the largest single commodity program handled by the MRC. Metal valued at more than $400,000,000 has been purchased in the past 4 years from the large producers. Postwar imports in substantial tonnage from Latin America were anticipated by United

States copper companies in competition with domestic metal, as a consequence of further lowering of the tariff.

WORLD PRODUCTION OF BLISTER COPPER, IN SHORT TONS
(After American Bureau of Metal Statistics)

	1939	1940	1941	1942	1943
United States	734,990	892,266	983,103	1,097,175	1,114,149
Mexico	53,790	45,003	56,911	56,907	49,342
Canada and Cuba	321,616	339,371	329,870	358,738	338,833
Chile	375,862	388,573	513,084	535,000	548,000
Other South American countries	43,731	57,364	51,857	47,835	45,300
Russia	118,000	125,000	†	†	†
Yugoslavia	45,920	47,346	†	†	†
Other European countries	117,424	118,200	†	†	†
Asia	161,982	151,180	172,600	171,300	176,000
Africa	393,442	479,400	457,000	485,000	470,000
Australia	26,000	26,000	26,000	27,000	26,000
Total*	2,402,475	2,678,203	2,901,925	3,052,571	3,070,557

* Includes small amounts from Newfoundland.
† Not reported.

In Chile, which is second only to the United States as a source of copper, copper mining is the dominant industry, and proved ore reserves are very large. The industry is 95 per cent American owned, the balance being controlled by French companies that operate the Chagres and Naltagua smelters. Mines and smelters employ about 26,700 workers and export about 500,000 tons of metal a year to the United States. The world's largest single ore body is reported at Chuquicamata (Chile Copper Company), where ore reserves exceed 1 billion tons with an average of about 2 per cent of copper. El Teniente mine of Braden Copper Company has reserves reported at about 250 million tons. Portrerillos mine of Andes Copper Company produces low-grade ore that is made commercial only because of the premiums paid by the MRC. Portrerillos and Chuquicamata are both porphyry coppers.

Chile, in 1945, exported to the United States 383,669 short tons of refined copper and 53,758 tons of blister. U.S. Commercial Company reported in May, 1945, that purchases had been negotiated with Chile for delivery in the third quarter, reflecting a decision by the WPB that copper requirements would continue for some time in excess of domestic output, in spite of the cutbacks to be made after VE-Day. Chile had increased copper production in the war period from 300,000 to 500,000 tons a year, it was announced in Washington in November, 1945, by the president of Chile, Juan A. Rios. In that country, economic and political influences required that the higher

production rate be maintained in postwar years, together with expanded trade with the United States.

The possible cutting in half of the 4-cent copper tariff by the United States would tend to ease problems of foreign copper producers. In November, 1945, Washington announced the purchase of foreign copper, mainly in Latin America, in the first half of 1946 at the rate of about 20,000 tons a month as recommended by the CPA.

Canada holds third place as a copper producer. Maximum output of 327,796 short tons of refined metal was attained in 1940 compared with other war years as follows: in 1939, 304,412; in 1941, 321,658; in 1942, 301,831; in 1943, 287,595 tons valued at $65,357,050. Production of copper in 1945 amounted to 238,975 short tons compared with 273,536 in 1944. Over-all production of copper in Canada from Sept. 1, 1939, to Sept. 1, 1945, was 1,784,200 short tons valued at $384,207,600. More than half of Canada's output is controlled by financial interests in the United States, the remainder being about equally divided between British and Canadian capital. Copper sulfate imported by Canada in 1943 (20 per cent from the United States and the balance from Britain) amounted to almost 5,000 tons. A $500,000 plant for producing sulfate is to be built in Canada, it was reported in January, 1945.

Canadian copper is in a very vulnerable position, George C. Bateman reported in April, 1945, following the cancellation in January of British contracts. The American market for this metal held various political uncertainties, he stated. European outlets for Canadian copper were beginning to develop, it was reported in September, 1945. Stocks of refined metal had accumulated in larger volume than ever before in Canada, most of the metal having been purchased by the United States and being held awaiting shipping instructions.

U.S. Commercial Company in May, 1945, negotiated a contract for a substantial tonnage of Canadian copper to be delivered in the third quarter rather than on a month-to-month basis. Total exports to the United States of Canadian copper in 1945 were 13,597 short tons in ore, matte, and regulus; 279 tons of blister; and 76,345 tons of refined metal. The Department of Munitions and Supply at Ottawa in June, 1945, ended restrictions on the purchase of copper in the form of wire, sheet, tube, wrought, and alloy. Copper and other nonferrous metals were made available for rural electrification and public utility services.

Copper held in Canada by the MRC was valued at $7,000,000 of the total value of $87,000,000 in metals and minerals in inventories held abroad. Copper valued at $685,000,000 was the largest single item of the total of $1,952,-

000,000 spent for metals and minerals by the Department of Commerce in foreign financial and supply transactions from July 1, 1940, through June 30, 1945.

Canadian copper sales to Britain were terminated in January, 1945, but were expected to be renewed before the end of the year. Copper stocks in Britain were down to 175,000 tons in June, 1945, from the 400,000 tons reported at the end of 1944. The British Ministry of Supply announced on Aug. 14, 1945, the removal by the Nonferrous Metals Control of all restrictions on the release of copper for fully manufactured goods.

Britain's position as far as raw materials were concerned did not give rise to anxiety, it was reported on Dec. 28, 1945, by the Board of Trade. Economy in the import of materials was required, particularly where these were of little aid to the export position. Copper was in adequate supply, with consumption of the virgin metal amounting to 218,725 long tons in the first 9 months of 1945 and consumption of scrap copper, 141,359 tons. Copper stocks in Britain on Feb. 28, 1946, were estimated at 90,500 tons, less than 4 months' supply at the rate of domestic consumption. In 1944, consumption amounted to 348,138 tons.

The Belgian Ministry of Economic Affairs announced in August, 1945, that all industrial requirements of copper and copper alloys could be supplied. Industrialists were advised to prove their needs to their trade council in order to procure both copper and tin.

Mexico, the second largest Latin-American copper producer, recovers about 50,000 tons a year. The output in 1941 amounted to 53,586 metric tons of concentrate and semirefined metal, of which 49,736 tons were exported. Greene-Cananea and Moctezuma Copper Company, the major producers, carried on capacity production during the war years at mines located in the states of Sonora and Boleo, Lower California. El Boleo mine is under French control. Smelters are located at Matehuala, San Luis Potosi, Cananea, and Santa Rosalia. Ore, concentrate, and refined metal are shipped to the United States. Cananea Copper Company, Anaconda subsidiary, in 1943–1944 built a concentrating plant for the treatment of low-grade ore, financed with a United States government loan of $12,000,000. United States interests control two-thirds of Mexican copper output, the remainder being equally divided between British and French companies. Mexico, in 1945, shipped 57,096 tons of blister copper to the United States. Prewar copper exports had average value of $15,000,000 a year.

In Peru, Cerro de Pasco Copper Corporation produces about 80 per cent of the total metal from five mines that have large reserves of high-grade ore. Cerro de Pasco also purchases copper concentrate from small mines owned by

Peruvians. Peru, in 1945, exported 23,010 short tons of blister copper to the United States. In Peru and Mexico, copper was one of 17 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus as part of the foreign procurement program initiated late in 1940.

In Bolivia, the Corocoro mine of American Smelting and Refining Company produces about 6,500 tons a year of 4 per cent copper ore. Copper industries of both Bolivia and Peru are controlled by American capital.

Argentina is not a copper producer but operates a copper-fabricating plant. The lack of coal in Argentina has shown it to be unsound policy to attempt industrialization of the mineral industries.

In Cuba, the only copper producer is the Matahambre mine, located in the province of Pinar del Rio. A new ore body was developed in 1944, and delivery before June, 1945, of 15,000 short tons of 32 per cent concentrate was contracted with the U.S. Commercial Company.

U.S.S.R., holding fifth place in 1939 as a copper producer, has reserves larger than Japan but smaller than the Belgian Congo. Output is about equal to domestic requirements. Important deposits are chiefly east of the Urals, in the Lake Balkash region of central Kazakstan. At Kounrad, reserves of many million tons are reported in porphyry-copper deposits. Prewar production was mainly secured in the Ural region, where sabotage was reported to have seriously damaged facilities. For some time prior to the First World War, Russia was the major source of copper, under British control. Just before the Second World War, extensive development was reported in opening Siberian and Far Eastern copper deposits.

In the Belgian Congo, copper mining operates as a colonization enterprise under Union Miniere de Haut Katanga. This includes refining and fabricating plants located in Belgium. The Belgian Congo ranks as the sixth largest copper-producing country. Cobalt and uranium also occur in the copper deposits. Belgium is the major importer, and substantial shipments are also made to other European countries. In 1945, the Congo exported to the United States 29,760 short tons of blister and 36,287 tons of refined copper.

In Rhodesia, copper mining has been encouraged by the British government. The ore is smelted and refined wholly within the Empire. In Northern Rhodesia and the Belgian Congo, great deposits of copper ore occur disseminated in a long belt of Precambrian sediments. A 70-mile strip of limy shales in Northern Rhodesia, paralleling the north boundary of the Belgian Congo, contains ore deposits over remarkably long distances and to great depths. The three large Rhodesian mines (Roan Antelope, Mufilera, and

Rhokana) in 1940 produced more than 365,000 tons of copper. Ore grade is reported at 3.5 to 7.9 per cent. American Metals Company is believed to have secured about 50 per cent of control of Rhodesian copper in 1942. In 1945, Northern Rhodesia exported to the United States 25,165 short tons of refined copper and 64,374 tons of blister. African copper is marketed in the less desirable form of fire-refined metal.

In both Germany and Japan, government policy arranged for subsidizing the copper industry. Japan protected smelters through an import duty on refined copper. Some 110 copper mines were in production in Japan in 1932. Japanese ore occurs both as replacement deposits and as fissure-vein deposits. The fissure and "black-ore" deposits are reported to be the most important. In the First World War, copper production expanded greatly in Japan. In the 1930's, it was reported to be national policy to hold domestic output at a minimum, leaving industry largely dependent on imported copper.

Imports of Rhodesian copper were reduced 25 per cent between April and June, 1944; and in July, increased shipments were arranged from the Belgian Congo and Canada. In July, 1944, MRC announced reduced purchases of ore from Chile. High-cost premium metal was to be eliminated until world requirements were met by mines operating without subsidy. Government foreign procurement, combined with private purchases, was at the annual rate of 1 million tons in February, 1945. The Office of Metals Reserve was reported on Aug. 10, 1946, to have contracted for 50,000 tons of copper at 15.75 cents a pound at Chilean ports, for delivery before Sept. 1.

Leo T. Crowley, Foreign Economic Administrator, announced in May, 1945, that reverse lend-lease through the British government in the first quarter of 1945 had made 30,000 tons of Rhodesian copper available to the United States. In the second quarter, an additional 42,000 tons was supplied as part of the 175,000-ton consignment requested by the United States before the end of 1945.

The Philippine Islands exported 11,956 metric tons of copper ore in 1939; in 1940, 13,086. Copper concentrate exported in 1939 was 9,958 metric tons; in 1940, 8,216. Production in 1941 is not reported, Japan having occupied the islands early in 1942. The major producer was Lepanto Consolidated Mining Company, which was reported to have been liberated from the Japanese in May, 1945.

Korea, in 1935, produced 2,170 metric tons of copper, as reported by Samuel H. Dolbear.

In Alaska, total mineral production to the end of 1944 included gold (70 per cent) and copper (25 per cent). No postwar expansion of copper mining is indicated, as reported on May 7, 1945, by the U.S. Geological Survey,

although possibilities are stated to exist for discovering new copper deposits in the large unexplored areas.

Imported copper, largely from Chile, Peru, Mexico, and Africa, amounted to 489,273 tons in 1942; in 1943, 423,618. The Foreign Economic Administration announced, in November, 1944, canceling contracts with two small, high-cost smelters in Chile; other agreements with foreign producers were due to expire at the end of 1944. Copper imports from Canada and Africa were arranged to the end of May, 1945; for the full year, an effort was to be made to hold domestic output at about 936,000 tons.

In Turkey, preclusive buying operations by the United Kingdom Commercial Company and the U.S. Commercial Company succeeded in eliminating purchases by Germany. The method followed was to force Germany's purchasing agents out of the open market by bidding the price to a point where Nazi credits were exhausted. Germany secured large copper stocks in Rhodesia and the Belgian Congo before September, 1939. It is reported that British exporters worked up to the last minute on the night of Sept. 3, 1939, clearing copper cargoes consigned to Germany for the war that was to start the next day. The strain on Germany's copper supply was eased by large-scale expansion of aluminum production for substitute metal. Among importing nations in 1938, Germany held first place, followed by Britain and the United States. Germany was the principal importer of copper ore from the British-controlled island of Cyprus. Of Canadian copper exports, in 1938, about half went to Germany and Japan.

In Germany, the Mansfield deposits, in Permian shales, were the principal copper source. The ore averaged 3 per cent of copper, and production had been secured for more than 250 years. Since 1925, the operation had been subsidized by the German government, which was made necessary by the low grade of the ore and low copper prices. The Rammelsberg pyrite deposits, near Hanover, were a source of small copper output.

The FEA reported, in August, 1945, that copper and copper concentrate were included with almost 350,000 tons of minerals and metals available in Norway for export, in spite of the extended military occupation by the Nazis. In the last 4 months of the year it was estimated that 1 million tons of metals, minerals, and fertilizers would move out of Norway. Swedish capital controls copper production in Sweden and largely in Norway.

In Japan, normal domestic requirements can be supplied from domestic production at the rate of about 100,000 tons annually. In the years preceding Pearl Harbor, Japan accumulated a large copper stockpile by means of metal looted from Asia as well as greatly stimulated domestic output. Large imports were secured from North and South America.

The Bor copper mines in Yugoslavia are reported to be the largest in Europe, valued at $42,000,000. Prewar ownership was held in France, the concession to be in effect from 1930 to 1960, but these mines were nationalized in October, 1944. About 60 per cent of the Bor shares were in the occupied zone of France and were taken over by the German economic dictator of Yugoslavia. This forced transfer was declared illegal under the UN agreement of Jan. 5, 1943. It was reported, in August, 1945, that mine operation was being conducted at less than 25 per cent of capacity. Settlement of the dispute with Yugoslavia was regarded as a test case having a bearing on the ownership of other Allied copper mines and concessions in the Danubian and Balkan states, Poland, and Hungary.

Postwar requirements of foreign copper are considered to be on a lower scale than the expanded rate achieved in 1943–1944. Foreign curtailment, in progress since the early part of 1944, was further increased when, in September, 1945, suppliers of copper in Chile and Peru were notified by the FEA that no copper would be taken from those two countries for the month of November. This was in accordance with the contract stipulation to give 3 months' notice of a change in requirements. No long-range foreign purchasing plan was to be announced until United States needs for the reconversion period had been studied in relation to potential domestic output of copper.

Under increased war requirements, foreign sources supplied almost one-third of United States requirements of copper, in spite of the expanded rate of domestic production. Copper imports, in 1943, were almost double those of the highest prewar year, at 647,000 tons; in 1944, imports further increased to almost 800,000 tons. In the first 7 months of 1945, imports were at the annual rate of 840,000 tons.

The MRC announced, in August, 1945, that purchases would be made of foreign copper on a month-to-month basis rather than quarterly, as before.

Heavy stocks held by the United States and Britain were stated, in August, 1945, to indicate a large oversupply over the next few years. Armaments and battlefield scrap are expected to add considerably to reserves of new metal. Producing capacity under war demands increased almost 50 per cent above prewar levels to more than 3 million tons a year, more than half of which filled military needs. War imports by the United States amounted to an estimated 3 million tons of copper.

Competition for world markets is expected to favor by-product copper produced in Canada and Central Africa to the disadvantage of Latin America. The need for imported metal in the United States is not expected to develop "for some time to come," in the opinion of A. M. Bateman. Reducing the duty from 4 to 2 cents a pound, in June, 1945, is expected by American

copper producers to admit about 100,000 tons a year of Canadian copper for use by the automobile industry.

Prices. The price of domestic electrolytic copper, f.o.b. refinery, remained under ceiling-price restrictions from August, 1941, through 1946, at 11.775 cents a pound. The price averaged 11.797 cents in 1941 and 11.296 cents in 1940. The average weighted price for all grades of copper, including bonus payments for overquota production and for special bonuses to marginal producers, was as follows: 12.1 cents in 1942; 13 cents in 1943; 13.4 cents in 1944; 13.6 cents in 1945, f.o.b. refinery, as calculated by the U.S. Bureau of Mines.

The ceiling price for electrolytic (cathode grade, 99.93 per cent and upward; conductivity to 103 per cent) and Lake copper (conductivity 99.5 per cent), delivered to the Connecticut Valley, remained at 12 cents a pound through the war period, increasing to 14.15 cents on June 3, 1946. Ten-year average prices were as follows: 1915–1924, 19.02 cents; 1925–1934, 11.67 cents; 1935–1944, 11.17 cents.

Export copper, net at Atlantic seaboard refineries, was priced as follows: 10.77 cents in 1940; 10.901 cents in 1941; 11.684 cents in 1942; 11.75 cents through July 12, 1946, when the price advanced to 15.925 cents. The price in September averaged 16.486 cents. Copper sheets, hot-rolled, were 20.87 cents a pound; copper in rolls, 19.37 cents; bare wire, carload lots, f.o.b. mills, 15.375 cents.

The London official maximum price for copper, £62 per ton, remained in effect from 1940 through Apr. 8, 1946. On that date, price ceilings on nonferrous metals were raised, the copper price moving up to £72 a ton ($288 U.S.). The British had been buying foreign copper at prices in excess of the United States ceiling. In June, 1945, Britain set a price of £68 10*s.* a ton electrolytic for copper sold to liberated countries, f.o.b. English ports; £68 for fire-refined copper (equivalent to 11.75 cents U.S. and 13 cents Canadian).

Copper sulfate was quoted on Sept. 1, 1945, at $5 per 100 lb., large or small crystals, in carload lots, f.o.b. New York; on Sept. 30, 1946, $5.65.

Price stability of copper since 1941 was a notable achievement in contrast to an increase of about 100 per cent in the First World War. The price range of American copper was as follows: from 55 cents in 1864 down to 4.9 cents in 1933. Under the Hawley-Smoot tariff (July 1, 1932, to Dec. 30, 1938), United States copper prices averaged about 6.5 cents a pound higher than foreign prices. Prior to the Second World War, foreign copper was imported in bond and reexported, after refining, for foreign consumption or used by fabricators and reexported with the benefit of a "drawback."

Metal duties on copper, according to the tariff act of 1930 and the revenue

bill effective June 21, 1932, with revisions to Feb. 1, 1943, resulting from all reciprocal trade agreements, were as follows: ore, matte, bars, ingots, pigs, regulus, plates, clippings from new copper, scrap and composition with copper chief value, 4 cents a pound for copper contained; rolls, rods or sheets, 2.5 cents a pound plus 4 cents on copper contained; seamless tubes and tubing, 7 cents; brazed tubes, 11 cents; plain wire, 25 per cent, all plus 4 cents additional on copper contained. The duty on brass and bronze tubes and tubing was 4 cents; brass rods, sheets, plates, etc., 4 cents; old brass and clippings, 4 cents; brass tubes, brazed, angles and channels, 12 cents; brass and bronze wire, 25 per cent.

The premium-quota plan, effective on Feb. 1, 1942, provided for payment by the MRC of a premium on all domestic production of copper in excess of the monthly quotas that were established by the WPB and the Office of Price Administration with the approval of the MRC. This premium reflected the difference between the ceiling price and the equivalent of 17 cents a pound Connecticut Valley, subject to prior termination of the national emergency before July 31, 1944. There has been no subsequent change in the ceiling price, the basic A premium remaining at 5 cents a pound. Congress extended the effective period of the plan to July 31, 1945, and again to June 30, 1946. The premium-price plan was broadened in April, 1943, to cope with increased labor costs. In a number of special cases, the OPA and the WPB advised established premiums higher than the basic A rate. The additional premium approved was to be specified in each case where a special quota was granted.

The ceiling price for copper allowed a 5 cent premium rate on production in excess of the A quota, on production in excess of the special quota, as specified. Producers of premium-price copper were required to submit a monthly statement on production costs in order to justify continuance of above-ceiling prices. It appeared in September, 1945, that considerable domestic high-cost production would be eliminated by reducing the amount of metal for which a mine would be paid a premium. Economic Stabilizer Chester Bowles announced on Mar. 30, 1946, that higher subsidies would be made to copper producers in order to offset increasing labor and other costs.

The OPA, on May 29, 1946, authorized a 20 per cent industry-wide increase for producers of copper, brass and bronze alloys, and scrap and secondary products, in a broad pricing adjustment for the purpose of offsetting rising costs of materials and labor. The new prices went into effect June 3. Copper mines affected were those which had authorized wage increases since Feb. 14, 1946. In order to preserve the same relationship between the base price of copper and copper scrap, the OPA raised prices for copper-

alloy scrap and brass-mill scrap. Producers of brass- and bronze-alloy ingots were allowed to raise their prices an average of 15.52 per cent.

The OPA stated that in addition to these price increases, adjustment soon would be announced to provide "compensating" increases for copper products, also effective June 3. Subsidy payments under the premium-price plan were continued, the increased base prices allowing a reduction in subsidy payments on lead and copper of about $7,500,000 a year.

For copper, maximum base prices delivered in carload lots at Connecticut Valley points were increased to 14.375 cents a pound; for copper received from mines not affected by approved wage increases the price remained unchanged. On Aug. 2, the two-band system of copper prices was eliminated by the OPA, which stated that wage issues had been settled throughout the industry. The ceiling of 14.375 cents a pound was established as the maximum base price for all electrolytic, Lake, or other fire-refined copper. The net price of export copper at Atlantic-seaboard refineries advanced to 18.05 cents on Nov. 27, 1946.

For copper and copper-alloy scrap, the price increased from 1.25 to 1.75 cents a pound, depending on grouping in OPA price schedules.

For yellow brass, Muntz metal, and nickel silver scrap, the price increased 1.25 cents a pound.

The OPA granted price increases to manufacturers of copper electrical coils and windings, reflecting the advances in copper prices on June 3; premiums for copper resellers were raised ¼ cent a pound in each quantity sales bracket. Effective Oct. 14, 1946, the OPA authorized increases of $2 to $4 a ton in premiums and toll charges for converting or casting refined copper into special shapes. Hoarding of copper scrap and copper-base alloy scrap by dealers and brokers was stopped on Oct. 30, 1946, by the CPA by an amendment to its inventory regulation.

The Office of Metals Reserve reported on Aug. 10, 1946, that Chile copper was being purchased for resale to domestic industry at a price equivalent to 16.5 cents a pound delivered to Connecticut Valley points.

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CORUNDUM

(Ore and Grain)

Properties. Corundum (aluminum oxide, with 1 per cent or less of iron and possibly titanium) is a natural alumina abrasive second only to the diamond in hardness (9); its specific gravity is 3.95 to 4.10. Its melting point is above 1950°C. It is brittle and very tough when compact, usually appearing in barrel-shaped crystals. It is insoluble in the strongest acids. Its luster is adamantine to vitreous. The color is inconspicuous bronze, bluish, or gray. Corundum is widespread and diversified in occurrence, with commercial grades described as "block" (crystals) or as "sand" (minute crystals or small grains).

Corundum is an important primary constituent in silica-deficient rocks such as nepheline syenites and syenites, at Craigmont and Bancroft, Ontario, Canada. The most common occurrence, as in South African deposits, is as a reaction casing between pegmatite dikes and intruded basic igneous rocks by a process described as desilication of the dike.

Natural corundum is generally classified as (1) gem stones (Oriental ruby and sapphire), (2) abrasive or common corundum, (3) emery. Artificial corundum for abrasives (alundum or carborundum) is produced by melting bauxite in an electric furnace.

Uses. As one of the four high-grade industrial abrasives, corundum was a key product filling important needs in aircraft manufacture and in the production of many specialized items for mechanization of the armed forces, particularly in grinding and polishing high-precision lenses for optical instruments used by the Army and Navy. For military and other equipment, coarse corundum grain is employed in grinding and polishing metals for snagging the forgings and castings of tanks and other heavy equipment.

In powdered form as loose grain, this abrasive makes possible the smooth surfaces required for the accurate performance of optical lenses. For other purposes, it is used on paper and cloth in the form of abrasive wheels, cylinders, blocks, and files of varying size and shape. Grinding-wheel manufacturers use coarser grain sizes; optical-lens makers use finer size products; the fine dust that remains from the two strategic uses is purchased by retail opticians.

Corundum is essential as a grinding medium to produce finish or precision

in the following strategic materials: optical elements of the highest quality for range finders, bomb sights, and scientific instruments; precision metal parts for torpedoes and aircraft engines; quartz crystal plates for military radios; armor plate and malleable castings for tanks and guns.

A specialized abrasive preferred for glass and metal finishing, corundum offers physical qualities of hardness and crystal structure not equalled by the synthetic products (fused aluminum oxide and silicon carbide), which reduce efficiency as much as 30 per cent. Corundum also is superior to emery and garnet. A major peacetime user is the automobile industry for cutting metals and hardwood.

Primary abrasive grain is prepared by grading the ore according to size. The coarse range of primary grains (8- to 30-mesh) is used to produce segments, sticks, and "snagging" wheels (heavy rough-grained wheels) for the grinding-wheel industry. The fine range of grains (70-mesh and finer) used by the optical industry for rough grinding produces "superfine flour" or "optical emery" employed for the finishing of optical surfaces, for which it is superior to all other abrasives. Particle sizes for "superfines" range from 500- to 2,600-mesh. The crystal structure of the corundum grain retains a rounded form when it is broken down from the coarse to superfine size, as required for optical grinding and finishing and for quartz crystal finishing.

War applications have been restricted to the most essential optical uses and for "snagging" wheels. The superfines are used on grinding machines for rough grinding of lenses and then reclaimed and regraded into the extremely fine sizes employed in finishing operations. These very fine grades are shipped all over the world in competition with Turkish and Naxos emery, particularly for use by opticians in the grinding and finishing of ophthalmic lenses.

Waste material secured in milling corundum ore, formerly used for valve grinding and scouring, was, under the urgency of war demands, being graded into coarse, intermediate, and fine groups of high-quality superfines to supply optical plants for mixing with the product of rough-grinding operations from which superfines are reclaimed.

This reclaiming of corundum is a process believed to have economic advantages for the postwar period. Garnet, of which there is unlimited supply, may develop into an important fine abrasive. Optical plants have adopted fine-grained diamond wheels and laps in the preliminary grinding of both flat and curved surfaces for optical finishing up to the polishing operation in order to conserve corundum optical grain and finishing flours. The natural grain has been conserved by the use of manufactured grain with natural corundum in producing snagging wheels without loss of efficiency and with a saving of corundum up to 50 per cent.

Postwar prospects for the natural alumina abrasives, corundum and emery, are regarded as being promising. These materials enter into the majority of manufacturing operations at some stage in processing. In cutting, grinding, and polishing operations, both of these materials are expected to continue in strong demand. Civilian uses of artificial abrasives, restricted in the war years, will be restored to a strong competitive position in the postwar period.

Domestic Sources of Supply and Production. The critical shortage of crystal corundum ore supplying the coarse-grain sizes required for snagging wheels led to including this mineral with 14 materials designated by the President on Dec. 20, 1940, as being subject to export license only. In October, 1941, demand for grain was well ahead of indicated output. Conservation Order M-89 was put into effect in February, 1942, requiring substitution of manufactured abrasives for corundum wherever feasible, using available corundum for the optical industry and for snagging-wheel production; every effort was to be made to increase the supply of ore from South Africa, the main source.

Allocation of corundum grain to essential uses in the war emergency resulted in increasing from 60 to 75 per cent the material used by the optical industry, whereas corundum taken by the wheel industry was lowered from the prewar rate of 40 to 25 per cent. The expanding requirements of the wheel industry resulted in depleted stocks in 1942 because of submarine action and the inability of the South American operators to expand production.

Throughout the war period, optical demands were met but shortages occurred in the snagging-wheel requirements. Substantial lend-lease needs for superfine corundum and snagging wheels were also supplied.

The first commitment for the purchase of corundum by the Metals Reserve Company was made in 1942. Ranking thirty-fourth among stockpile items, corundum valued at $803,033 was delivered to the MRC, which held material inventoried at $86,590 on Oct. 31, 1944. This mineral was designated by the War Production Board on Mar. 1, 1944, as insufficient for war uses plus essential industrial demands. Corundum, grain basis, amounting to 1,443 long tons was held in government stocks by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration.

The government stockpile was reported on July 17, 1944, by *The Wall Street Journal* to contain 1,384 net tons of corundum ore. In the postwar period, the demand for corundum will depend on the volume of industrial production for stimulating output in relieving shortages of goods and services of many kinds.

Corundum was included by the WPB, in June, 1945, on a list of materials

and products with nine other minerals and certain ferroalloys that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and it was anticipated that further changes in controls would be announced. Corundum ore and corundum in grains or ground were removed on Sept. 17, 1945, from import controls by the WPB. The new general inventory regulation was revised on Sept. 16 by the WPB to exempt from all inventory restrictions abrasive products made of natural or manufactured abrasives, including all items under the Controlled Materials Plan Code 720. The CPA reported on Nov. 30, 1945, that corundum was among the materials in short supply. It could be released to private industry only when ample supplies were proved to be available. All controls on corundum were removed by the Office of Price Administration on Mar. 11, 1946, when Order M-89 was canceled.

Corundum is imported chiefly as crude and is crushed and graded for domestic consumption. Bauxite abrasives and silicon carbide from domestic sources have been developed as substitutes for the natural corundum. Low-grade ore containing about 3 per cent of corundum is treated by flotation to produce a 50 per cent concentrate. Crystal ore produces both wheel and optical grain; boulder ore must be crushed to approximately 35-mesh to liberate impurities.

In the United States, systematic corundum mining was started at Corundum Hill, Macon County, North Carolina, in 1871 and in 1880 at Laurel Creek, Ga. Continuing until 1905, production was revived in 1917–1918; further work was done in 1944, although no output was recorded. In Gallatin Valley, Montana, mining and milling operations were carried on, 1901–1904, at the Elk Creek mine. Reopened late in 1944, the Elk Creek property was reported to be an important source of crystal ore that might continue in production in the postwar period. Corundum-bearing formations have been found along the strike for more than a mile.

The need for corundum in war industry and the uncertainties of long ocean hauls led to intensive investigation, in 1942, of known or potential domestic deposits. The WPB requested a survey of old producing localities in North Carolina, and the U.S. Bureau of Mines also conducted studies of deposits in South Carolina and Montana.

It was reported that mining operations were started in 1943 by Withers, Inc., near Clover, S. C. The ore occurs in three veins. Tests by the optical industry showed the material to be of a quality similar to South African corundum. Operations were suspended before the end of 1943.

Production in Montana and Canada is expected to increase domestic supplies temporarily by about 50 per cent. Present sources of supply show

promise of being adequate to meet increased postwar demand, although Transvaal "crystal" corundum is reported to be nearing exhaustion.

World Production, Imports and Exports. Imports in 1940 increased more than two and one-half times over 1939, to 2,922 short tons valued at $165,270. In recent years, domestic uses of corundum have depended on imported material from South Africa, with small shipments received also from other countries. Imports of corundum ore, in 1941, amounted to 5,865 short tons, the highest quantity since 1924 and more than 100 per cent above 1940. Imported corundum declined 19 per cent, in 1942, to 4,739 tons, as reported by the U.S. Bureau of Mines. In 1943, it increased 20 per cent in volume and 28 per cent in value as compared with 1942 and was less than the record of 1941 by only 3 per cent.

In northern Transvaal, major producer since the First World War, the main productive belt includes some 300 small deposits located between the towns of Louis Trichardt and Pietersburg. The ore occurs in pegmatite and as placer deposits. Ore (crystal) is collected from individual diggers and either hand-sorted for shipment or processed in a mill at Pietersburg before shipment to ports on the east coast.

The record imports of South African corundum in 1926 were almost equalled in 1935, when United States requirements were the highest since 1926. A dependable record of foreign output is available only for Canada and South Africa, the latter producing 4,322 tons in 1936 and 4,000 to 7,000 tons a year since the peak in 1942. Improved beneficiation at the source of supply is needed to reduce the delivered cost, including the long freight haul. Exploration and development are required in South Africa if the present position as principal source of supply is to be maintained. A modern mill located at Pietersburg started production early in 1944, concentrating reef corundum, or plumasite, which occurs in veins or feldspathic dikes similar to the Craigmont deposit in Canada.

In the state of Ceara, Brazil, production in undisclosed volume has been secured, stimulated by high prices. In India and Madagascar, corundum crystals occur in weathered syenite and in schists intruded by pegmatites; production has been intermittent. In Russia, the mineral is recovered from syenite dikes and from a type of anorthosite. Large production is reported, but no statistics are available.

Regular shipments have not been received from Canada (Craigmont area) since 1921, but the WPB reported, in July, 1944, that a limited quantity of material suitable for optical uses only would be obtainable in October from reworking the Craigmont dumps, west of Ottawa. The same WPB report

stated that low imports from South Africa had led to serious shortage, threatening to continue for several months.

In Canada, major corundum producer, 1901–1915, production was resumed in 1944, the concentrates being shipped for grinding and for the preparation of fine powders and flour at the plant of American Abrasive Company, Westfield, Mass. At the request of the MRC, arrangements were made by Wartime Metals Corporation, Montreal, to treat tailings from the Craigmont property, Renfrew County, Ontario, where stocks amounted to about 125,000 tons grading 3 per cent of corundum. A 200-ton gravity mill was installed early in 1944.

CORUNDUM IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

	1940	1941	1942	1943
Ore	2,922	5,865	4,739	5,686
Grains, ground, pulverized or refined*	67	51	62	123

* Corundum and emery combined.

Abrasive wheels, emery and corundum, exported from the United States were valued at $125,303 in 1939; in 1942, $3,665,386; in 1943, $1,334,654.

Prices. Crude crystal ore, imported before the war, f.o.b. steamer at South African port, ranged from $61 to $69 per long ton; boulder corundum ore was $18.30 to $46 a long ton.

On Apr. 12, 1945, *E & M J Metal and Mineral Markets* quoted natural corundum, size 8- to 60-mesh, inclusive, at 8¾ cents a pound; size 70 to 275, 9¾ cents; size 500, 30 cents; size 850 to 1,000, 45 cents; size 1,200 to 1,600, 65 cents; size 2,600, 70 cents.

The MRC was permitted by Order 177, effective Dec. 10, 1942, to sell and deliver South African crystal corundum ore to the American Abrasive Company at a maximum price of $88.10 per short ton, delivered at Westfield, Mass. Effective Feb. 6, 1943, MRC prices were increased to $107 per net ton for crystal and $74 per net ton for boulder corundum ore, delivered at Westfield. Price levels of March, 1942, were continued by Maximum Price Regulation 327, on Feb. 22, 1943. Corundum grain was included under the Maximum Price Regulation on Apr. 28, 1942. On and after Jan. 30, 1943, American Abrasive Company was permitted to sell optical-grade grain corundum in all sizes, 60- to 250-mesh, inclusive, at 9.75 cents per pound, f.o.b. mill.

South African corundum is marketed in the United States in accordance

with grading regulations imposed by the Transvaal, based on alumina content and screen-sized limits.

Canadian corundum concentrate is required to have a minimum corundum content of 65 per cent and a minimum content of magnetic material.

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CRYOLITE ORE

Properties. A double fluoride of aluminum and sodium, cryolite, in the pure state, contains 12.8 per cent of aluminum, 32.8 per cent of sodium, and 54.4 per cent of fluorine. Snow white to brown in color, the mineral (a fused salt) fuses at 950°C. with practically no loss on firing. Its hardness is 2.5; its specific gravity, 3.

Cryolite is an easily melted mineral in which aluminum oxide, prepared from bauxite ore, is dissolved in electrolytic cells. The mineral has the unique property of dissolving alumina and conducting electricity.

Synthetic cryolite, which is available as a substitute for the natural mineral, is prepared from fluorspar (calcium fluoride), soda ash, and sulfuric acid. Production of artificial cryolite, in which objectionable impurities are lower than in the natural mineral, is obtained by treating fluorspar with sulfuric acid to produce hydrofluoric acid; this is neutralized with the proper amounts of soda ash and aluminum hydrate.

Making 1 lb. of aluminum metal requires 2 lb. of aluminum oxide, 0.8 lb. of carbon anodes, 0.1 lb. of cryolite, 0.1 lb. of fluorspar, and 12 kw.-hr. of electricity.

In order to obtain high purity (more than 99.99 per cent of aluminum), the usual carbon cathodes are replaced by cathodes of aluminum-copper alloy. Cathodes are placed in reduction cells, or pots, the dimensions of which are limited to a few feet.

Uses. Cryolite, imported in relatively small quantities, is a key product that fills an important industrial need. Used chiefly as a source of metallic aluminum and as a metallurgical flux and solvent in smelting the metal, cryolite is meeting competition from artificial cryolite made from sodium carbonate, bauxite, and fluorspar; productive capacity for the synthetic product is limited.

The mineral is also employed, in small amounts, in the manufacture of certain sodium salts, as an electric insulating material, as a binder for abrasives, and in the preparation of insecticides.

Cryolite is an important source of fluorine, 1 ton containing 1,088 lb. compared with 974 lb. to 1 ton of fluorspar. In the manufacture of opal glass, cryolite is superior to fluorspar. It has also found strategic applications in the manufacture of certain kinds of tough porcelain and for glazes and enamelware.

Manufactured fluorine salts, such as artificial cryolite, sodium silicofluoride, and sodium fluoride, have been employed in the manufacture of opaque glass and enamels. Synthetic cryolite has been used to a limited extent by insecticide industries.

Domestic Sources of Supply and Production. The first commitment for the purchase of cryolite by the Metals Reserve Company was made in 1942. Cryolite ranked twenty-third in cost of delivery among the stockpile items held by the MRC, and deliveries had a total value of $3,436,701 of which $3,066,893 was reported in the inventory of Oct. 31, 1944. Cryolite, refined equivalent, amounting to 25,512 short tons was held in government stocks by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration.

The War Production Board placed cryolite under complete allocation and use control on Sept. 18, 1942, when General Preference Order M-198 was issued. This required special authorization of the WPB for the delivery or use of both natural and artificial cryolite, the only exception being for use as an insecticide.

Government stockpiles of 38,515 net tons were reported by *The Wall Street Journal* on July 17, 1944. All restrictions on the use of cryolite were removed by the WPB on Oct. 6, 1944.

The U.S. Bureau of Mines reported production of artificial cryolite in 1942, at East St. Louis, Ill., by Aluminum Ore Company, which also had a plant under construction near Bauxite, Ark. Small production was also reported by Pennsylvania Salt Manufacturing Company. This company completed a commercial plant in 1943, located at Cornwallis Heights, Pa., but production was not started there or at the Arkansas plant.

World Production, Imports and Exports. The only source of supply is the large Danish-owned deposit at Ivigtut, Greenland, where cryolite is associated with pegmatite within an intrusive mass of porphyritic granite. Three grades of refined cryolite are marketed, the highest containing a minimum of 98 per cent of cryolite (sodium aluminum fluoride) and a maximum of 1.5 per cent of silica. The next two grades, differing mainly in fineness, have a sodium-aluminum fluoride content of 93 to 94 per cent.

IMPORTS OF NATURAL AND ARTIFICIAL CRYOLITE FOR CONSUMPTION IN THE UNITED STATES, IN LONG TONS
(After U.S. Bureau of Mines)

Country	1940	1941	1942	1943
Canada	.....	4		
Greenland	25,818	26,680	64,565	46,400
France and Germany	40			

In the period 1915–1935, imports for consumption in the United States averaged 5,441 tons. Volume increased in 1940 to 25,818 long tons valued at $1,322,775; in 1942, 64,565 tons valued at $3,859,875.

Prices. The price of cryolite in 1940 was quoted by the U.S. Bureau of Mines at $51.25 a ton. The average annual price, 1915–1935, was $67.78, with a maximum in 1929 of $86.25 a ton.

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DIAMONDS

(Industrial)

Properties. The diamond is chemically identical with graphite, into which it can be converted by the action of heat or electricity. The diamond possesses adamantine to greasy luster; it is brittle and colorless to gray, brown, yellow, and, sometimes, blue to black. Its hardness is 10; its specific gravity, 3.5 to 3.53. Although it is the hardest substance known, tantalum or an alloy of tantalum competes with it. (C; atomic number, 6; atomic weight, 12.01; melting point, 3500°C.)

The coefficient of expansion increases very rapidly above 750° and diminishes very rapidly at low temperatures. The diamond is transparent to X rays, a ready method for detecting paste imitations. Borneo stones are said to have the greatest hardness. Natural carbon abrasives include industrial diamonds (glaziers' and engravers', unset, and miners') and bort.

Bort is a gray cryptocrystalline diamond. Impurities and inclusions give the stone a gray to black color. Shot bort is steel gray and has great toughness. Hailstone bort is less hard than common bort and in appearance like cement, gray to gray-black in color. Carbonado, or carbon, is black to gray-black bort, massive, sometimes granular to compact.

The diamond, a product of deep-seated crystallization of certain ultrabasic rocks, occurs in the groundmass of kimberlite (porphyry) in pipes of volcanic rocks. Other occurrences are in alluvial deposits, along shore lines concentrated by wave action, and in conglomerate and phyllite dikes.

Uses. The consummate hardness of the diamond has made it most useful for purposes of grinding, polishing, and drilling. Without the diamond, satisfactory precision tools, truing wheels, and wire-drawing dies cannot be produced, no substitute having been found. Greater need for abrasive diamonds was developed in the manufacture of war materials through the development of harder metal alloys and the need for greater accuracy and higher working speeds. The manufacture of precision lenses and supersmooth finish for bearings developed as vitally important in war industries.

In 1940, increased application was made of diamond-impregnated wheels and tools with a powdered metal bond, and there was a greater demand for drill bits mechanically set with small stones. As compared with the First World War, the use of industrial diamonds has increased nearly forty times.

The use of diamonds has grown on a scale comparable with mechanization of industry. Greater efficiency has resulted from the new technique of mechanically setting stones in core bits, reaming shells, and various matrices, particularly powdered metal, plastics, and ceramic bonds. Smaller and less expensive stones have been used than those formerly employed, when setting was done by hand. Small stones are sounder than the larger sizes. Diamond dust, formerly a waste product, is added to powdered metal or bonded compositions to make abrasive wheels employed in shaping extremely hard alloys that have an essential place in industry. Diamonds are vitally needed, in addition to abrasive uses, because of abrasion-resistant qualities which make them essential as dies in drawing wires or filaments of copper, tungsten, and brass and as atomizers in oil-burning equipment.

In 1944, the National Bureau of Standards was reported to be developing standardization of trade practice in designation of grain size for diamond dust. The National Academy of Sciences, in 1943, sponsored a series of tests on diamonds for grinding-wheel tooling as a result of a threatened shortage of stones for this use. Diamond grinding wheels, of minor importance early in the war, advanced in industrial application in 1944 to become the largest single use of the industrial stones. The greatly expanded applications of strategic importance include the following: mechanical fuses in timing instruments for bombs, switches, and microgears; bearings for meters and other scientific instruments; and watch and chronometer jewels.

The diamond has always been the only material used for cutting or engraving the diamond itself and is now also applied for cutting and drilling glass and porcelain, for fine engraving such as scales, for drilling in dentistry, as a turning tool for hard rubber, and for finishing accurate truing work. For rock drills and for revolving saws for stone cutting, diamonds set in steel tubes, disks, or bands are employed. In wire drawing, a hole tapering in toward the center is drilled through the diamond where metal is drawn through this, giving uniform thickness of wire.

In certain types of work, such as oil-well drilling, cobalt-tungsten-carbon and carboloy (tungsten carbide) are used as diamond substitutes. Small cast pieces of the alloy are welded to the cutting edge of rotary drills or on the wearing surfaces of such articles as tail skids, shovel teeth, and other appliances, giving increased life and efficiency to the article treated.

Larger diamonds are used in wheel-dressing tools, the smaller sizes being employed in diamond-core drilling. A great increase was noted in 1942 in the use of bonded diamond tools for grinding hard and brittle metals, nonmetals, and synthetics. A new bond of the ceramic vitrified type with a high glass content was introduced in 1942 as a result of research. In 1943, great increases

were recorded in the use of crushing bort in bonded wheels and other tools and diamond dust for grinding vital parts of radio and radar equipment.

Domestic Sources of Supply and Production. As one of the critical materials being stockpiled by the government in 1940 to safeguard the output of aircraft engines, industrial diamonds could be exported only under license, according to the Presidential proclamation effective on July 5, 1940. Early in 1941, the procurement division of the Treasury Department purchased Brazilian diamonds valued at $100,000. The War Production Board designated industrial diamonds on Mar. 1, 1944, as sufficient for war uses plus essential industrial demands.

The first commitment by the Metals Reserve Company for the purchase of industrial diamonds was made in 1941. The diamond ranked fifteenth in relative cost of deliveries to the stockpile, and purchases by MRC were valued at $12,099,422. The inventory on Oct. 31, 1944, was $8,619,432. The Office of Metals Reserve reported the government stockpile, on Oct. 31, 1945, at 3,529,883 carats.

Stimulated by the defense program, the industrial use of the diamond in the United States probably exceeded 2 million carats a year, with stockpiles adequate for only a year's requirements. In 1940, the strong demand both in this country and in Great Britain led to upward trending prices.

Production of glaziers' and engravers', unset, and miners' diamonds increased 194 per cent in 1940–1942. Imported industrial stone expanded from 6,882,248 carats in 1941 to 11,203,704 in 1942.

Only negligible sources of diamonds are known in the United States. A prospecting and sampling project was carried on by the U.S. Bureau of Mines in Arkansas in 1943. Diamonds represent the second largest nonmetallic mineral imports recorded in 1939, accounting for 12 per cent of total nonmetallic imports. In the past 30 years, there has been an eightfold increase in consumption of diamonds, indicating the possibility of a shortage at some future time.

The Department of Interior reports that the postwar diamond cutting and polishing centers are to be located in the United States, Palestine, and Brazil. Through the war years, the world was adequately supplied with cut stones by about 11,000 artisans and apprentices, one-third of the prewar labor forces of the industry when it was centered in Belgium and the Netherlands.

The Industrial Diamond Association of America was formed in February, 1946, for the purpose of promoting the progress and development of the industrial-diamond and diamond-tool industry. It was proposed to carry on research in the use and manufacture of industrial-diamond tools.

Industrial diamonds adequate for the needs of industry were reported by

the Civilian Production Administration on Nov. 30, 1945. In August, 1945, the WPB informed the Industrial Diamond Advisory Committee that consumption of diamond powder (crushed bort) was at the rate of 35 per cent in excess of the available supply. Although production had increased 50 per cent in 1944 over 1943, the demand continued far in excess of supply, as reported by the WPB miscellaneous minerals division. Shipments received from Britain were reported to be exhausting stockpiles. A contract was negotiated to continue the rate of shipments through 1946. After the stockpiles had been exhausted, the world output in 1947 would determine the rate of consumption. Stockpiles of industrial stones for diamond drills were expected to be exhausted early in 1946, when it would be necessary to limit consumption to the current output.

World Production, Imports and Exports. Imports from South Africa, which supplies over 90 per cent of industrial diamonds, and Brazil totaled 3,809,071 carats valued at $11,026,563 in 1940 compared with 3,568,730 carats in 1939. Imports in 1943 exceeded 12,000,000 carats. Belgium and its colonies and the British Empire are self-sufficient in industrial diamonds. Other world powers are dependent almost entirely on foreign sources. Diamond production in both Africa and Brazil, where tropical disease was formerly a critical hazard, would be at least one-third the present rate if medical research and sanitation had not advanced tropical hygiene. Dr. C. K. Leith has shown that increase in available stocks of industrial diamonds has resulted from improving the health of the working force.

Market estimates of total industrial diamond sales are as follows: in 1938, £4,050,000; in 1941, £2,000,000; in 1942, £4,250,000; in 1943, £6,000,000. The all-time record of $104,000,000 in 1945 for rough diamonds was expected to be followed by about $64,000,000 in 1946, owing to the supply shortage. The demand for industrials grew so strong in the war period that much of the smaller flawless stone marketed in prewar years as gem material was diverted to war purposes as abrasives and cutting dies. World output was estimated at 14,250,000 carats in 1940; in 1941, slightly less than 9,350,000 carats.

Diamonds were discovered in Brazil in 1729 at the time when colonization started; output increased from about 330,000 carats valued at $7,350,000 in 1941 to more than 400,000 carats in 1944, the higher rate of production being due in part to the price increase. All diamonds are mined from river-bed or bench deposits, largely by means of panning operations and with pick and shovel. Produced mainly near Diamantina, Minas Gereas, and in the state of Matto Grosso, fields of the Tocantins River basin, state of Goyaz, are reported to be of equal importance. Some production is secured in the state of

Para. Mines in Bahia produce carbonado. Diamonds are found partly in river gravels and partly in breccia on the high lands. River deposits are described as rolled quartz pebbles mixed with ferruginous clay resting on a bed of clay.

In Brazil, the industrial diamond was one of 17 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for the purchase of the entire exportable surplus as part of the foreign procurement program initiated late in 1940. The U.S. Purchasing Commission in Rio de Janeiro bought 184,347 carats at a cost of $3,461,284 from Jan. 1, 1942, to June 30, 1943. In prewar years, about 30 per cent of Brazilian diamonds exported were for industrial purposes and 70 per cent for gems. This ratio was reversed during the war period.

In Venezuela, production from the diamond fields to help meet war requirements for industrial stones was reported, in February, 1945, at the annual rate of about 24,000 carats. Russia announced, on May 21, 1945, the discovery of 19 new diamond deposits in the Ural Mountains. Soviet diamond production in 1944 was reported to have set a new record. The Urals were reported, in 1942, as a new source of alluvial diamonds.

Major production of industrial diamonds is secured from Africa. In South Africa, diamonds were discovered in the Kimberley district in 1867, in gravels along the Vaal and Orange rivers as far as Hope Town. The principal mines have been the Kimberley, DeBeers, Dutoitspan, Wesselton, and Bulfontein, located in a district 3½ miles in diameter. At each of the mines, the diamond-bearing pipe or volcanic neck is intrusive in flat-lying black shale. Altered kimberlite below the zone of weathering is described as "blue ground," through which the diamonds are scattered. Important mines are located in the Orange Free State (the Jagersfontein) and in the Transvaal (the Premier). Diamond-bearing kimberlite is also reported in Rhodesia, and gravel and beach deposits are found in Cape Province and West Coast.

Since the First World War, production of diamonds in Africa has shifted to the Congo, the Gold Coast, Sierra Leone, and Angola, where almost 90 per cent of the world total was secured in 1938. In these newer districts, diamonds are recovered at lower cost from alluvial deposits. Kimberlite deposits in South Africa are now producing fewer and lower grade stones than formerly. Although not yet exhausted, many of the mines have been closed owing to higher costs of operations at depth and because higher prices are necessary to make operations profitable.

In 1941, U.S. Bureau of Mines reported 94 per cent of diamond production secured in the Belgian Congo, the Gold Coast, Sierra Leone, and Angola; 2 per cent came from South Africa and South-West Africa; 4 per cent from

Brazil, Venezuela, and British Guiana. The Beceka mines of the Belgian Congo were stated to be the major center of production.

In Australia, diamonds have been found in New South Wales, Victoria, Queensland, and South Australia.

In 1940, the diamond-cutting industry of Amsterdam and Antwerp was dispersed by the German occupation, to New York, Palestine, Brazil, South Africa, Canada, Britain, India, and the West Indies. The postwar survival of some of these appears likely, particularly in New York, Canada, Palestine, and South Africa, for producing gem stones and bort suitable for use in diamond drilling and other cutting tools required by industry. Cutting was being reestablished in Antwerp in June, 1945; and by June, 1946, that city had regained its position as the leading diamond-cutting center with about 14,000 cutters. In Amsterdam, only 700 of the prewar 3,500 expert workers were reported active in February, 1946, the other diamond cutters having been exterminated in German concentration camps. Large stocks of stones were stolen in the war years. Amsterdam established a school to train 10,000 cutters and polishers. Palestine's richest industry in the war years was diamond-cutting, giving a $30,000,000 export balance in 1945.

Diamond Corporation, which marketed 90 to 95 per cent of world production in 1943, is a purchasing agency of the diamond producers. It was formed in 1930 to replace the DeBeers and the Barnato groups, which formerly fixed quotas and prices. The giant monopoly was formed for the purpose of stabilizing the industry through restrictions on production and sales. In the Second World War, London was selected as the world marketing center for diamonds. In March, 1942, Diamond Corporation was placed under control of the British government in order to assure a supply of industrial stones for strategic uses and to prevent sales of rough diamonds for speculation and hoarding.

"Of all the mineral industries, none is subject to such strict and unquestioned control as the production and sale of diamonds—both gems and industrial grade." The control of a single corporation has embraced more than 90 per cent of the industry and includes most of the new diamond fields. The price policy of the monopoly has been regarded as reasonably satisfactory.

The Foreign Economic Administration followed the policy by withdrawing from public purchase of foreign industrial diamonds when possible, returning the trade to former private channels if no impairment to the war effort resulted.

Prices. The price advanced from $2.73 to $2.89 a carat from 1939 to 1940; in 1941, $2.17; in 1942, $1.98, as reported by the U.S. Bureau of Mines. By agreement of the producers, diamond prices remained unchanged

in the war period. Diamond Corporation announced a new policy on Feb. 13, 1946, of adjusting the selling price of rough diamonds in accordance with ruling market prices. Demand for industrial diamonds was reported to be "insatiable" even after war industry had been demobilized, and prices of "common crushing bort" were raised from 50 cents to $1 per carat; other industrial stones increased 30 per cent.

In Canada, the Price Board removed industrial diamonds from price control on Mar. 15, 1946.

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EMERY ORE

(Turkish)

Properties. An impure granular variety of corundum containing magnetite, hematite, or iron spinel, emery has a broader application as an abrasive than corundum. Both are natural alumina abrasives. Its specific gravity is 3.7 to 4.3; its hardness, 8. Emery occurs as a granular or massive, dark-colored, dense mineral resembling iron ore in appearance.

A variety of garnet known as almandite (a silicate of iron and aluminum), transparent to deep red in color, has been employed for strategic purposes as a substitute for emery and corundum.

Uses. In the production of essential war materials, emery sticks, emery cloth, and emery paper were adapted to a wide range of manufacturing processes. Emery had been used for centuries as an abrasive, and war requirements led to various new applications. Floors surfaced with a coating of graded emery aggregate, Portland cement, and water are rendered nonslippery even when wet; the floor gives good traction and has increased load-bearing properties and high resitance to wear.

Emery (or garnet) particles, held in a special plastic synthetic-resin binder, were employed by the Navy as a fire-resistant, nonskid deck covering adapted for use around gun emplacements on battleships. This abrasive material, in the form of a viscous fluid, is stored ready for use in metal containers. It is applied to wood, concrete, or steel floor surfaces either by spray guns or with a trowel. The coating dries in a few hours and is not affected by ordinary temperatures. It is durable and corrosion resistant.

Emery wheels are made by consolidating the powdered mineral with an agglutinating medium, such as shellac, silicate of soda, or vulcanized rubber. The wheels are employed in grinding, shaping, and polishing steel and other metals, as well as in the preparation of nonslippery surfaces. Plate-glass manufacturers and lapidaries make use of a very fine emery dust in polishing operations.

Domestic Sources of Supply and Production. In 1942–1943, the entire domestic output, amounting to 5,277 short tons valued at $49,413 (1942), was from three operators near Peekskill, N. Y. This value was 16 per cent higher than 1941 output, the increase in volume being 8 per cent; in 1943, the value was further increased by 28 per cent, the volume for the first time

exceeding garnet. Record output, in 1918, amounted to 10,422 tons, including a small amount of corundum.

Production in 1941 was 4,876 tons; in 1942, 5,277; in 1943, 6,666 tons valued at $63,195. Production formerly was secured from deposits associated with periodotites, located near Chester, Mass., and at several other localities in the United States. Producers in 1942 were Joe DeLuca, Di Rubbo & Ellis, and Scalzo & Pisano. Domestic production of emery sold or used by producers was valued at $42,484 in 1941; in 1942, $49,413; in 1943, $63,195.

The principal domestic source of garnet is Barton Mines Corporation, North Creek, Warren County, New York. Ore is produced by open-pit mining at this property, where the mill was the first nonmetallic project to adopt heavy-mediums separation (float-sink) processes and the first to use ferrosilicon as the separating medium other than in the treatment of iron ores. This has resulted in a greater proportion of garnet recovery in the minus ½- plus ⅛-in. range, leading to larger production without employing additional workers.

World Production, Imports and Exports. Imported emery ore, in 1940 amounted to 5,718 tons valued at $73,935; no imports were reported from 1941 to 1943. Imported paper and cloth of emery and corundum were valued at $91,112 in 1940; in 1941, $165,544; in 1942, $156,846; in 1943, $76,193. Imported wheels, files, and other manufactures of emery, corundum, and garnet were valued at $2,473 in 1940; in 1941, $476; in 1942, $1,329, in 1943, $108,018.

Emery was imported chiefly because of industrial necessity under war conditions. Exports of emery, corundum, and domestic abrasive wheels, in 1940, were valued at $179,514; in 1941, $144,393; in 1942, $3,665,386; in 1943, $1,334,654. In 1942, exports were higher than in any year since 1918.

No records are available of the greatly expanded supplies secured from Turkey since 943. Important sources in Asia Minor, south of Smyrna, include Gumach Dagh, Kula, and mines in the hills between Thyra and Costbonnar. In these localities, emery and corundum occur as rounded masses embedded in a crystalline limestone associated with schist and granite.

Australia has emery deposits of good quality, but distance from markets has delayed development.

Prices. The price of first-grade domestic crude emery ore, f.o.b. New York, was $10 a ton, as quoted Apr. 12, 1945, by *E & M J Metal and Mineral Markets*. This price had been in effect through 1943. Other domestic ore was $16 a ton, delivered to grinders. American grain emery was 5 cents a pound, in 350-lb. bags, f.o.b. Pennsylvania.

Turkish and Naxos grain emery was quoted at 7 cents a pound; Khasia, 6 cents, f.o.b. Pennsylvania.

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FELDSPAR

Properties. The feldspars are alumina-silicates of potassium, sodium, calcium, and barium. All 11 types of feldspar have a similarity of crystal form and cleavage; the color range is usually white, pink, yellow, or green. Alteration products include kaolin and calcite.

Feldspars are of three main types: potash spars, microcline and orthoclase; soda feldspar, or albite; and soda-lime, or plagioclase, feldspars. Celsian (barium feldspar) and potash-barium feldspar are minor types. "Cornwall stone," formerly imported from England, has been duplicated in the United States by "Carolina stone," a synthetic mixture of the same materials (feldspar, quartz, and kaolinite).

The feldspars have similar properties. Their hardness is 6 to 6.5; their specific gravity, 2.56 to 2.76. The melting point of potash spar is 1200°C.; albite, 1110°C.; and anorthite, 1532°C.

Workable deposits are granitic pegmatites. Large pieces of spar are secured by means of hand-sorting coarsely broken rock. Iron-bearing biotite, garnet, and tourmaline are impurities that are usually sorted out before the feldspar is used. Glass spar, for glassmaking, of the No. 2 grade must contain a minimum of 17 per cent of alumina; the No. 1 grade limits the free-quartz content to 6 per cent. Pottery spar usually has a high-potash content and 73 to 65 per cent of silica. Glaze spar is typically high in soda. These three types of ground spar are distinct from crude spar; the latter may contain more mica but must be free from quartz (grit).

Uses. The first record of making porcelain, for which orthoclase feldspar is used, was in China prior to 945; the first feldspar mine, at Ytterby, Sweden, was opened in 1780. In modern practice, orthoclase is also employed in the manufacture of many ceramic glazes and as a source of potash.

Of ground feldspar marketed in the United States, an average of 95 per cent is consumed by the ceramic industries, more than 50 per cent being used in the manufacture of glass. In addition to its use for pottery and enamelware, crude feldspar is employed as an abrasive by manufacturers of soap and cleansing and nonskid compounds. Glass containers and building materials were substituted for metals needed more urgently in making war materials. Electrical porcelain and radio and radar parts were among many essential war uses.

The glass industry, in 1939, consumed 53 per cent of ground feldspar;

pottery makers took 34 per cent; enamel manufacturers, 11 per cent; and the balance was used for soap, cleansers, sweeping compounds, abrasives, and ceramics. Glass containers were the most important product in the war period, increasing 12 per cent in 1942 over the previous year and 17 per cent in 1943. Production of plate glass was 20 per cent higher in 1943, when heavy demands were made for vitrified porcelain.

An essential war application was in the production of plastic body armor made of laminated glass cloth. This new material was ready for combat use by the U.S. Navy and Marine Corps for assault troops just before the war with Japan ended. The armor was demonstrated to be effective against bullets and fragments. Glass-cloth combat jackets for ground troops were given a preliminary test on Okinawa. These jackets, called Doron, were described as lighter, more pliable, and more comfortable than steel, although bulkiness gave the glass jackets a disadvantage. The Naval Research Laboratory started the plastic-armor research program in December, 1940, supported by the Navy Bureau of Aeronautics and the Army Quartermaster Corps.

Fiber-glass manufacture developed into two main branches in the war years: bat wool and textile. The former is one of the most efficient insulators known and has been used particularly in the construction of prefabricated houses. In airmen's life jackets, glass, replacing kapok, resists organisms that attack other substances. In the textile industry, glass is being developed for use in tablecloths and other applications. A fiber-glass cloth used to reinforce plastics for aircraft construction and for other purposes was reported to produce a material lighter than aluminum, stronger than steel, and having elastic and physical properties superior to either metal.

Nepheline is being used by the glass industries to replace feldspar, as the high-alumina content is an important advantage. Increasing amounts are being used in various types of ceramic bodies, the dust residue being employed for grinding and polishing as a substitute for pumice and in the heavy-clay industries. In Russia, nepheline is employed in the aluminum industry as a substitute for bauxite.

War uses made increased demands for vitreous porcelain and for welding-rod coatings. An effective extinguisher for magnesium bombs was developed in 1942, making use of ground feldspar and aplite. War priorities led to reduced output of floor and wall tile and of porcelain-enameled products.

Postwar applications of glass are expected for structural and other uses, replacing plastics and such metals as copper, brass, tin, lead and steel. Glass brick, hollow tile, and glass walls and partitions have been widely discussed for application in postwar construction. Continued use of glass containers is expected, replacing tin and steel. Expanded development is expected of

glass fiber, glass wool, and combinations of glass fibers and plastics. Large consumption of feldspar for porcelain production is expected to continue, replacing various metals, including chrome and steel. Greater demand is expected for enameled products, such as kitchen equipment, refrigerators, and stoves. For making artificial teeth, a small tonnage of selected crude spar is used, valued much higher than the No. 1 commercial spar. In prewar years, major consumers were pottery, tile, and sanitary-ware manufacturers.

Domestic sources of supply and production. Feldspar production in 1943–1944 was at capacity. Domestic production of feldspar in 1938 accounted for about 60 per cent of the world total. The glass industry reported a shortage of available supply, although milling capacity was adequate for requirements. Sales in 1944 were 5 per cent higher than in 1943, at 325,000 tons compared with 253,466 tons in 1939 valued at $1,112,857, 29 per cent above 1938. Ground feldspar, in 1939, sold by merchant mills, increased 21 per cent to 259,194 short tons valued at $2,862,278. Crude feldspar produced in 1941 was 338,860 long tons; in 1942, 316,166; in 1943, 308,180 tons valued at $1,646,277; in 1946, 400,000 tons.

At Kona, N. C. (Consolidated Feldspar Corporation), a new flotation mill reported to be the world's largest went into production in February, 1945, treating alaskite, which is too fine-grained to permit hand-sorting. Rated capacity is 750 tons a day, with quartz and mica as by-products. Feldspar miners were asked by the government to recover all possible associated mica. Froth flotation had been developed as an efficient method for the separation of feldspar and quartz. This process makes possible the more economical recovery of feldspar.

Beneficiation of low-grade feldspars has included the processing of run-of-mine spar by fine grinding and removing impurities either by screening or air separation, followed by magnetic separation. The application of flotation makes possible the replacing of hand mining by large-scale quarrying operations.

High-grade potash feldspar is mined in Colorado, South Dakota, Arizona, California, and Wyoming. The principal production in the East comes from North Carolina, Virginia, Maine, New Hampshire, New York, and Connecticut. These last states produce both potash and soda spars. Glaze spar is mined in small quantities in Pennsylvania and Maryland. In the future, a larger percentage of production is expected to be mined in granite than in pegmatite dykes.

In New Hampshire, feldspar producers changed over in 1944 from hand- to mechanical-production methods, some mines adding crushing and picking belts. Flotation mills have been installed by several producers to concentrate subgrade rock in order to fill grinders' requirements. Mining and preparation

methods adopted under the stress of war may be maintained in modified form in the postwar period.

UNITED STATES FELDSPAR PRODUCTION AND IMPORTS, IN LONG TONS
(After U.S. Bureau of Mines)

Product	1941	1942	1943
Crude feldspar	338,860	316,166	308,180
Imports	11,253	9,525	11,912
Ground feldspar	354,417	327,786	335,810
Imports	.....	.....	41

World Production, Imports and Exports. World production of feldspar increased from 275,000 long tons in 1920 to about 500,000 in 1940. Feldspar is imported from Canada primarily because of economic advantage, the volume in 1939 amounting to 7,480 tons valued at $52,141; in 1944, 13,081 tons. Of total consumption in 1937 of ground feldspar, imports represented only 6 per cent. In the war period, imports of nepheline syenite from Canada were much larger than shipments of feldspar. Transportation and cost advantages make imports from Canada economical, although adequate domestic supplies are available in the United States. Canada produced 20,385 tons of feldspar in the first 9 months of 1945 compared with 17,146 tons in the same period of 1944. Canada and U.S.S.R. are the only producers of nepheline syenite. In Ontario, American Nepheline Corporation has been active since 1936, when a processing mill was erected at Lakefield. A more modern mill at Rochester, N. Y., now treats most of the output and supplies glass and pottery grades and small amounts of enamel grade.

WORLD PRODUCTION OF FELDSPAR, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Argentina (shipments)	1,051	1,220	2,981	5,650	*
South Australia	615	1,072	1,081	*	*
Western Australia (exports)	3,853	3,561	*	*	*
Canada (shipments)	11,306	19,464	23,623	20,203	23,499
Egypt	74	138	52	19	20
Finland (exports)	5,596	*	*	*	*
British India	501	*	*	*	*
Norway (exports)	21,282	*	*	*	*
Sweden	40,792	*	*	*	*
United States (sold or used)	257,534	295,430	344,299	321,240	313,126

* Data not available.

Prices. The price quoted by *E & M J Metal and Mineral Markets*, Sept. 30, 1946, for white potash feldspar, 200-mesh, in bulk, was $17 a short ton,

f.o.b. North Carolina and Maine, in effect since 1941. Granular glass spar, white, 20-mesh, was $12.50 a ton, f.o.b. North Carolina; $12.50, in bulk; semigranular, $11.75. Soda feldspar, 200-mesh, white, f.o.b. North Carolina and Maine, was $19.

Quotations on Spruce Pine, N. C., or Keene, N. H., basis, for Virginia feldspar, were as follows: No. 1, 230-mesh, $18; 200-mesh, $17. No. 17 glassmakers' was $11.75; No. 18, $12.50. Enamelers' was $14 to $16 a ton.

Average values for ground feldspar ranged from $6.91 to $17.86, in 1943, slightly higher than in 1942. Colorado feldspar, in 1943, averaged $6.91 per ton; South Dakota, $7.71; North Carolina-Tennessee, $11.80; New Jersey, $17.59.

Canadian nepheline syenite, 1942–1944, was quoted by the U.S. Bureau of Mines as follows: Grade A, 20-mesh, bulk, in carlots, $11.75 a ton, f.o.b., Lakefield, Ontario; 200-mesh, $16.50, f.o.b., Kingston, Ontario; grade B, dust in bulk, in carlots, $10 to $13 a ton, f.o.b. Lakefield.

Canadian crude feldspar for export or shipment to domestic mills was $6 to $7.50 a ton, according to grade, f.o.b. rail, in 1944. Selected crude dental grade for export to the United States was $45 to $53 a ton, carload lots. Canadian ground spar for domestic granular glass trade was $12.50 a ton in 1944; 200-mesh pottery grades, carload lots, f.o.b. mill, $16.50 to $20 per ton.

The United States tariff on imported crude feldspar is 25 cents a long ton; ground feldspar, 15 per cent ad valorem. Crude nepheline syenite is duty free; ground, 15 per cent ad valorem.

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FLUORSPAR

Properties. A soft, somewhat brittle mineral, fluorspar varies in color from white to dark blue; it has a vitreous luster. Fluorspar (calcium fluoride) contains 51.1 per cent of calcium and 46.9 per cent of fluorine. (F, atomic number, 9; atomic weight, 19; melting point, 223°C.) Only four other elements have melting points lower than fluorine, which is the most reactive of all elements. Its hardness is 4; its specific gravity, 3 to 3.25.

Fluorspar, although rarely contaminated with impurities, is generally associated with other minerals from which it must be separated for commercial use. Most abundant in veins and in sedimentary formations, it belongs to a small group of "persistent minerals" that are less sensitive to physical conditions.

The origin of commercial deposits of fluorspar is believed to be associated closely with deep-seated magmatic emanations. In the Illinois-Kentucky district, the sedimentary rocks that enclose fluorspar deposits have been intruded by dikes, sills, and plugs. Fluorspar, a low-temperature mineral, weathers to gravel spar, which is distinct from the gravel fluorspar (a milled product) used for the steel trade. Fluorite, although often very pure, may be associated with barite, calcite, and sulfides of lead and zinc.

Optical fluorite (calcium fluoride) is slightly harder than Iceland spar, a diagnostic difference between the two minerals being cleavage. Fluorite has perfect cleavage in four directions, each fragment being an octahedron. Its melting point is 1378°C. Fluorite holds a unique position among minerals for highly specialized optical use, owing to low refractive power and very weak color dispersion. The so-called "apochromatic objective" used with microscopes consists of fluorite placed between lenses of glass and represents the finest type of objective that optical art produces.

Uses. Its importance as a strategic mineral is due to the use of fluorspar as a flux in smelting metals, particularly in the open-hearth manufacture of steel, the manufacture of alloy steel and ferroalloys in the electric furnace, and foundry work and in the preparation of aluminum. The fluorspar industry is dependent primarily on steel and aluminum production. In the Second World War, consumption of fluorspar was increased far beyond all previous demands of metallurgy. Fluorspar (8 to 10 lb. per ton of steel output) is used in the basic open-hearth process; it is added to the bath just before the furnace

is tapped in order to render the slag more fluid and partly to desulfurize the molten metal. In the electrolytic process of aluminum manufacture, high-grade fluorspar, fused with bauxite and soda ash, is used as a molten bath.

The second largest application is in the chemical industry for the manufacture of hydrofluoric acid. One of the essential uses of this acid is as a catalyst in the production of aviation gasoline. For these purposes, fluorspar must be sulfur-free, containing a minimum of 98 per cent of calcium fluorite and less than 1 per cent of silica.

Important amounts of fluorspar are used by the ceramic industries, in opal or opaque and colored glass and in various enamels for coating metalware. Fluoride glass is being given intensive study in the light of modern chemistry, the chemical research director of Bausch & Lomb Optical Company reported in January, 1946. He predicted that glass containing little or no silica would be used on an increasing scale. Fluoride nonsilica glass has proved its value in the photographic field.

Fluorspar is also an essential mineral in the manufacture of cement, calcium carbide and cyanamid, abrasives, heat-resistant brick, and carbon electrodes. It is employed in the manufacture of refrigerants and insecticides. Manufactured fluorine salts are sometimes used in making opaque glass and enamels.

The mineral lepidolite is also used as a source of fluorine as well as for its content of lithia, potash, and alumina. Zinc chloride, usually cheaper than sodium fluoride, is generally preferred as a wood preservative although it is inferior to the fluoride. Other fluorspar substitutes are bone ash and other calcium phosphates. Fluorspar has no substitute in the manufacture of hydrofluoric acid and its derivatives.

Demands in 1944 were unusually heavy, particularly for the glass and enamel trades. Of domestic consumption in 1944, about 83 per cent was for steelmaking (80 per cent in 1936); 9 per cent was taken by the glass industry (in 1936, 6 per cent); enamel industry and vitrolite, 3 per cent; hydrofluoric acid and derivatives, 4 per cent (in 1936, 7 per cent).

"Acid" grade fluorspar is employed in aluminum refineries for making synthetic cryolite. Application in welding-rod coatings is important. Calcium fluoride (fluorite) is employed as a welding flux in the metallurgical industries. For the more specialized uses, material of high quality is demanded.

Optical fluorite crystals like Iceland spar are essential to the microscope industry and in the manufacture of various optical instruments. Great transparency to the ultraviolet and infrared parts of the spectrum has given this mineral vital importance in making prisms for spectrographs and as part of the lens system in telescopes to correct certain color effects. Transparent,

flawless crystals are sold at premium prices for use in lenses and lens systems to correct chromatic and spherical aberration. A substitute for optical fluorite is lithium fluoride, in large, clear, carefully annealed crystals, as produced by Harshaw Chemical Company, Cleveland, Ohio.

First attention is to be given fluorspar, among the nonmetallics, by the U.S. Geological Survey for uses under postwar economy, the promise of broad applications in future indicating that present facilities have not been overexpanded. The demand for fluorspar will depend on the volume of industrial production of the metallurgical industries for stimulated output in relieving shortages of goods and services of many kinds.

The fluorides were reported in 1944 to be promising substitutes (with lithia and strontia) for lead in glazing pottery. This application in the postwar period may compensate for the loss of military uses. A postwar application on a broad scale is expected to be the use of soluble fluorine salts (sodium fluoride) in municipal water treatment.

Wartime research, resulting in fluorine production increased from a few pounds a day to tons, at costs reduced by more than one-third, developed such new products as paints, textiles, plastics, and insecticides. Dr. J. H. Simons, Pennsylvania State College, reported in 1946 that fluorocarbons, having chemical inertness and resistance to combustion, heat, or chemical attack, are suited for use as fire extinguishers, turbine impellents, fireproofing materials, thermal and chemical resistant resins, and various other purposes.

Domestic Sources of Supply and Production. Fluorspar mining in the United States was marked by intense activity in 1940–1945. In 1942, shipments of 360,316 short tons were 37 per cent greater than in 1916; imports reached the record low level of 2,151 tons, 71 per cent lower than in 1941; in 1943, imports jumped to the highest figure recorded since 1930, to 43,570 short tons valued at $643,409. Exports were 26 per cent lower than in 1941 and increased only slightly in 1943.

Production and shipments, in 1943, increased 28 and 13 per cent over 1942 to 433,000 and 406,016 short tons, respectively. Illinois supplied almost half of total shipments in 1943, and new records were established by Colorado and New Mexico. More shafts were put down and more mills built in 1942 than in any previous year. Producton of metallurgical grade was less than requirements in 1942–1943. Stimulated output made it possible to meet the increased demand for acid-grade material; there was reduced consumption of ceramic-grade in 1942–1943. On recommendations by the Army Air Force, fluorspar plants in the Rosiclare district were protected against sabotage by fences.

Flotation tests on fluorspar ores from various sources have indicated that

effective separation of the ore is possible once the interfering shines have been removed, with fluorite recovery of more than 97 per cent in the final concentrate.

The Western Fluorspar Corporation, Cowdrey, Colo., has installed a sink-float plant treating ore from the open-pit mine; and in June, 1944, Tintic Standard Mining Company placed in operation its new concentrator for producing fluxing-gravel fluorspar at its silver-lead mine near Milford, Utah. Initial output of acid-grade fluorspar was secured in June from the flotation mill of Alloy Metals Division, Continental Machines, Inc., El Paso, Tex. Successful concentration by means of the ferrosilicon heavy-mediums process was started in March, 1944, by Rosiclare Lead and Fluorspar Mining Company. The flotation mill of Minerva Oil Company, Cave-in-Rock, Ill., went into operation in March, 1944.

The United States is both the largest producer and consumer, with peacetime imports—largely from Germany—accounting for as much as 50 per cent. Germany (including Austria) produced 35.2 per cent of the world total in 1938, compared with United States production of 17.2 per cent. Postwar production can be increased above prewar peak rates if market demand is adequate. Elmer H. Pehrson, U.S. Bureau of Mines, in 1944 estimated commercial fluorspar reserves to be adequate for 40 years, based on annual rate of consumption, 1935–1939. This reserve is stated to be only of quantitative significance and does not imply that consumption could be sustained at the assumed rate. A supply for 5 to 25 years is assumed for submarginal and highly speculative fluorspar material.

Harold L. Ickes, Secretary of the Interior, stated in December, 1945:

> We have less than a 35-year peacetime commercial supply of fluorspar and twenty other minerals . . . which we shall have to import in larger and larger quantities. . . . We cannot afford another prolonged war in 20 or 30 years.

Defense Plant Corporation spent an estimated $809,000 of government funds in building three mills for treating fluorspar. These included the Minerva operation at Cave-in-Rock (fluorspar-zinc mine and mill) and mills at Northgate, Colo., and Los Lunas, N. M., operated by the Western Fluorspar Corporation and the Zuni Milling Company.

Of domestic consumption, 1936–1940, the Kentucky-Illinois district supplied 80 per cent; 4 per cent came from Colorado; the balance was imported. New Mexico and other Western states have substantial ore reserves, but development has been delayed because of long distances to steel centers. Western ore reserves were estimated in 1936 to be sufficient for domestic requirements for 140 years.

In the prewar period, a small area along the Ohio River in southern Illinois and western Kentucky produced 92 per cent of the domestic supply (161,647 short tons in 1936), of which about three-fourths was used by basic open-hearth steel plants. Fluorspar deposits along the Rosiclare fault at Rosiclare, Ill., have been among the greatest in the world. The vein is nearly vertical and has been productive over a length of about three miles, to a depth of 720 ft., as reported in 1938. Extensive flat-lying deposits near Cave-in-Rock contain many vugs in which flawless optical fluorite occurs. Deposits of gravel, or residual, spar are more abundant in Kentucky, where proved ore bodies are less extensive and smaller but more numerous than in the Rosiclare district.

In 1944, new records were established for production, shipment, and consumption of fluorspar, as reported by U.S. Bureau of Mines. Production of finished fluorspar was about 415,000 short tons in 1944, including about 18,000 tons of fluxing-gravel fluorspar produced at the Gila, N. M., mill and held in the government stockpile of the Metals Reserve Company. In 1943, production amounted to 405,600 tons. Acid grade produced was less than demand; metallurgical and ceramic grade exceeded requirements. Stocks at mines of finished fluorspar at the end of 1943 were 19,000 tons; July 31, 1944, 30,188, and at producers' plants, 99,785; at the end of 1944, 20,000 tons. At the close of 1944, stocks at producers plants were 102,000 tons; at the close of 1943, 106,000. Of 1944 consumption of about 405,000 tons, the steel industry took 56 per cent (60 per cent in 1943); 32 per cent was taken by the hydrofluoric acid industry (30 per cent in 1943); consumption by the glass industry increased 36 per cent above 1943 to 28,000 tons. In July, 1945, production and shipments of finished fluorspar of domestic origin of all grades were 32,381 and 34,953 short tons, respectively, a decrease of 6 per cent in output from June but a 4 per cent increase in shipments.

The first commitment for the purchase of fluorspar by the MRC was made in 1942. Ranking twenty-fourth in relative cost of delivery to the MRC stockpile, fluorspar valued at $2,591,934 was delivered. The inventory on Oct. 31, 1944, was valued at $1,459,296. On Oct. 31, 1945, government stocks held by the Reconstruction Finance Corporation through the Office of Metals Reserve included 177,557 short tons of metallurgical fluorspar and 22,007 short tons of acid grade.

Government stockpiles were reported on July 17, 1944, by *The Wall Street Journal* to contain 60,604 tons of fluorspar and 12,164 tons of ore. The War Production Board designated fluorspar, on Mar. 1, 1944, as insufficient for war uses plus industrial demands. The restricted shipping plan that had been in effect since January, 1943, was discontinued on Aug. 12, 1944, for the purpose of allowing equal distribution of available metallurgical-grade fluor-

spar. The WPB, in January, 1943, controlled shipments of metallurgical and ceramic grades. Consumers having an inventory greater than "a practical working minimum" were not permitted to obtain additional supplies. Steel manufacturers were asked to use minimum amounts of metallurgical grade, replacing where possible with flotation concentrates, which were in adequate supply. Fluorspar adequate for industrial needs was reported by the Civilian Production Administration, on Nov. 30, 1945.

Average consumption dropped from 6.4 lb. in 1942 to 5.9 lb. in 1943, per long ton of basic open-hearth steel produced, with basic electric steel furnaces the chief users of flotation concentrates. The WPB controlled deliveries of higher grades of metallurgical fluorspar after Aug. 30, 1943, leading to larger production.

At the Cougar fluorite mine, southwestern Utah, Tintic Standard Mining Company operated a 150-ton gravity mill to produce metallurgical-grade fluorite, purchased by the MRC. The Cougar Spar and the Eagle Mountain properties, in Texas, where a mill was built, were included with other properties, located in Kentucky and New Mexico, explored by the U.S. Bureau of Mines, 1940–1944. This work resulted in the discovery of almost 500,000 tons of fluorspar, of which 334,000 tons were on the Cougar property.

Extensive fluorspar deposits of the Western states generally occur in igneous formations, in contrast to the occurrence in limestone, sandstone, and shale in the Illinois-Kentucky district. Important deposits, including those developed under the urgency of war demands, are located in the Castle Dome district, Arizona; near Afton, Calif.; Jamestown district, Northgate,

CONSUMPTION OF FLUORSPAR IN THE UNITED STATES, IN NET TONS
(After U.S. Bureau of Mines)

Uses	1942	1943
Basic open-hearth steel	217,100	205,676
Electric furnace steel	25,300	28,236
Bessemer steel	200	236
Iron foundry	3,600	3,378
Ferroalloys	4,200	3,882
Hydrofluoric acid	81,600	113,614
Primary aluminum	2,000	2,758
Primary magnesium	700	3,025
Glass	18,500	20,592
Enamel	3,100	1,726
Welding rod	1,300	2,286
Cement	400	262
Miscellaneous	2,800	3,214
Total	360,800	388,885

and Wagon Wheel Gap, Colo.; near Beatty, Nev.; Luna County, New Mexico; and in Texas. In New Hampshire, a concentrating plant was built in 1935 in Cheshire County. Smaller deposits are located in Utah, Washington, and Tennessee.

Postwar consumption of fluorspar up to 250,000 tons a year has been forecast by the U.S. Bureau of Mines for several years after VJ-Day. Requirements of ceramic and metallurgical grades are expected to exceed the prewar levels. Important new uses and a growing demand for the former uses of hydrofluoric acid led to increased war application, and substantial demand is expected to continue in the postwar years.

The sink-and-float mill of the MRC at Gila, N. M., was being maintained in standby condition in January, 1945. Facilities were ready in February, 1945, for expanding production of anhydrous hydrofluoric acid to 9,500 tons per quarter. In the war years, the output rate for hydrofluoric acid was almost doubled.

Optical fluorite is produced chiefly in southern Illinois, where every fluorspar mine is a potential source of the optical trade. Only a few of the operators, however, make any effort to recover the material. Several hundred pounds are sold each year to optical manufacturers and mineral dealers.

DOMESTIC FLUORSPAR PRODUCTION, IN NET TONS
(After U.S. Bureau of Mines)

State	1939	1940	1941	1942	1943
Kentucky	89,563	103,939	142,862	134,133	109,849
Illinois	75,257	104,698	133,333	161,949	198,789
Colorado†	7,569	11,032	15,566	31,743	49,145
New Mexico	6,477	7,986	19,089*	23,291	38,378
Nevada	3,520	5,803	8,967	8,020	8,653
Utah	385	142	748	1,018	51
Washington	.....	.....	104	48	

* Includes Texas.
† Includes Arizona.

DOMESTIC PRODUCTION AND CONSUMPTION OF FLUORSPAR, IN SHORT TONS
(After U.S. Bureau of Mines)

	1939	1940	1941	1942
Production*	182,771	233,600	320,669	360,316
Consumption	196,097	236,989	316,009	353,451

* Price range: in 1939, $20.27 per ton; in 1942, $24.69.

World Production, Imports and Exports. Consumption in the United States in 1940 increased to 217,200 short tons (176,800 tons in 1939), and

imports dropped to 11,871 tons (in 1939, 16,302; in 1941, 7,524). Exports in 1940 were chiefly to Canada (7,922) and India (560). Late in 1943, production expanded to exceed the heavy rate of consumption, and further increases were secured in 1944. Normally, however, the United States depends on foreign sources to supplement domestic supply.

Canada, in 1944, produced 6,924 tons valued at $217,701; in 1943, 11,210 tons; in 1942, 6,199. Over-all production of fluorspar in Canada, Sept. 1, 1939, to Sept. 1, 1945, amounted to 38,800 short tons valued at $988,400. Part of the requirements of Canadian steel mills is supplied by fluorspar of inferior quality produced at Madoc, Ontario, where fluorspar suitable for the optical trade is also reported. Rich deposits of fluorspar near tidewater are being investigated in southern Newfoundland, near East St. Lawrence. All imported fluorspar was delivered at ceiling prices or less, duty free. Ottawa, in December, 1944, ruled that imports of sodium fluoride for use in the treat, ment of water as a preventive of dental caries were made exempt from the wa- exchange tax of 10 per cent ad valorem. Fluorspar was placed on the list or minerals requiring a permit for exportation from Canada, in 1942; this restriction was withdiawn Apr. 1, 1944, affecting shipments to the United States and to any part of the British Empire. Imports are chiefly from Newfoundland.

Mexico, since 1941, has been exporting an average of 15,000 tons annually of fluorspar to the United States. La Azul mine, located 95 miles south of Mexico City, is reported to be one of the largest fluorspar deposits in North America. Production of both acid and metallurgical grades under Japanese ownership was maintained on a small scale until 1941, when the Mexican government prohibited the export of any mineral to Japan. The Board of Economic Warfare secured regular shipment from this mine to the United States early in the war.

In Mexico, fluorspar was one of 17 minerals included in the agreement negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus as part of the foreign procurement program initiated late in 1940.

The United States reduced the duty on imported fluorspar, containing not more than 97 per cent of calcium fluoride, from Mexico from $7.50 to $5.625 a short ton.

Spain and South Africa were sources of fluorspar imported by the United States in 1945. Switzerland and Japan are reported to be sources of fluorspar suitable for the optical trade. German manufacturers are dependent on foreign deposits of optical fluorite.

In 1938, countries producing less than 2.5 per cent of the world total were as follows: Newfoundland, 8,900 metric tons; South Africa, 4,700; seven

other countries recorded a total of 9,400 tons. Fluorspar deposits in both England and Spain are associated with lead ore. In Chosen, a substantial prewar producer, little is known of the character of the deposits.

WORLD PRODUCTION OF FLUORSPAR, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Argentina (shipments)	739	597	2,027	2,350	*
Queensland	20	888	706	914	*
Canada	218	4,041	5,020	5,624	10,965
Mexico (exports)	.....	9,271	10,521	5,365	22,269
Newfoundland (shipments)	11,227	14,697	11,581	32,660	66,170
Norway	2,367	*	*	*	*
Spain	8,408	9,097	15,410	48,000	*
South Africa	10,322	7,421	3,900	4,185	2,317
United States (shipments)	165,808	211,917	290,905	326,871	368,330

* Data not available.

Prices. Prices on bulk ore, Sept. 30, 1946, f.o.b. Kentucky-Illinois mines, were $30 per ton for 60 per cent of CaF_2 and not over 5 per cent of SiO_2; $37 a ton for acid 97.5 per cent and 1 per cent ore; 82 per cent of CaF_2 and not over 6 per cent of SiO_2, f.o.b. Colorado mines, $21.50 a ton. Foreign fluorspar gravel, 85 per cent of CaF_2 and not over 5 per cent of SiO_2, was priced at $33 per net ton, duty paid, Baltimore or Philadelphia. In 1940, the price range was $19 to $22 per short ton.

Effective Jan. 15 to June 30, 1945, the MRC purchased from producers fluorspar ores suitable for treatment at the plant at Gila, N. M., continuing the purchase program of the International Minerals and Chemical Corporation, as agent for the MRC, to acquire small tonnages. To be acceptable, ore must contain a minimum of 40 per cent of calcium fluoride and be suitable for the treatment known as the sink-and-float method. The base price of 15 cents was established per unit (1 per cent) of calcium fluoride contained for ore containing minimum of 50 per cent, the base price to be reduced by 0.4 cent per unit for each 1 per cent under 50 per cent.

The maximum Office of Price Administration price on any shipment of metallurgical grade fluorspar, prior to Aug. 30, 1943, was the effective CaF_2 content, plus shipping charges to consumers' plant, either from producers' shipping point or from Rosiclare, Ill., whichever is lower, based on the following grades:

70 per cent of CaF_2 or more	$33 per short ton
65–70 per cent	$32 per short ton
60–65 per cent	$31 per short ton
Less than 60 per cent	$30 per short ton

On and after Aug. 30, 1943, the maximum price f.o.b. a consumers' plant was set at $30, plus freight; on a sale or delivery to which the WPB certified that higher grades were required, the maximum price was to be computed by using the applicable price listed above. The Price Control Act, which expires Mar. 31, 1947, regulates prices, allocations, and imports of fluorspar and other minerals and metals.

According to the tariff act of 1930, corrected to Feb. 1, 1943, the duty on metallurgical-grade fluorspar, 97 per cent and less CaF_2 content, was $5.625 a ton; over 97 per cent, acid and ceramic grades, $3.75.

Prices in 1941 were 17 per cent greater than the average in 1935–1939. Subsequent to 1941, prices were under government control and were raised to higher levels for the purpose of stimulating production.

The price of optical fluorite varies according to the size of flawless pieces, varying from $1 to more than $10 a pound. Selected crystals selling for $50 to $75 a pound were reported in 1941.

In Canada, the price of domestic metallurgical fluorspar was set in 1942 by the Metals Controller.

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GRAPHITE

(Flake, Lump, Amorphous)

Properties. One of the three principal forms of carbon (in addition to diamond and charcoal), graphite is a soft, gray to black, unctuous form of carbon. Physically, it differs markedly from both the diamond and charcoal. Its hardness is 1 to 2; its specific gravity, 2.1. It is opaque even in finest particles and extremely resistant to the action of acid or heat. It is a good conductor of heat and electricity.

Graphite is separated into two classes: natural and manufactured. The two forms of natural graphite, always crystalline, are designated as "crystalline" and "amorphous," both of them composed of individual grains that differ in size but are alike in crystalline structure and have a dull gray luster. Amorphous graphite, according to the trade, means the form where the individual grains are too small to be distinguished. Artificial, or manufactured, graphite is produced by heating a mixture of a carbonaceous material, such as anthracite culm or petroleum coke, with smaller amounts of quartz and sawdust. These are decomposed at about 7500°F., and the impurities volatilized.

Graphite is chemically identical with the diamond, which can be converted into graphite by the action of heat or electricity. The melting point of pure carbon is the highest of any of the elements. (C, atomic number 6; atomic weight, 12.01; melting point, 3500°C.)

Plumbago, a trade term, refers to massive graphite as found in Ceylon. All natural graphites contain impurities, particularly mica, calcite, quartz, and feldspar. Finished grades and classifications depend on the type of ore and separation used. The purer and better grades—flake and crystalline—are distinct from amorphous, which appears as a black flour. Several refining processes are used, including flotation, air separation, and washing.

Crucible grade ranges in size from 20- to 50-mesh. Ceylon crystalline-lump and chip-vein graphite are the purest commercial natural graphite. Vein graphite is graded as needle lump, lump, chip, and dust. Large lump, less desirable than crucible lump, does not have the structure necessary for making crucibles.

Amorphous graphite in such high-grade deposits as those located in the state of Sonora, Mexico, averages 86 per cent of carbon. Low-grade ore is used in paints and foundry facings.

Uses. Manufactured graphite is widely used in industry for lubricants, dry batteries, and electrodes in sharp competition with natural graphite, the latter being used for lead pencils, crucibles lubricants, paints, and foundry facings. Its high conductivity makes it useful in the electrical industry for dynamo brushes, electrodes, dry batteries, and other objects. Amorphous graphite is used for stove polish, glazing powder, and a wide variety of minor applications.

A critical rather than a strategic material, graphite fills an important place in national defense. Graphite, for use as a "moderator" in slowing down the action of neutrons of uranium, was a primary material used in research leading to construction of the atomic bomb.

Laboratory work on this major project, starting in February, 1940, required large quantities of graphite for the purpose of making critical measurement and preventing loss of uranium neutrons. Pure graphite and metallic uranium valued at $100,000 were required in the first contract signed by the National Defense Research Committee with Columbia University, on Nov. 8, 1940.

Crucibles containing about 50 per cent graphite are a wartime necessity in making special castings used in building naval and merchant vessels and for retorts used in recovering secondary zinc. Special-type crucibles are being made with Alabama flake. Recently, there has been a preference for Madagascar flake, compared with market demands in 1914–1918 for Ceylon plumbago.

In foundaries during the war period, an acute need existed for graphite in the form of black, greasy powder. Lower grades are employed as foundry facings to spread over sand molds so that part of the mold can be separated after hot metal has been poured. High-grade graphite, a lubricant withstanding high temperatures, is much in demand for foundry crucibles and with carbon in making electrodes for electric furnaces in electric smelting, remelting, and refining processes for remaking scrap metals. For every ton of metal treated in the electric furnace, 10 to 20 lb. of electrodes are consumed.

Graphite crucibles continue to be used in fairly large numbers in melting nonferrous metals and some steels. Flake graphite is employed in retorts for smelting and refining zinc and brass. Where electric furnaces have been adopted for the manufacture of high-grade steel, graphite crucibles are not required.

Expanded war demands for all types of graphite are not expected to continue into the postwar period. Smaller requirements are expected in peacetime, and large stocks of the ore have accumulated. Uses have increased for the amorphous graphite because larger supplies are available and because crystalline

graphite (not including crucible grades) is interchangeable in use with the amorphous. Enlarged war requirements for carbon electrodes and lubricants resulted in increased production of manufactured graphite. Postwar demand was reported by the U.S. Bureau of Mines to depend on improving and standardizing the grades of domestic graphite.

Domestic Sources of Supply and Production. Graphite deposits in the United States are numerous but are low grade and result in high-cost production. In Pennsylvania and Alabama, the U.S. Bureau of Mines and Geological Survey estimate available resources at 300,000 short tons, including 25,000 tons of flake graphite. The material is too soft for crucible grades but is suitable for other uses.

Aftcr a 10-year inactive period, mining was revived in the Alabama graphite district, in response to war demand. Other graphite areas in the United States also became active. Government contracts to produce and stock domestic graphite were canceled in 1944, when output dropped to 5,408 short tons compared with 9,939 short tons in 1943 valued at $903,102; in 1942, 7,253 tons of amorphous and crystalline grades were produced.

National security now depends on only a fraction of the production from foreign sources that was the major origin of supplies as recently as 1931. Shortages of imported material, 1941–1942, led to extensive field and laboratory investigations by the U.S. Bureau of Mines and Geological Survey. This detailed study is expected to result in the successful postwar production of domestic graphite.

Large submarginal domestic resources of flake graphite, a deficient mineral, are available in terms of prewar consumption under emergency conditions and at a high price. In the postwar period, greater dependence on foreign sources has been indicated.

The manufacture of crucibles, stoppers, sleeves, and nozzles, in 1944, required 67 short tons of domestic flake, fines, and amorphous material, as reported by the graphite branch, War Production Board.

Increased production and sales of manufactured graphite were reported by the Ascheson Graphite Division of National Carbon Company, New York City. In 1943, production of domestic natural graphite was reported from eight states. Three producers were actice in Alabama (Alabama Flake Graphite Company, Ceylon Graphite Company, Crucible Flake Graphite Company); one each in Michigan, Montana, Nevada, New Jersey, New York, Rhode Island, Texas; Benjamin Franklin Graphite Company, Pennsylvania.

Consumption of Ceylon lump graphite, in 1942, amounted to 800 short tons. The WPB estimated 1943 requirements at 900 tons. Stocks held at the end of 1942 amounted to 1,300 short tons, equal to a 15 months' supply.

Stocks of graphite fines represented a 2 years' supply. Crucible flake stocks amounted to 3,600 short tons at the end of 1942, a supply adequate for 9 months; this increased to the equivalent of a 15 months' supply at the end of 1944, based on the current rate of consumption.

Domestic production of crystalline and amorphous grades, in 1942, amounted to 7,070 short tons, used as crucible flake and in foundry facings and paint.

Of the commodities purchased by the Metals Reserve Company in 1940, graphite was one of the first seven on which a commitment was made for stockpiling. Graphite ranked 28 in relative cost of delivery to the MRC stockpile, and graphite purchases cost $1,801,864, the inventory of Oct. 31, 1944, showing material valued at $445,200. Government stocks of graphite held by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, were as follows: Madagascar flake, 558 metric tons; fines, 1,658 metric tons. Ceylon graphite, 90 to 95 per cent, was 54 long tons; plus 95 per cent, 207 long tons.

Certain grades of graphite were included by the WPB, in June, 1945, with a list of materials and products that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and it was anticipated that further changes in controls would be announced. Crucible-grade graphite (about 10 per cent of domestic consumption) was removed from the strategic class when the WPB amended Order M-61 controlling graphite allocations, on Nov. 11, 1944. Ceylon amorphous graphite, containing 95 per cent of graphitic carbon in lump or ground form, was the only graphite retained on the restricted list. This continued to be listed as short by the Civilian Production Administration on Nov. 30, 1945. The material was to be turned over to private industry as soon as supplies were demonstrated to be ample. On Mar. 31, 1945, Madagascar flake was released from public purchase as a result of the favorable stock position shown by this material at the end of 1944.

Graphite was included under General Imports Order M-63 on Dec. 28, 1941. This placed imports of critical materials under government control. Order M-61 was issued on Feb. 17, 1942, by the WPB. This restricted the use of plus 35-mesh Madagascar flake graphite to the manufacture of crucibles. The MRC was named as sole importer of Madagascar flake. This order was amended on Dec. 4, 1942, to include all crystalline graphite that would stand on a No. 50 mesh screen, U.S. sieve series.

The creation of a state or international monopoly of pure graphite, as a material required in making atomic explosives, was one of the technical difficulties brought under the authority of the Atomic Energy Commission

which was to be established by the United Nations Organization, as voted on Jan. 24, 1946, by the UN Assembly in London.

World Production, Imports and Exports. Imported graphite for crucible use was a key product that filled an important industrial need. In 1940, Madagascar flake was imported in quantity triple the average annual imports for the preceding 5 years. Production in 1939 was as follows: Chosen, 78,201 metric tons; Ceylon, 22,756; Mexico, 9,815; British India, 951. Figures are not available for United States and U.S.S.R. World output of all grades of graphite amounted to about 140,000 short tons a year.

The principal occurrences of graphite are located in Ceylon, Madagascar, U.S.S.R., Germany, Austria, Czechoslovakia, Canada, Chosen (Korea), and Mexico:

Canada, in 1944, produced 1,582 tons valued at $171,166; in 1943, 1,903 tons valued at $197,431; in 1942, output was valued at $117,904, chiefly foundry grades, with some high-grade lubricating flake. The Black Donald mine, near Kingston, Ontario, was placed in production after several years of inactivity, with ore reserves reported at 40,000 tons to a 300-ft. depth. The mill was equipped by Ventures, Ltd., with a capacity of 50 to 75 tons daily. Two companies in Ontario make artificial graphite.

High-grade graphite is obtainable in quantity only from Ceylon and Madagascar. Shipments were interrupted in 1942–1943 by submarine activity, but the import situation eased considerably in 1944. Ceylon shipped 20,501 tons in 1943.

Korea (Chosen) produced about 30 per cent of total prewar supplies of graphite, the United States importing about 50,000 tons a year for foundry and lubricant purposes. Graphite was the only mineral imported in prewar years by the United States from Korea while that country's mineral resources were under intensive development by Japan, as reported in March, 1945, by the U.S. Department of Foreign Commerce.

Mexico produces a major part of natural-graphite requirements of the United States. Annual output averaging 20,000 tons is secured chiefly from mines in the state of Sonora. Output in 1941 was 18,621 metric tons, all of which was exported. In Mexico, graphite was one of 17 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus as part of the foreign procurement program initiated late in 1940. On Dec. 23, 1942, a trade treaty was signed with Mexico reducing ad valorem duty on graphite from 10 to 5 per cent, to be effective for 3 years and thereafter until 6 months after notice of termination has been served by either government.

In Brazil, many graphite deposits are reported by M. L. Cooke, most of

them conveniently located in the industrial region of Sao Paulo. Near Rio de Janeiro, the São Fidelis deposit contains a coarse crystalline Ceylon-type graphite. In 1944, it was reported that quantity production of this material could be secured.

In Alaska, graphite has not yet been brought into widespread commercial production, as reported on May 7, 1945, by the U.S. Geological Survey, but favorable possibilities have been indicated for important advances in the postwar period.

The Foreign Economic Administration reported, in August, 1945, that graphite concentrates were included in almost 350,000 tons of minerals and metals available in Norway for export, in spite of the extended military occupation by the Nazis. In the last 4 months of the year, it was estimated that 1 million tons of metals, minerals, and fertilizers would move out of Norway.

WORLD PRODUCTION OF NATURAL GRAPHITE, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Argentina	.....	100	135	248	*
Queensland	.....	63	320	324	*
Brazil (exports)	*	*	60	72	1
Canada (exports)	1,199	1,381	905	463	*
Ceylon (exports)	22,756	24,414	*	27,872	20,830
Madagascar	12,270	15,311	13,018	12,000	18,000
Mexico	9,815	12,327	16,928	20,811	20,677
Spanish Morocco	*	353	408	*	*
South-West Africa	.....	71	188	*	1,359
South Africa	59	78	62	233	621
United States	*	.....	*	6,459	9,016

* Data not available for publication.

Prices. Prices for domestic flake graphite paid by the MRC, in 1944, were as follows: No. 1A, 14 cents a pound; No. 1, 13 cents; No. 1B, 12 cents; No. 2, 11 cents; No. 3, 7 cents; No. 4, 5 cents.

Prices for Madagascar and Ceylon graphite in carlots, f.o.b., New York, duty paid, were as follows (1942–1943): Madagascar, No. 1 Flake, 9 to 16 cents a pound; No. 2 Flake, 7 cents; fines (ground), 55 to 70 per cent of carbon, 3 cents; Ceylon lump, 10 to 12 cents; carbon lump, 9 to 10 cents; chip, 7 cents; dust, 4 to 5 cents.

The United States general tariff on natural amorphous and artificial graphite is 5 per cent ad valorem; it is 15 per cent on crystalline lump, chip, and dust grades; flake, 30 per cent.

Graphite not ground or otherwise manufactured enters Canada free of

duty. The Canadian tariff of 7½ per cent ad valorem applies to imports from the United States, 10 per cent from other countries. The duties on ground and manufactured graphite (not including crucibles) are as follows: British, 15 per cent; United States, 22½ per cent; general, 25 per cent.

The Office of Price Administration allowed no increase in the ceiling prices of graphite and metal graphite brushes and contacts when an advance in the prices of electric motors became effective May 13, 1946.

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INDIUM

Properties. With a specific gravity of 7.28, indium is a very soft, silvery metal. It boils at red heat and has a low melting point of 155°C. (In, atomic number, 49; atomic weight, 114.76.) Indium is one of the 19 industrial nonferrous metals used essentially as alloying constituents. It occurs generally in association with sphalerite.

Uses. Indium, a metal of strategic value, has been widely used in steel for war materials. Corrosion-controlling properties of cadmium-nickel and copper-lead bearings used in aircraft, truck, and marine engines are decisively improved by the addition of very small amounts of indium as a coating for the bearings. This application consumed a large part of the metal in 1942–1943. Platings and diffused platings on cadmium and other low-melting alloy bearings are essential for aircraft motors. Electrodeposition of indium on lead and other nonferrous metals, followed by heat treatment, has proved useful for certain bearings. Treatment with indium is reported to lengthen the life of bronze bearings on heavy-duty machines.

Indium plate is expected to be widely used in surfacing various types of rubbing surfaces in wearing parts of engines and machines. Indium provides corrosion resistance without impairing the fatigue resistance and other properties of cadmium-alloy bearings for aircraft and other high-duty internal-combustion engines.

In lead-silver solders, the addition of 1 to 2 per cent of indium improves coverage, bonding strength, and spreadability. Indium-zinc coatings have been used for hollow-steel propeller blades for aircraft.

The metal readily alloys with gold to produce low-melting alloys of high gold content, the hardness increasing with indium additions. Indium-zinc and indium-gold alloys have unique characteristics for brazing and form hard, corrosion-resistant alloys that are easily applied, either as a coating or when worked in mass. Decorative plating and solders employ small amounts of indium. Successive plating of gold and indium, then alloying by diffusion at about 330°F., produces a corrosion-resistant coating for the harder alloys.

Small quantities of indium are used in producing electrical contacts, as a glass colorant, in jewelry and dental alloys, and to improve the tarnish resistance of silverware.

Domestic Sources of Supply and Production. Current supplies are available from the treatment of large stocks of zinc and lead residues. Indium-

bearing ore amounting to 50,000 tons and having an average indium content of 2 troy ounces per ton has been developed in Mohave County, Arizona, by the Indium Corporation of America. In March, 1945, large supplies and competition for business led to a price reduction. Although Indium Corporation of America (subsidiary of Anaconda and Oneida, Ltd.) is the principal distributor, production is secured from Anaconda Copper Mining Company, Eagle-Picher Mining & Smelting Company (which operates a small pilot plant), American Metal Company, American Smelting & Refining Company, and National Zinc Company.

Production, in 1942, was reported by *The Wall Street Journal* at 65,000 troy ounces. Sales of indium metal and salts tripled in 1942 compared with 1941 and nearly tripled again in 1943, as reported by Indium Corporation of America. Production figures are withheld by the U.S. Bureau of Mines, which stated that indium-metal output in 1943 was more than one-third higher than in 1942.

World Production, Imports and Exports. Canada, in 1942, produced 471 troy ounces valued at $4,710. Later output has not been reported. First production was reported in 1941 by Consolidated Mining & Smelting Company of Canada, Ltd., Trail, British Columbia.

Foreign production has been reported, by the U.S. Bureau of Mines, in Germany and Belgium, possibly also in Japan and U.S.S.R.

Prices. Indium was quoted May 10, 1945, by *E & M J Metal and Mineral Markets*, at $4 per troy ounce, 99.9 per cent pure; the price was down to $3 on Sept. 1, 1945; on Dec. 1, $2.25, which remained in effect on Sept. 30, 1946. In 1942, electrolytic-grade indium was reduced from $30 to $15.

In 1924, the price was $10 a gram for 98 per cent indium metal. This was reduced to $12.50 an ounce in 1940; in 1942, $10. The price was further reduced, on Mar. 14, 1944, to $7.50 to $8.50. The market standard, which formerly had been advanced from 98 to 99 per cent, was changed to 99.9 per cent.

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IODINE

(Crude)

Properties. A gray or purple-black, crystalline solid, iodine in vapor form is one of the heaviest known gases, 8.8 times as heavy as air. Solid iodine has a specific gravity of 4.7 and is the heaviest of the nonmetallic elements. (I, atomic number, 53; atomic weight, 126.92; melting point, 113.5°C.) Only six of the common elements have a lower melting point than iodine.

Uses. In the United States, no shortage was threatened under war conditions. Various sources of reclaimed iodine have been used by the photographic-chemical industry, the pharmaceutical industry, and plants producing organic or inorganic iodine-bearing preparations.

Iodine was used almost entirely for war and essential civilian requirements in the war period. Essential requirements were in medicinals, as a disinfectant. Iodine salts have important medicinal and industrial uses in photography, stock feed and human food, organic syntheses, analytical reagents, leather manufacture, and special soaps.

Of prewar requirements, 70 per cent was for making potassium iodide, 5 per cent for sodium iodide, 15 per cent for resublimed iodine, and 10 per cent for other compounds.

Domestic Sources of Supply and Production. Iodine was placed under export control early in 1941. The commercial recovery from oil-well brines has been carried on in the United States as well as in Russia, Poland, and Mexico. The U.S. Bureau of Mines is not at liberty to publish figures on domestic output, which amounted to 299,286 lb. valued at $242,422 in 1937, the product of plants of the Dow Chemical Company and Deepwater Chemical Company. This rate was considerably increased during the war period.

The domestic iodine industry was established in 1928 by the Dow Chemical Company, which recovered the material from oil-well waste waters near Shreveport, Ala. This plant was later shut down, after similar recovery had been established at Venice and Seal Beach, Calif. Since 1937, Deepwater Chemical has made similar recoveries at Compton, Calif., from oil-well waste waters. The iodine content was reported by the U.S. Bureau of Mines at an estimated 45,655 lb. per million gallons of water. Production in 1943 increased to a new record. Seaweed has furnished limited supplies of iodine.

Stocks were maintained equal to a normal supply for 2 years. Crude iodine imported in 1940, primarily because of economic advantage, was six times the 1939 quantity, at 622 tons valued at $1,296,181.

The War Production Board issued a general import order on Dec. 17, 1942, prohibiting imports and exports of iodine except by authorized persons.

World Production, Imports and Exports. German imports amounted to 140 short tons in 1938; in 1939, 135 tons. The chief world source was formerly Chilean nitrate, as a by-product chiefly from caliche recovered in two modern Guggenheim-process nitrate plants. The Chilean monopoly in iodine was closely associated with the nitrate industry prior to the First World War. Chile's largest foreign market was the United States, which was lost after the process was developed for recovering iodine from certain salt brines.

In 1942, the Chilean Nitrate Sales Corporation, New York City, held stocks of iodine estimated at a year's supply; in 1943, about 1,000 tons. Crude iodine imported from Chile amounted to 200,000 lb. in 1939; in 1940, 1,244,-146; in 1941, 1,010,039; in 1942, 951,243; in 1943, 2,744,930.

Small recoveries are made from salt wells in Java and Italy.

Prices. The price advanced from 81 cents a pound in 1937 to $1.04 a pound in 1940. In 1936, the price of iodine dropped to 90 cents a pound from the 1931 rate of $4. In 1942–1943, the price was $1.35 a pound, less 5 per cent, in 150-lb. kegs. Resublimed iodine in 5-lb. bottles, 50-lb. lots, was $2 a pound.

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IRIDIUM

Properties. One of the metals allied with platinum, iridium is characterized by its hardness, white color, high melting point, and resistance to attack by destructive chemicals and to oxidation at high temperatures. In hardness of slightly under 200 (Brinell), iridium is exceeded by two other platinum metals, osmium and rubidium. In density, iridium and osmium exceed other platinum metals. The modulus of elasticity (75 million pounds per square inch) is the highest measured with any metal. Its fusing point on the International Temperature Scale is 2454°C. compared with 1773.5°C. for platinum. (Ir, atomic number, 77; atomic weight, 193.1; specific gravity, 22.42.)

One of the most difficult analytical problems of the platinum group is the separation of iridium from rhodium, the former having almost twice the atomic weight and density of rhodium. These two are used as hardening alloys for the softer platinum-palladium pair.

Other important properties of the platinum metals are the following: catalytic activity, low vapor pressure, high strength at elevated temperatures, high ductility, low coefficient of thermal expansion (about the same as glass), stable thermoelectric behavior, high temperature coefficient of electrical resistivity, high resistance to spark erosion, high and maintained reflectivity.

Uses. War demands for essential equipment made it necessary to stop the use of iridium for jewelry. Increasing application has been made in magneto contacts for aircraft. Iridium is used with osmium to make gold pen points and watch and compass bearings. In the electrical industry, platinum-iridium alloys had various essential war applications for telephone, telegraph, and electrical control systems. In 1942, the electrical industry became the major user of iridium and other platinum metals; the chemical industry remained in second place; jewelry, which was formerly first, dropped down to third place.

In the electrical industry, platinum-iridium and osmium-iridium-ruthenium alloys are employed as contacts for communication and other relays, magnetos, thermostats, voltage regulators, and control devices and in spark-plug electrodes, resistors, overload electrical fuses, and detonator fuses. Chemical uses of platinum-iridium were for solid or clad corrosion-resistant equipment; crucibles; bursting or frangible safety disks; anodes for "per salts," halogens, organic oxidations, electroplating, and electroanalysis;

cathodes for electroanalysis; optical parts; buzzer nozzles; gas meters and orifices. Dental uses included casting and wrought alloys, tooth pins and anchorages, and reinforcement for dental porcelain. Jewelry and decorative uses included medals, watch cases, spectacle frames, ring blanks, and decoration in conjunction with gold.

Iridium, like the other platinum metals, has important applications in war equipment produced by the chemical and electrical industries. It has been employed as a hardening addition to platinum in the manufacture of laboratory vessels, surgical tools, hypodermic needles, and thermoelements and in compounds as a fixing agent and porcelain pigment.

Domestic Sources of Supply and Production. Large quantities of iridium and other platinum metals have been made available by improvements in processes for refining copper-nickel ores. Since 1929, larger and more diversified markets have been found for the platinum metals, along with the rapid increase in production.

Iridium and other platinum metals produced in the United States (new) amounted to 15,839 troy ounces in 1942; in 1943, 18,495. Secondary recovery was as follows: in 1942, 4,045: in 1943, 9,352. Stocks in hands of refiners, importers, and dealers at the end of 1942 were 35,280 oz.; in 1943, 42,081. Domestic production and imports were lower than consumption.

The first commitment for the purchase of iridium for government stockpiling was made by the Metals Reserve Company in 1941. *The Wall Street Journal* reported, on July 17, 1944, that government stockpiles held 2,453 troy ounces of iridium and 40 oz. of osmiridium. Platinum metals, including iridium, holding twenty-second place among the 22 stockpile items, had a total value of $3,764,526 of which $1,216,754 remained in the inventory of Oct. 31, 1944. Iridium amounting to 3,147 troy ounces was held in government stocks by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration.

IRIDIUM RECEIVED BY REFINERS IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

	Domestic from			Foreign from	
	Crude platinum	Ore	Gold and copper refining	Crude platinum	Nickel and copper refining
1942	3,329	2	35	221	1,515
1943	1,932	..	47	...	3,307

Order M-162 was announced by the War Production Board, effective on Oct. 31, 1942, prohibiting the use of platinum alloys in the manufacture of jewelry. Iridium was placed under full allocation on Apr. 30, 1943, uses being limited to contact points, fuse wire for detonators, electrical primers, and laboratory wire, in amended Order M-49.

IRIDIUM RECOVERED BY REFINERS IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

	New	Secondary
1939	1,051	2,767
1940	1,517	1,365
1941	1,392	659
1942	5,102	1,552
1943	5,286	2,771

IRIDIUM, OSMIUM, RHODIUM, AND RUTHENIUM SOLD TO CONSUMING INDUSTRIES IN THE UNITED STATES IN 1943, IN TROY OUNCES
(After U.S. Bureau of Mines)

Industry	Ounces
Chemical	4,154
Electrical	15,851
Dental	160
Jewelry	2,080
Miscellaneous	4,559
	26,804

Consumption of the minor platinum metals—iridium, rhodium, osmium, and ruthenium—accounted for only 5 per cent, or 26,804 ounces, of the total platinum group in 1943. Iridium and ruthenium were the most extensively used of this minor group, sales of iridium being 24 per cent higher than in 1942.

World Production, Imports and Exports. World output in 1939 amounted to 148,877 troy ounces of platinum and 135,402 oz. of other platinum metals. Estimated world production in 1939 was 540,000 oz. of platinum and allied metals (in 1942, 790,000) as follows: Russia 100,000 oz. (in 1943, 100,000); South Africa, 66,342 oz. of platinum, osmiridium, and other platinum metals (in 1943, 49,361). Colombia exported 39,070 oz. of placer platinum (in 1943, 39,961); United States, 32,460 oz. of placer platinum (in 1943, 27,162) and 66 oz. of platinum metals contained in ore, while refineries produced 5,270 oz. of platinum (in 1943, 5,205) and 3,364 oz. of other platinum metals (in 1943, 5,185). No figures were reported for New South Wales, the Belgian Congo, Ethiopia, Italy, and Japan.

The Department of Munitions and Supply, Ottawa, announced in June, 1945, the removal of all restrictions on the distribution of iridium. Record output in Canada was 226,600 troy ounces in 1942 (other platinum metals) compared with 135,402 in 1939. Recovery is secured from nickel-copper ores of the Sudbury district.

Colombia exported 39,961 oz. of crude platinum in 1943 (49,163 in 1942). Production is reported for only one operator, South American Gold & Platinum Company: in 1943, 23,945 oz. of crude platinum metals; in 1942, 25,786 oz.

The chief foreign markets for exports of refined platinum metals and alloys, 1942–1943, were Canada, Argentina, Cuba, Australia, Palestine and Trans-Jordan, Brazil, and Chile.

REFINED IRIDIUM (UNMANUFACTURED) IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

Country	1942	1943
Canada	399	*
United Kingdom	485	1,056
Other countries	*	
Value	$102,848	$133,342

* Less than 1 oz.

WORLD PRODUCTION OF OSMIRIDIUM AND "OTHER" PLATINUM METALS, IN TROY OUNCES
(After U.S. Bureau of Mines)

Country and product	1939	1940	1941	1942	1943
Tasmania (placer osmiridium)	283	*	*	*	*
Canada (other platinum metals)	135,402	91,522	97,432	226,600	*
Papua (placer osmiridium)†	4	*	*	*	*
South Africa (osmiridium from gold ores)	7,031	*	*	*	
United States (other platinum metals)	3,364	3,304	4,689	5,472	5,185

* Data not available.
† Year ended June 30 of year stated.

Prices. The price of iridium sponge or powder was quoted by *E & M J Metal and Mineral Markets*, May 10, 1945, at $120 per troy ounce, commercial purity of at least 99.5 per cent. This figure has been in effect since Feb. 1, 1943, under Maximum Price Regulation 309, as published by the Office of Price Administration. The price had been $165 up to Feb. 1, 1943, although in 1940 a shortage led to a temporary price increase to $275 an ounce.

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IRON AND STEEL

(Ore, Pig, Scrap)

Properties. Ranking second to aluminum in abundance within the earth's crust, iron is one of the eight elements that account for about 98.5 per cent of the composition of the outer 10 miles of the earth's crust, of which iron represents about 5.01 per cent. Because of its abundance, ease of reduction, and industrial utility, iron accounts for more than 90 per cent of total production of about thirty metallic elements used industrially. (Fe, atomic number, 26; atomic weight, 55.85; melting point, 1553° C.)

The ratio of iron to nonferrous-metal production dropped from 20 to 1 to 14 to 1 in the 50-year period ending in 1934. This ratio in 1943 was estimated at about 12 to 1. Iron production in 1942 amounted to about 65 million tons compared with 1,800,000 tons of copper and 1 million tons each of lead, zinc, and aluminum.

Iron has a specific gravity of 7.3 to 7.86 and hardness of 4 to 5. Pure iron is a moderately soft, malleable, grayish-white metal. Its electrical conductivity is about one-seventh that of copper. The physical properties of iron undergo a great change by the addition of a small percentage of certain other elements. This change determines the variety of uses for which iron and steel are employed. Special alloy steels are discussed in connection with the various alloy elements, particularly manganese, chromium, nickel, molybdenum, tungsten, vanadium, and copper.

Iron-ore minerals, in order of importance, are hematite, magnetite, limonite, siderite, and pyrite. The most satisfactory ore grades from 48 to 68 per cent of iron with a minimum of silica, titanium, phosphorus, and sulfur. Iron ores occur in rocks varying widely in geologic age, from Precambrian to recent. The wide range of origin of deposits has been classified as follows:

1. Segregation deposits crystallized from once molten rock, such as the MacIntyre mine in the Adirondack region, New York.
2. Contact metamorphic deposits, such as those of Iron Springs, Utah.
3. Sedimentary ores, such as the Lake Superior region, England, and France.
4. Replacement deposits formed by meteoric waters in calcareous rocks, such as at Bilbao, Spain.
5. Residual deposits of limonite, such as in Virginia.

6. Lenticular bodies of magnetite or pyrite in metamorphic rocks formed by the alteration of previously existing ore deposits.

7. Gossan ores formed by limonite capping on oxidized sulfide bodies.

8. Placer deposits of magnetite sands.

Iron oxides (mineral pigments) include ocher (ocherous iron oxide) and the claylike materials umber and sienna. War industries used these materials in the calcined and air-floated state, production being limited by rigid specifications.

Uses. Iron and steel undoubtedly stand first among all industries responsible for making the United States a great nation, both in war and peace. Steel is the cheapest, most abundant, and most versatile of all metals. Iron ore ranks in national importance before both coal and copper. Under war conditions, iron and steel have proved to be basic materials for plant construction and transport facilities for a mechanized army and for a major part of the weapons manufactured. Ships plate, armor for tanks, and other weapons from rolling-mill plates proved inadequate for the peak demands in 1943–1944, when shipbuilding activities of the nation consumed over 21 per cent of all domestic steel produced. As one example of a multitude of essential uses, a battleship of the Iowa class requires 400 million feet of finely woven steel wire to protect the 1,800,000 ft. of electrical cable.

Sources of iron ores, as well as coal and petroleum, have been of primary value in sustaining commercial development of the United States, Britain, France, Russia, Japan, and Germany and will be of vital concern in the postwar expansion of Canada, China, Brazil, and Venezuela.

Iron ore is used primarily in the manufacture of pig iron, from which steel is derived. Large tonnages of iron ore are employed in smelting nonferrous ores and in the manufacture of ferroalloys, as well as in the production of pigments, cement, and hydrogen gas and in gas purification. In 1943, cement making required 30,689 tons of iron ore; paint, 8,912 tons; ferromanganese, 3,592; smelter flux, 3,863; other industries used 7,571 tons.

In the 297,000 war planes built by the American aircraft industry in the war years, more steel was used by weight than any other metal; a B-29 Superfortress required 50 tons of steel as shipped from the mill before being machined down into finished equipment. Special steel was supplied for army helmets sufficient for producing about 23 million helmets.

Under the pressure of war, vastly improved steels for all classes of consumer goods were developed. Thousands of new and older applications in the heavy industries and in better manufacturing tools have been made possible by the newly developed steel quality. Alloys, generally grouped as "stainless steels," now number more than one hundred types.

Exacting military demands in the war years resulted in greatly increased technologic advances in quality, performance, and adaptability of steels. Continued study of the physical chemistry of steelmaking contributed to better regulation of metallurgical reactions, slag composition, temperature measurement for open-hearth and electrical furnaces, and deoxidation. Better practices and improved standards, including seamless tubing, have been developed for Bessemer steel. Greater refinement of practice and control of product have been secured.

Research on alloying elements led to developing National Emergency Steels, which employed the available alloying agents and utilized the alloy content of scrap as far as possible. Many of the alloy steels, formerly made in an electric furnace in only limited quantity, can now be made in huge open-hearth heat. The addition of boron for hardening produced the so-called "intensified" steels.

Precise heat-treating procedures and properly regulated cycles have been developed in improving standard steels. Corrosion-resisting stainless steels have found broad application for war materials, and new uses have been proposed to benefit from the high strength, light weight, and resistance to corrosion. The electrolytic process for tin plating was developed in response to war demands after Japan cut off sources of tin. A saving of 60 per cent of the tin formerly required is achieved by electrically plating a wide ribbon of thin steel as it passes through a tin solution, rolling out at high speed to the shear and inspection table. An ordinary tin can is 98.5 per cent steel with a 1.5 per cent coating of tin. The manufacture of tin plate in normal times required about 3 million tons of steel a year.

New grades of alloy seamless tubing, developed for aircraft construction, will be available for many peacetime uses. Many war applications were made of sheet or strip steel on which a thin phosphate film is deposited. Other coatings have been developed for strip and wire. New pickling processes have been evolved and advances made in forging and casting steel. High-strength steels have been made available for weight reduction of rolling stock. Welding of steel plates has become a common tool of fabrication after its development for wartime ship construction. Advances in the deep drawing of steel resulted from research required in making steel cartridge cases early in the war, when a brass shortage occurred.

A new "supercharger" steel was developed to operate under high temperature in the exhaust system of aircraft, and this was readily adaptable for gas-turbine blading in the new "rocket" planes. Military steel springs for use in jeeps and tanks indicate important industrial applications in the postwar period. Special steels developed for landing mats will have postwar uses in

minimizing soil erosion and for abrasion-resisting grips for conveyor belts, a special galvanized sheet steel for air-conditioning ducts, better enameling stock for signs and construction, and household goods.

In stressed members, high-tensile steel provides extra strength that permits more efficient design and lighter construction of such equipment as elevators, conveyors, screens, cars, and stripping shovels. Fine-grained low-alloy steels allow accurate heat-treatment, abrasion and corrosion resistance, strength, ductility, weldability, and high resistance to impact, wear, and fatigue.

Wire rope, described as a "sinew of war and industry," is formed of many individual wires drawn from steel for transmitting power. Preformed and braided by a method that makes wire-rope work easier, it develops less friction and serves longer. Many of the new fields of use developed for war purposes indicate new peacetime applications. Wire rope embedded in tough rubber (compass 250 steel-cable belt) forms treads for tanks; it has double the horsepower rating and longer life than other belts now available. The only stretchless belt, it transmits up to 37 hp. per inch of width.

Wire rope has vital military and naval applications such as steering controls for PT boats and controls for aircraft, guns, and turrets. Airplane cable ranges in size from $\frac{1}{16}$-in. diameter to large ropes having strength ranging from 550 to 3,000,000 lb. dead weight. Barrage balloons were operated with wire-rope mooring lines and dangled preformed wire ropes to entangle enemy planes. The 4,000 ships of the U.S. Merchant Marine have an annual requirement estimated at 10,000 miles of wire rope. Towing lines and winch lines are standard equipment on tanks, half tracks, gun carriers, and trucks.

The Foreign Economic Administration announced, early in June, 1945, that 180 locomotives, costing under $80,000 each, had been ordered from United States manufacturers by the United Nations Rehabilitation and Relief Administration. These were for delivery to Greece, Yugoslavia, Poland, Czechoslovakia, and Albania, before March, 1946. Baldwin, American Locomotive, and Lima were the three companies to manufacture this equipment, of which 50 per cent was to be turned out by Baldwin.

Replacing pig iron as a permanent ship ballast, reducing cost, and saving valuable metal, crushed magnetite from Lovelock, Nev., and Portland cement are mixed with magnetite sands recovered magnetically from beaches in California. The mixture is placed as concrete in ship bottoms to set as permanent ballast.

Iron paint is one of the most durable surface finishes. Iron oxide pigments are used in painting military establishments and equipment. The paint trade uses high-grade ocher, umber, and iron oxide. The illuminating-gas industry

is a major consumer of the oxide. In powder metallurgy, iron is employed for producing intricate gears and parts.

No substitutes are available for iron and steel, either for industry or for mechanized war. In aircraft, substitutes have been used in the form of aluminum alloys but were later replaced by certain chrome steels. Substitutes have generally proved to be inferior in various respects, resulting in increased weight and reduced durability in order to secure equal strength. They usually involve higher costs. Making steel into useful products for American life gives employment to over 40 per cent of the nation's factory workers.

The war taught steel producers many improvements in metallurgy. A large number of new markets have been opened for flat-rolled steel, in producing which great improvements were introduced.

Domestic Sources of Supply and Production. Four years of war led to an increase of almost 60 per cent in the tonnage shipped from the Minnesota and Michigan iron ranges. Total output of domestic iron ore through 1943 is reported by Elmer W. Pehrson, U.S. Bureau of Mines, to amount to 2,613 billion long tons compared with 5,478 billion tons representing ore reserves of present commercial grade still in the ground (one-third this amount is inferred ore). Production amounted to 516,158,500 tons of iron ore between January, 1940, and January, 1945. Although some of the richest iron deposits are now being depleted, production for a period of about 111 years remains available based on the annual rate of use in 1935–1939; submarginal and highly speculative resources of iron ore are considered adequate for more than 500 years (63 billion long tons). This estimate is stated to be highly speculative or remote because of uncertainties in basic calculations, high costs of recovery, or technologic problems involved in utilizing the iron-bearing material. Steel requirements in 1970 are calculated at upwards of 115 million tons, as reported by the War Production Board in June, 1945 (almost equal to total world output in 1935). Future pig-iron requirements were estimated at 61 million tons, assuming increased use of scrap, with lower ratio of pig iron to steel. (Capacity, in 1945, was 67½ million tons; plate-steel capacity, 13 million.)

From the national standpoint, America is in a stronger position in iron ore, coal, and potash than in other mineral reserves, it was reported by Elmer W. Pehrson, in January, 1945. It was forecast that per capita steel consumption would expand to more than 1,200 lb. a year by 1970, when annual steel requirements would exceed 94 million tons, compared with installed capacity of steel in 1945 of 93.5 million tons. The ratio of iron-ore production to pig-iron production has been 1.72 to 1 in the past 10 years, which indicates iron-ore requirements in excess of 95 million tons in 1970. The quantitative significance of estimated reserves does not imply that reserve tonnage could

sustain consumption at the theoretical rate for the full period of more than a century. In the Lake Superior district, estimated reserves of commercial-grade ore are equivalent to less than 25 years at the current rate of output.

Much smaller tonnage figures have been published by others; one of these more conservative estimates shows that tonnage of high-grade ore adequate for large-scale production will be exhausted at the end of 1948, with the end of low-grade domestic reserves being reached in 1961. The controversial problem of reserve tonnages has attracted wide attention, emphasized by the fact that shipments of iron concentrates have increased steadily since 1934.

Supplies of iron ore and seven other major ore minerals that may be expected to last 100 years or more are available in the United States.

The high quality ores which are found in the Mesabi Range in Minnesota will soon be only a rusty memory. At the prewar rate of extraction, the remaining tonnage will be exhausted in 22 years.

This was reported by Harold L. Ickes, Secretary of the Interior, in December, 1945.

The United States is provided with two of the world's five most productive iron ore districts: Lake Superior (62 million tons produced in 1940) and Birmingham, Ala. (7 million tons in 1940). The other three districts are located in Lorraine, France (31 million tons); Krivoi Rog, southwest U.S.S.R. (18 million tons); and Kiruna, northern Sweden (12 million tons). The promise of great productive postwar capacity has been shown in North America (Labrador) and South America (Brazil and Venezuela). American capital either controls or is substantially interested in these new deposits and in Cuba and Chile.

A premium payment plan for the merchant pig-iron industry was announced on Sept. 17, 1946, by Wilson W. Wyatt, Housing Expediter. The program provided for government paymenrs of $8 a gross ton for production over base period quotas by operating plants and $12 a ton for production from plants to be reopened. Urgent need for stockpiles of iron and steel scrap was reported Sept. 17, 1946, by the War Assets Administration.

The U.S. Bureau of Mines examined many hundreds of iron-ore deposits in 1940–1944, with the result that ore reserves amounting to 155 million tons were developed in 22 deposits, of which the larger tonnages are located in Alabama, Arizona, California, Montana, Nevada, Tennessee, and Utah. In an effort to offset the rapid depletion of iron ore, a tailings-treatment plant started operation early in 1944 to recover iron from old tailings dumps, which were estimated to contain about one-third of the tonnage of crude ore treated. The tailings dumps have an iron content ranging from 15 to 35 per cent.

Domestic production of iron ore in 1945 was 6 per cent lower than in

1944, as reported by the U.S. Bureau of Mines, at 88,754,000 gross tons. Shipments of iron ore from mines for the year 1945 were 88,156,000 gross tons; in 1944, 94,544,635; in 1943, 101,247,835. Iron ore mined in 1944 was 93,524,797 tons. Iron residue, the by-product of pyrite roasting for sintering and for consumption in blast and steel furnaces, amounted to 592,908 tons in 1944 compared with 652,513 tons in 1943. Total stocks of iron ore at mines at the end of 1944 were estimated at 4,424,000 gross tons; 5,169,525 on Dec. 31, 1943; 4,996,622 on Dec. 31, 1945.

Iron ore was produced by 18 states in 1944; in 1943, 286 mines were active; in 1942, 327; in 1940, 230 mines in 19 states; in 1939, 17 states produced iron ore; in 1945, 16. The Lake Superior region accounted for 84 per cent of the ore mined in 1944 (79 per cent in 1945, 85 per cent in 1943, 83 per cent in 1940); Southeastern states, 8 per cent; Northeastern states, 4; Western states, 3.5; by-product ore, 0.5. There were 29,636 men employed in mining iron ore in the United States in 1943; in 1942, 28,956. The steel industry employed 567,200 workers in April, 1945, compared with 573,400 in April, 1944. Average employment in all 1945 was 548,000 as against 571,200 in 1944.

The greatest change in raw materials since 1918 has been in the type of furnace coke used. The amount of blast-furnace charge declined from 54 to 12 per cent from 1918 to 1944; in the same period, sintering capacity for iron-bearing materials increased from 2,900,000 to 27,000,000 tons.

Mesabi Range shipped 62,509,212 tons in 1944; Vermilion Range, 1,538,560. Cuyuna Range of Minnesota ships more than 90 per cent of its ore classified as manganiferous grade: total output in 1944 was 2,538,492 tons from 17 open-pit mines; in 1943, 2,274,841 tons plus 235,249 tons of non-Bessemer ore. Total iron ore shipped down the Lakes and all-rail from Lake Superior was 74,624,000 gross tons in 1945; in 1944, 80,678,516; in 1943, 84,537,254; in 1942, 92,076,781; in 1941, 80,116,360.

Consumption of Lake Superior ore was 13,353,123 tons in January and February, 1945; for all of 1944, 80,790,000; in 1943, 84,537,254; in 1942,

LAKE SUPERIOR IRON ORE, AVERAGE ANALYSES OF SHIPMENTS IN 1943
(After Lake Superior Iron Ore Association)

	Tons	Iron	Phos.	Sil.	Mang.	Moist.
Bessemer	18,685,514	54.09	0.039	8.26	0.39	9.58
Non-Bessemer	57,816,092	51.43	0.073	7.93	0.71	11.78
Non-Bessemer (high-phos.)	4,712,348	50.98	0.410	7.41	0.35	9.42
Manganiferous	3,254,945	43.58	0.213	9.99	6.07	10.84
Siliceous	647,448	36.76	0.020	43.14	0.09	2.93
Total and average	85,116,347	51.58	0.091	8.32	0.82	11.06

86,225,460; in 1941, 76,335,682. These figures include consumption by Canadian furnaces of 2,512,609 tons in 1944; in 1943, 2,442,448.

The expansion program of the steel industry in the 3-year period ending December, 1943, provided new mines having annual output estimated, when completed, at 15 million tons of ore, 14 million tons of new blast-furnace capacity, more than 12 million tons of new steelmaking capacity. About 10 per cent of the steel industry was owned by the Defense Plant Corporation and represented an investment of about one billion dollars. Ingot capacity in the United States was increased from 81,828,958 net tons on Jan. 1, 1939 (35.3 per cent controlled by United States Steel Corporation); on Jan. 1, 1946, capacity was 91,890,560 tons, of which U.S. Steel controlled 31.4 per cent (increased to 32.7 per cent in June, when U.S. Steel purchased the Geneva plant with an annual capacity of 1,283,000 tons, in addition to government facilities at Homestead, Pa., of 1,895,000 tons).

The steel industry in 1944 set an all-time record close to 90,000,000 tons compared with 88,836,366 net tons of ingots in 1943, when mill operations were at 98.1 per cent of capacity; in 1942, 86,029,921 (96.9 per cent of capacity). This compares with the peacetime peak of 63,206,000 tons in 1929. Production of steel ingot increased from 86,981,662 tons in 1940 to 89,552,961 tons in 1944; in the first 9 months of 1945, 86.6 per cent of capacity at 61,886,532, for all 1945, output was estimated at 80,000,000 tons. The American Iron and Steel Institute on Jan. 1, 1945, reported ingot capacity at 95,505,280 net tons; there were 170 furnaces in blast out of 197 available, Jan. 1, 1945, compared with 182 furnaces out of 196 available a year earlier and 184 out of 191, Jan. 1, 1943. Only one charcoal blast furnace remained in operation, at Nunberry, Mich.

The U.S. Bureau of Mines reported pig iron shipped from blast furnaces, as follows: in 1944, 60,995,977 net tons having an average value of $20.97; in 1943, 60,787,159 tons valued at $1,273,634,210 (average $20.95); in 1942, 59,100,601; in 1941, 55,223,641. Production of pig iron and steel increased 1 per cent in 1944, when ferroalloy shipments decreased 7 per cent after attaining a maximum annual rate of 15 million tons. In 1944, for the fifth consecutive year, steel-ingot production exceeded previous records at 89,552,961 net tons (95.4 per cent of capacity); in 1943, 88,836,366 (98.1 per cent of capacity); in 1940, 66,981,662.

Ferroalloys produced in 1941 amounted to 1,719,785 short tons valued at $204,856,619. Production of open-hearth, Bessemer, and electric ingot and steel for castings was at 95.4 per cent of steel-mill capacity in 1944. Output in January, 1945, at 7,204,303, and February, at 6,657,703, was lower than for any month since July, 1942.

Alloy steels were in plentiful supply on Jan. 1, 1944, as announced by the Office of War Information, but facilities for rolling were short. Finished plate was expected to continue on the critical list. The American Iron and Steel Institute announced that alloy steel amounted to 10,525,436 tons in 1944; in 1943, 13,149,818; in 1942, 11,526,000.

Of the three major steelmaking processes, the basic open hearth produced about 80,400,000 tons in 1944 compared with 78,600,000 tons in 1943; electric furnaces produced about 4,200,000 tons in 1944 with rated capacity of 5,400,000; Bessemer operations produced an estimated 5 million tons in 1944, about 10 per cent less than in 1943 and comparing with capacity of more than 6 million tons.

From January, 1940, to October, 1944, steelmaking facilities increased more than 12,400,000 tons to 94,000,000; blast-furnace capacities increased 12,700,000 tons to 68,400,000. Total steel output in 1944 was about 89,641,-600 tons, including 10,600,000 tons alloy steel compared with 88,900,000 in 1943, including 13,100,000 tons of alloy steel. Steel production in 1945 was 79,745,581 net tons, as reported by the American Iron and Steel Institute. Steelmaking capacity was at the annual rate of 95,505,280 tons of ingots and steel for castings on Jan. 1, 1945; Jan. 1, 1946, 91,890,560 tons as a result of the abandonment of older steelmaking facilities. In the war years, new capacity installed amounted to almost 14 million tons.

Geneva Steel Works, near Provo, Utah, built by the DPC at a cost of $191,000,000 and operated by U.S. Steel Corporation, had annual capacity of 1,200,000 tons. This was rated as the world's most modern steel plant. The structural mill for producing structural shapes and billets was shut down June 4 and the plate mill, producing at a monthly rate of about 45,000 tons, was expected to close in August, 1945. The War Assets Corporation on May 23, 1946, approved the sale of the Geneva plant for $47,500,000 to U.S. Steel Corporation, which would spend an additional $18,600,000 to reconvert the plant for the production of semifabricated steel to be finished at Pittsburgh, Calif., where new cold-reduction facilities were to be erected.

The effective use of the Geneva plant for war purposes and common defense was a primary objective of the sale, under the Surplus Property Act. The original facilities of the plant were to be preserved in a good state of repair for a period of not less than 5 years. It was estimated that 2 years would be required to equip the plant for peacetime use.

Fontana Steel Works, near Los Angeles, Calif., with annual capacity of 700,000 tons, was built by the Kaiser Company on a loan from the Reconstruction Finance Corporation of $115,000,000, of which all but $40,000,000 was to be repaid at the end of the war. These two plants were estimated to

require an additional investment of about $40,000,000 for peacetime conversion to sell steel at $6 to $12 a ton less than Eastern mill products. Conversion of the Fontana plant to produce this sheet steel for civilian goods was authorized in June, the change in the rolling mill and plate mill expected to be completed within 8 months at a cost of $1,500,000.

The western market had prewar requirements for steel products equivalent to 3,500,000 to 4,000,000 tons of ingots a year compared with a 2,019,000 net ton plant capacity of ingot steel. War expansion has raised production facilities to 4,900,000 tons, which represents about 5 per cent of the United States total. Postwar operation of new western plants at a satisfactory rate and at competitive costs is contingent on finding a solution for certain problems, including (1) recapitalization, (2) developing new markets, (3) lower freight rates, (4) technical improvement in quality of western iron ores and coking coals, and (5) securing adequate scrap iron.

Rustless Iron and Steel Corporation is the largest producer of free-machining grades of stainless steel. Domestic steel production, in the period 1929–1939, dropped 16 per cent, according to the American Bureau of Metal Statistics.

Steel-mill operations, reported by the American Iron and Steel Institute, amounted to 55,854,523 tons in the first 8 months of 1945 compared with 89,575,853 in all of 1944; in 1943, 88,836,366. Cutbacks in steel orders following VE-Day were responsible for the reduction to 87.9 per cent of capacity, the lowest since June, 1940, compared with 95.4 per cent in 1944 and 98.1 per cent in 1943.

Steel production in 1944 was adequate for about 60 million tons of products, of which more than half went to the Army, Navy, and Maritime Commission; 14 million tons went to the FEA, Office of Defense Transportation, War Foods Administration, and other war-supporting agencies; about 10 million tons were utilized for civilian economy compared with more than 30 million tons a year consumed in the prewar period for steel products (7 to 9 million tons for automobiles).

Natural-mineral earth pigments and manufactured iron oxide pigments amounted to 97,018 short tons in 1944; in 1943, 100,216. Production was secured mainly from Pennsylvania. Processing was also reported in Georgia, California, and 12 other states. Synthetic iron oxides were in heavy demand for military uses and essential industrial paints. Olive-drab pigments, manufactured from ocher and other yellow pigments, are employed for textiles and for painting mobile military equipment, ammunition, and many types of naval craft.

Production and calculated salvage of purchased scrap reported by the

U.S. Bureau of Mines in June, 1945, amounted to 1,969,312 gross tons in April, 1945, compared with 1,800,196 in the same month of 1944.

The WPB announced, in June, 1945, that steel and wire rope would continue in short supply for nonessential uses. Certain ferroalloys were included by the WPB, in June, 1945, with a list of materials and products that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and it was anticipated that further changes in controls would be announced.

The WPB stated on Aug. 11, 1945, that the 45-day limitation on users' inventories of sheet and strip steel had been narrowed to apply only to carbon-steel sheet and strip and to silicon electrical sheet and strip. Effective on Sept. 17, the Office of Price Administration authorized a 10 per cent increase in gray iron castings manufacturers' "base period" ceiling prices. On Sept. 21, 1944, the WPB predicted that all products needed for maintenance and operation of steel mills would soon be "readily available." A high rate of operation for a long period was said to be assured for manufacturers of malleable iron castings.

The WPB stated that allocations of scrap iron and steel to mills and foundries would stop on Sept. 30, although allocations already issued would remain in force until the date of expiration. The WPB, on Oct. 1, 1945, eliminated the stock-preference plan under which steel warehouses obtained their supplies from mills during the greater part of the war period. This move was made by revoking Direction 3 to the General Preference Order M-21. On Sept. 5, *Iron Age* stated that most steel mills "have already put new schedules for finishing units into effect right on the heels of the war business cancellations experienced over the past few weeks." Future prospects were considered to be good for carbon steel but poor for alloy steels as a result of greatly expanded capacity for war production. Rapid reconversion of manufacturing plants was an important factor in stabilizing the iron and steel industry.

Leo T. Crowley, FEA administrator, reported on Mar. 28, 1945, that lend-lease goods sent to the Allies in 1944 included 4.6 per cent of domestic supplies of iron and steel. The Combined Steel Committee, made up of representatives of agencies in the United States, Canada, and Britain, was organized on Dec. 14, 1942, for the purpose of assembling and reviewing data relating to supply and consumption.

On May 4, 1945, the Steel Advisory Committee reported that steel could be supplied for all military and war-supporting demands for the Pacific campaign and also provided for full-scale production of durable goods, including automobiles and refrigerators for civilian consumption. The Controlled Materials Plan, undertaken in April, was followed by the recommendation

that all controls be revoked on production and use of steel with the exception of a single priority rating for military procurement, similar to the MM rating proposed in the program of the Period I Planning Board of the WPB. General Preference Order M-21 gave the WPB sole control over iron and steel and several other metals in the transition period of about six months after VE-Day, providing that producers could sell metal only to those manufacturers who held allocation "tickets" issued for war or civilian use. Removal of all steel controls would leave civilian-goods manufacturers faced with various other shortages, including lack of skilled workmen. In April, 1945, a program was undertaken for the purpose of dealing with the problem of completing war work, rearranging plants, and equipping with machine tools.

The WPB released steel mills, on July 1, 1945, to deliver metal to non-priority manufacturers of civilian goods. The relaxed allocation of steel and certain other metals included under the CMP made possible the resumption of peacetime production within a few months. Action by producers was to be dependent on retooling their plants and securing materials and labor. The CMP was to be terminated on Dec. 31, 1945, when it was planned to end rationing to authorized users. On July 1, relaxing the plan permitted delivery of steel and certain other metals after priority users had secured all supplies required.

The first commitment by the Metals Reserve Company for the purchase of iron ore was made in 1941. In 1942, iron and steel were added to the list of materials for government stockpiling. Iron and steel ranked tenth among stockpile items in cost of deliveries ($29,464,711), the value shown in the inventory of Oct. 31, 1944, being reduced to $2,006,235.

The WPB reported on Jan. 8, 1945, that steel supplies were about as low as at any time since 1942. The carbon-steel allotment to the Office of Civilian Requirements, in the first quarter of 1945, was cut from 228,000 to 163,800 tons. An additional allotment of 250,000 tons was made for civilian goods manufactured under the "spot" authorization plan. Plate and strip mills were expected to be held at capacity production in order to supply material for the 9 million tons of merchant ships scheduled for launching before June, 1945.

The proposed release of steel without allotment orders, on July 1, where delivery did not interfere with war production or priority consumer requirements, was announced by J. A. Krug on May 10, 1945. Until more supplies became obtainable, large quantities of steel would not be available for "hard goods" such as automobiles, furniture, trucks, refrigerators, and stores. Export requirements on orders from the U.S. Army included 91,540 railroad cars of various types for shipment to India and to five countries in Europe, in

addition to 3,700 cars for Mexico, Argentina, and Brazil. It was also reported, in May, 1945, that large numbers of cars were on order for domestic use. On June 21, 1945, the WPB reported that 1 million instead of 500,000 tons of steel would be available for unrestricted civilian uses in the July–September quarter. Revised production ceilings were issued for automobile manufacturers, allowing the output of 691,018 cars in the 9 months starting July 1.

The Office of Price Administration removed ceiling control, in October, 1945, on stainless steel, tool-steel scrap, ferroboron and other boron alloys, and ferrophosphorus. The CMP regulating the distribution of steel, copper, and aluminum was ended by the WPB on Sept. 30, 1945. Government funds amounting to $1,095,000,000 were provided for war expansion of the steel industry in 1941–1945, adding about 15 million tons capacity. Construction amounting to $1,310,000,000 was financed by the industry, which planned to spend an additional $200,000,000 to reconvert plants and equipment for nonmilitary and civilian use, as reported in May, 1945, by the American Iron and Steel Institute. Part of the reconversion program was to affect the continuous wide-sheet mills, meeting war demand for heavy plates used by shipbuilders, and the steel fabricating departments and plants producing such war goods as deckhouses for merchant ships, tank armor, and artillery shells. Reconversion costs were estimated at less than 10 per cent of total financing since 1940 to secure war materials.

The Civilian Production Administration in February, 1946, announced plans to increase production of pig iron 500,000 tons a year by reopening three blast furnaces, in order to increase supplies of cast-iron soil pipe and cast-iron radiation, bathtubs, sinks, and other products needed in the expanded housing program. The blast furnaces were at Struthers, Ohio, (Struthers Iron and Steel Company), with a capacity of 13,440 tons a month, and at the following facilities owned by the DPC: Granite City, Ill. (operated by Koppers Coal & Coke Company), 18,000 tons a month; Gadsden, Ala. (operated by Republic Steel Corporation), 6,000 tons a month.

The CPA reported on Mar. 7, 1945, that iron and steel inventories continued to be limited to a 45-day supply by Direction 8 to Priorities Regulation 32. Grants of CC and MM ratings on steel orders had been suspended at the beginning of the steel strike in January, 1946. The bottleneck-breaking order, Priorities Regulation 28, was to be reestablished due to the rise in the steel-operating rate to 90 per cent from below 50 per cent during the coal strike as well as favorable future prospects, and CPA reimposed priority aid for steel manufacturers in the fourth quarter of the year, it was announced on July 29, 1946. CPA asked for advance applications for critically needed

products in the housing program in order to ascertain the impact of these needs on total steel production.

In May, 1945, the Surplus Property Board appointed Dr. J. R. Mahoney, of the University of Utah, and Samuel Moment, of the Bonneville Power Administration, to prepare a report on the economic and marketing problems relating to government-owned aluminum and steel plants. The studies were to be used as a basis for plant disposal.

War demands for increased production of iron ore were met largely by the open-pit mines, which are approaching exhaustion. Postwar study is to be made of lower grade iron-ore resources. Government purchase of sub-

PIG IRON AND FERROALLOY CAPACITIES, IN SHORT TONS
(After American Iron and Steel Institute)

January 1	Coke	Charcoal	Pig iron	Ferroalloys	Pig iron	Total
1939	232	4	55,162,374	1,060,416	103,040	56,325,830
1940	228	4	54,635,740	992,320	95,580	55,723,640
1941	227	4	56,522,370	980,660	106,560	57,609,590
1942	234	4	59,211,850	1,075,570	106,560	60,393,980
1943	238	4	62,859,330	967,000	107,200	63,933,530
1944	245	2	66,344,780	990,300	56,190	67,391,270
1945	*	*	65,264,210	992,600	64,480	67,313,890

* Not reported.

PIG IRON PRODUCTION, INCLUDING FERROALLOYS, IN SHORT TONS
(After American Iron and Steel Institute)

1914–1923	716,104,603	1941	56,686,604
1924–1933	659,607,093	1942	60,903,304
1934–1943	403,243,509	1943	62,769,947
1939	35,677,097	1944	62,900,000 (estimated)
1940	47,398,529		

PIG IRON CONSUMPTION IN STEELMAKING, IN SHORT TONS
(After U.S. Bureau of Mines)

Furnace type	1939	1940	1941	1942	1943
Open hearth	26,826,172	36,297,250	42,481,404	45,538,846	47,107,608
Bessemer	3,603,199	3,828,978	5,993,264	6,131,222	6,257,927
Electric	30,542	46,506	72,758	92,878	393,819
Cupola	3,349,198	4,106,119	5,388,747	4,490,532	3,602,918
Air and Brockelsberg	329,317	374,187	604,835	555,436	537,902
Crucible	92	184	207	221	457
Puddling	27,959	28,293	54,183	49,835	38,231
Direct castings	1,066,220	1,504,311	1,590,074	2,183,913	2,376,297
Total	35,232,699	46,185,828	56,185,472	59,042,883	60,315,159

marginal ores for stockpiling is one policy under consideration. Open-pit reserves in the Lake Superior district, which has produced about 85 per cent of all the iron ore mined in the United States since 1915, are expected to be exhausted in about 26 years. Greater attention is expected to be given to beneficiating low-grade ores as a substitute for high-grade material, with increased imports from Canada, South America, and Cuba. Postwar requirements are estimated by the U.S. Bureau of Mines at about 70 million gross tons a year of iron ore, 60 million tons of steel, and 40 million tons of pig iron for both iron and steel furnaces.

World Production, Imports and Exports. The production of cheap iron and steel is largely controlled, outside the United States, by Great Britain (supplemented by Spain and Scandinavia), the Belgium-Ruhr basin and the Lorraine area, Silesia and Sweden, the Ukraine and southern Ural Mountains of U.S.S.R., and North India. These areas, with Brazil and Venezuela, the United States and Labrador, and China, are equipped with the raw material to play an active part in world industrial expansion.

Canada, in 1945, had expanded steel facilities and introduced new products to the point of almost complete independence of imports. Prewar imports included sheets and castings, which are now produced by the sheet and strip mill of the Steel Company of Canada, Ltd. In Canada, iron ore produced in 1944 was 549,922 tons (shipments totaled 498,635 tons from Michipicoten and Steep Rock); in 1943, 641,294; in 1942, 545,306. Ore imported in 1943 totaled 3,125,342 tons; in 1944, 3,638,000. Iron oxides produced in 1944 amounted to 10,335 tons valued at $172,223; in 1943, 8,401; in 1942, 9,304. Important tonnages of beneficiated siderite ore were being produced at the New Helen mine, Michipicoten, Ontario, and operations were started in 1945 at the neighboring Josephine mine. A third producer in Ontario, Steep Rock Iron Mines, Rainy River district, made initial shipments of 16,411 tons of high-grade hematite in 1944, and total shipments in 1945 were about 505,000 gross tons. The 1946 output was scheduled at about 1 million tons. In New Brunswick, output of 127,734 tons of hematite and magnetite was recovered in 1943 from the Bathurst mine by Dominion Steel and Coal Corporation, earlier output having been secured in 1915 and preceding years.

In May, 1945, the Josephine mine, adjoining the New Helen, was placed in production by Michipicoten Iron Mines. Algoma Ore Properties, Ltd., contracted to purchase an annual minimum of 75,000 gross tons of open-hearth lump ore and 194,000 tons of hematite ore concentrate for a 7-year period. Ore is sintered, then shipped 100 miles by lake boat from Michipicoten Harbour to the plant of Algoma Steel Corporation, Sault Sainte

Marie, Ontario. Over-all production of iron ore in Canada, Sept. 1, 1939, through Sept. 1, 1945, amounted to 3,127,500 short tons valued at $9,542,200.

Canada's production of ferroalloys has been one of the major fields of expansion in the war period. Steel production in Canada follows the United States, Russia, and Great Britain. Both production and consumption expanded greatly in the war period, from 1,509,480 tons of ingots and castings in 1939 to 3,024,410 in 1944 and with an estimated 2,881,323 produced in 1945. Consumption jumped from 1,563,391 tons in 1939 to the 1942 peak of 4,297,974 tons. The 1945 consumption is estimated at 3,599,000 tons.

CANADIAN PRODUCTION OF PIG IRON AND STEEL, IN NET TONS
(After American Iron and Steel Institute)

Year	Basic	Foundry	Malleable	Ferroalloys	Total
1939	735,571	80,314	31,878	82,359	930,122
1940	1,091,583	120,875	96,640	138,605	1,447,703
1941	1,272,171	115,791	140,091	204,354	1,732,407
1942	1,645,847	159,979	169,189	213,636	2,188,651
1943	1,456,549	148,653	153,067	197,094	1,955,363
1944	1,534,140	143,762	174,726	182,428	2,035,056
1945*	.....	.....	.....	186,978	1,642,733

* Estimated.

CANADIAN STEEL PRODUCTION, IN NET TONS
(After American Iron and Steel Institute)

Year	Open hearth	Bessemer	Electric	Total
1939	1,428,184	Converter	81,296	1,509,480
1940	2,045,574	Converter	128,313	2,173,887
1941	.....	.....	.....	2,712,151
1942	2,651,279	5,402	464,680	3,121,381
1943	2,484,544	.....	362,192	2,996,978
1944	2,517,511	.....	360,896	3,024,410
1945*	.....	.....	.....	2,881,323

* Estimated.

The last steel-control order in Canada was revoked on Nov. 22, 1945. Price controls on steel were continued under direction of the Wartime Prices and Control Board, with the retirement of the Steel Controller. Structural steel shapes had been standardized in the war period, reducing the number from 267 to 70 sizes. The use of steel in construction was sharply restricted under war conditions, and rigid controls were imposed on pig iron and steel scrap.

In Alaska, the U.S. Bureau of Mines, 1940–1944, developed the Kasaan

property (Project 927). Trenching, drilling, tunneling, and shaft-sinking indicated about 1,200,000 tons of ore averaging 50 per cent of iron, suitable for low-cost mining by open-pit methods. Favorable possibilities were indicated for important advances in the postwar period in Alaska, as reported on May 7, 1945, by the U.S. Geological Survey.

Great Britain increased output of iron ore from 14,443,146 metric tons in 1937; in 1939, 14,486,000; in 1943, 18,487,000; in 1945, 14,000,000. In 1943, steel output amounted to 13,031,000 tons compared with 6,500,000 tons in prewar years; in 1944, 12,142,200; in 1945, 11,819,900. Exports of iron and steel from Great Britain were as follows, not including government munitions but including military goods to Russia (except munitions) and exports under lend-lease to the United States: in 1942, 257,622 tons; in 1943, 134,649; in 1944, 219,473.

The Iron and Steel Trades Confederation, on June 24, 1945, demanded expansion of Britain's iron and steel industry to annual production of more than 18 million tons. This compared with the capacity of 15 million tons planned by British steel companies to allow for actual production of something under 12 million tons, which was considered inadequate to provide workers with continuous employment. In August, 1945, British Iron and Steel Foundation announced starting work on the $480,000,000 program that included construction of new coke ovens, rolling mills, strip mills, and blast furnaces. Of the 98 blast furnaces in Britain, 10 are to be rebuilt, and 19 new ones constructed.

A newly set-up British Iron and Steel Research Association was reported in November, 1945. This was to spend $1,772,000 a year for the next 5 years on research developments in the industry. The Iron and Steel Control together with the Nonferrous Metals Control and the Light Metals Control were to continue under the authority of the Ministries of Supply and Aircraft Production, which were to carry the primary government responsibility in the field of engineering. The Raw Materials Department and the Raw Materials Controls of the Ministry of Supply were transferred to the Board of Trade.

German industry, in 1932, used 3.5 million tons of steel, expanding under Hitler's program of rearmament to 22 million tons in 1938. German steel capacity, including seven occupied countries, was estimated at 48 million tons. This figure is believed to be lower than 1919 output, when Germany produced 11 million tons. At the crest of German power, it is estimated by the American Iron and Steel Institute that steel capacity in Axis Europe was second only to that of the United States, amounting to 60 million tons (including 28 million tons within Germany). According to a report in February, 1946, by the British Iron and Steel Federation, peak production in Germany

was reached in 1943 with pig iron amounting to 24,200,000 metric tons and steel amounting to 30,600,000 metric tons. Steel capacity available to Germany in November, 1944, was believed to be reduced to about 36 million tons, following the loss of Italy, France, Belgium, Luxemburg, the Balkans, and Hungary. In January, 1945, capacity was reduced to not more than one-third the output secured in the best war years. Senator Harley Kilgore reported, on July 10, 1945, that only minor repairs would be required to restore this industry to production.

Even if the Goering Works at Salzgitter and Ling and other steel plants in central Germany escaped serious war damage, great difficulty was anticipated in competing, in quality and in cost of production, with plants in the Ruhr and in other parts of Europe.

Of Germany's steel-producing machinery, about 50 per cent was to be destroyed or removed as reparations, it was stated by Col. James Boyd, chief of the industry division, Office of Military Government, on Oct. 10, 1945. The objective was to transform the German economy from that of a nation producing armaments and heavy machinery to that of an agricultural state geared to the production of consumer goods. Some 75 per cent of German industry remained intact or in condition to be repaired, in spite of the almost incessant bombing prior to VE-Day. In the British zone, the German iron and steel industry was working at about 10 per cent of peak output, it was reported in November, 1945.

On Jan. 11, 1946, the Allied Control Council decided that Germany would be allowed steel production capacity of 7,500,000 tons a year, with actual output to be held under 5,800,000 tons. Only the older steel plants would be left to Germany, as far as practicable. About 70 per cent of the ingot-producing capacity of Germany proper was in the British zone, with 5 million tons in shape to restore to immediate operation. Production was at the rate of 100,000 tons a month early in 1945. Steel exports were restricted to 600,000 tons compared with prewar exports exceeding 3 million tons a year.

Poland, combining the new and old industrial regions of Upper Silesia, was reported in July, 1945, to have the greatest industrial power in Europe west of Russia. Numerous iron and other mines as well as great steel plants are located between the old Polish borders and the Neisse and Oder rivers, in Upper Silesia. This had been a vital source of steel for Germany, prior to Russia's conquest in January, 1945. Low-grade iron ore is produced locally and supplemented by scrap materials brought in from Central Europe. In 1928, Poland occupied twelfth place among steel-producing countries and stood thirteenth in pig-iron output. In 1938, the Trans-Olzan area of Silesia was

incorporated into Poland, the iron mines and steel plants increasing pig-iron output by about 55 per cent and steel output by 50 per cent.

U.S.S.R. has reserves of iron ore "more than adequate to meet domestic requirements," it was reported in Washington in January, 1946, based on information submitted by the Office of Strategic Services. World superiority in all minerals, except tin and silver, was made possible in Russia as the result of a policy of importing minerals rather than using the known domestic deposits, leaving untouched vast reserves of essential materials.

The wartime production of Spain and Sweden was reported by the British Iron and Steel Federation to have been comparatively unchanged. In France, the output was about one-fourth the 1937 rate. In Belgium, wartime output was about 35 per cent of the steel production in 1937; the industry was operating at 32 per cent of the 1937 rate, in November, 1945, due to fuel shortages, and Luxemburg was at 22 per cent of the 1937 figure.

Japan, of the five leading industrial nations, is seriously deficient in supplies of iron ore. This critical shortage, which applies to various other essential and critical mineral reserves, led Japan in the 1930's to make concerted efforts to secure control of foreign sources. Production was gained in Malaya, and exploration was undertaken in Australia and the Philippines. Iron and coal deposits in Manchuria and North China have been stated to be the primary reason for Japanese conquest in those areas. Japan will regain economic domination over those areas of Asia if pig iron should be permitted to be shipped to fabricating plants located on the Japanese home islands, it was reported on Oct. 11, 1945, by Edwin C. Pauley.

Substantial deposits of iron ore in Korea (Chosen) were acquired by Japan in 1936 by forced sale, as reported in March, 1946, by the U.S. Department of Foreign Commerce. Iron ore amounting to about 6 million tons was produced in Korea in 1939, the iron and steel industry being heavily subsidized by the Japanese government. This was greater than output by Manchuria. Iron deposits of Korea have high-grade ore estimated at 10 to 40 million tons and 1 billion tons of low-grade ore averaging 30 to 35 per cent iron.

Peak production of steel in Japan was attained in 1943, thereafter declining steadily as a result of naval blockade and bombings, as reported by the American Iron and Steel Institute in April, 1946. Wartime peak steel output in Japan (9,656,000 net tons) was less than 11 per cent of the United States maximum annual production. Home islands of Japan were credited with 90 per cent of the total from Japanese-controlled plants, the balance being secured from Showa, Manchuria, and Keijibo, Korea. Japan's prewar steel output increased from 2,070,000 tons in 1930 to 6,991,000 tons in 1937 and

7,453,000 tons in 1941. Large prewar purchases of steel scrap were made by Japan in the United States. Steel output in Japan at the end of 1945 was at the annual rate of about 120,000 tons.

In the Philippine Islands, output of iron ore in 1939 amounted to 1,154,738 metric tons; in 1940, 1,191,641. Total prewar production was exported to Japan, which is assumed to have continued mining operations from early 1942 until February, 1945, when Luzon was liberated.

In 1937, the following countries produced iron ore in excess of 1 million tons: Spanish Morocco, Unfederated Malay States, Austria, Czechoslovakia, Chile, Newfoundland, and Norway. Smaller output was recorded for 21 other countries.

In the following table, world trade in iron ore is shown representing about 93 per cent of total shipments in 1938. All trade is represented, over 75,000 tons, between any two countries, in thousands of metric tons:

1. *France*	
To: Belgium	8,600
Germany	5,666
United Kingdom	323
Netherlands	83
Total	15,513
2. *Sweden*	
To: Germany	8,992
United Kingdom	1,367
Czechoslovakia	798
Belgium	549
United States	217
Poland	191
Netherlands	167
France	103
Total	12,685
3. *Algeria*	
To: United Kingdom	1,355
Germany	755
Belgium	156
France	106
Total	2,755
4. *Belgium*	
To: Germany	1,829
France	134
Total	2,047
5. *Norway*	
To: Germany	1,118
United Kingdom	580
United States	77
Total	1,916

6. *Spain*		
To: Germany		1,083
	United Kingdom	602
	Italy	99
	Total	1,835
7. *Newfoundland*		
To: Germany		1,122
	Canada	551
	United States	151
	Total	1,824
8. *Chile*		
To: United States		1,603
	Total	1,603
9. *British Malaya*		
To: Japan		1,556
	Total	1,556
10. *Morocco (French and Spanish)*		
To: Germany		590
	United Kingdom	305
	Italy	216
	Total	1,492
11. *Philippine Islands*		
To: Japan		911
	Total	918
12. *Sierra Leone*		
To: Germany		462
	United Kingdom	195
	Poland	81
	Total	876
13. *Tunisia*		
To: United Kingdom		464
	France	82
	Total	632
14. *United States*		
To: Canada		572
	Total	601
15. *Yugoslavia*		
To: Hungary		174
	Rumania	114
	Czechoslovakia	82
	Total	374
16. *Brazil*		
To: Netherlands		118
	Poland	100
	Total	369
17. *Greece*		
To: Germany		249
	Total	357
18. *British India*	Total	269

19. *Czechoslovakia*	
To: Hungary	194
Total	203
20. *Australia*	
To: United States	84
Japan	76
Total	160
21. *Cuba*	
To: United States	99
Total	152
22. *Switzerland* Total	134
23. *Indo-China*	
To: Japan	89
Total	89
24. *Austria*	
To: Czechoslovakia	78
Total	87
25. *China*	
To: Japan	79
Total	79

Steel capacity near the end of 1940 is shown in the following comparison of facilities controlled by the Axis and United Nations. Peak production in prewar years is used as the basis of estimated pig-iron production.

UNITED NATIONS AND AXIS CONTROL OF STEEL CAPACITY 1940, IN THOUSANDS OF METRIC TONS
(After "*World Minerals and World Peace*")

	Axis powers	Axis occupied and controlled	Total Axis	United Nations	Others*	World total
Pig iron	23,850	24,065	47,915	67,244	500	115,659
Steel	35,560	29,410	64,970	109,501	510	174,981

* Turkey, Spain, Portugal.

The United States, in 1940, imported 2,479,326 gross tons of iron ore, 3 per cent over 1939. Chile supplied 68 per cent, or 1,682,600 tons. In 1943, ore was imported from Africa, Brazil, Canada, Cuba, Mexico, Newfoundland, Spain, and Sweden. Canada and Cuba each supplied 9 per cent, in addition to 3,908 tons of pyrite ash from Canada; 8 per cent was imported from Sweden. Exports to Canada amounted to 1,386,097 tons; other countries received 207 tons.

Export requests for 4 million net tons of steel in the first half of 1946 were reported by the CPA, on Dec. 15, 1945, to have been cut down to about 850,000 tons "to prevent any drastic drain on the domestic economy." Exports

were being reduced to the minimum amount necessary to meet essential rehabilitation needs in Europe and Africa.

United States steel exports totaled 35,800,000 net tons in 1941–1945, the amount being slightly less than domestic consumption by the shipbuilding industry, as reported by the American Iron and Steel Institute. In 1945, 7,911,-711 tons of steel were exported, exceeded only by the 8,752,712 tons exported in 1940. About one-fourth these exports, chiefly semifinished products, went to Britain; Canada and Russia also received large shipments.

In Australia, a wartime survey of iron-ore resources was made for the Munitions Department. Prime Minister J. B. Chiflay reported on May 29, 1946, that this survey located accessible good-grade ore adequate for 100 years' domestic requirements. Other less accessible deposits are also known.

The Foreign Economic Administration reported in August, 1945, that iron concentrates and ferroalloys were included in almost 350,000 tons of minerals and metals available in Norway for immediate shipment, in spite of the extended military occupation by the Nazis. In the last 4 months of the year, it was estimated that 1 million tons of metals, minerals, and fertilizers would move out of Norway.

With capital available from new materials exports and from loans through the Export-Import Bank for purchase of machinery and equipment in the United States, certain Latin-American countries were attempting to utilize raw-material products locally by erecting new blast furnaces and rolling mills for iron and steel products and electric furnaces for special steels and ferroalloys.

In Brazil, iron-ore deposits represent the chief mineral reserve and are perhaps the largest known. Deposits located in the states of Minas Geraes and Matto Grosso are estimated at several billion tons, including upward of a billion tons of over 60 per cent hard hematite ore in Minas Geraes, lower in phosphorus and silica than most deposits now under production. Exports of this ore, largely from the Habira mine, in 1944 amounted to about 350,000 tons. The present inefficient narrow-gauge railway causes a loss on ore exports. Coal from the Santa Catharina fields, 600 miles southeast of the iron ore, is being studied for use in the manufacture of coke, for which coal is now being imported.

Brazil has annual output of 160,000 tons of pig iron from 14 blast-furnace plants of which several use charcoal as fuel. Independence of most iron and steel imports is to be gained with completion of the 300,000-ton Volta Redonda plant. Full operations were started on June 9, 1946, initiating "Brazil's steel era." Total construction costs, including development of coal, iron, limestone, and other mineral deposits, are estimated at $100,000,000,

including $45,000,000 in credits extended by Export-Import Bank. Volta Redonda may be expanded to four blast furnaces, nine open-hearth furnaces, and rolling-mill capacity enlarged to 1 million metric tons a year. The plant was started in 1940, and equipment was imported from the United States over submarine-infested sea routes.

Prewar steel consumption in Brazil was 22 lb. per capita compared with 880 lb. in the United States. Domestic production of pig iron, from small charcoal furnaces, was about 200,000 tons a year, with 450,000 tons imported. In 1942, steel mills in Brazil produced 160,000 tons of steel and 150,000 tons of sheet iron. Smaller iron ore deposits have been reported in the states of Bahia, Parana, and Santa Catharina.

In Mexico, iron ore produced in 1943 amounted to about 100,000 tons averaging 62 per cent of iron, from El Cerro de Mercado deposit, Durango. Reserves are estimated at 100 million tons which, combined with reserves at several other mines, exceed estimates of ore available in the United States. Ore is shipped to the 900-ton blast-furnace plant at Monterrey. In 1941, Mexico produced 78,774 metric tons, of which 2,806 tons were exported. In 1943, 130,000 tons of pig iron and a wide variety of iron and steel materials were produced. The steel plant and rolling mills, early in 1945, were reported working at capacity to supply large domestic demand for steel bars, sheet iron, structural steel, and rails. In November, 1943, it was reported that the $10,000,000 Altos Homos steel plant was under construction by Armco International Corporation, financed in Mexico. Prewar imports of iron and steel amounted to about $6,000,000 a year.

La Consolidada, the largest Mexican steel company, is controlled by United States capital with Mexican participation in ownership. A $3,000,000 construction program was announced, on Dec. 18, 1945, to add a new rolling mill having an annual capacity of 136,000 net tons and a new rod mill to produce steel products at present not manufactured in Mexico. These plants were to be in operation before July 1, 1946. Consolidada operates open-hearth furnaces on the United States-Mexico border, where pig-iron and steel ingots are ample for Mexican requirements.

In Venezuela, iron ore follows petroleum in importance among natural resources. Under development since 1940 by the Iron Mines Company of Venezuela (Bethlehem Steel Corporation) at El Pao, iron ore is to be exported in 1946 at the rate of 2 million tons a year. The ore will be crushed, hauled 30 miles by rail to the Orinoco River, carried in shallow-draft boats 150 miles to an island near Trinidad, and reloaded to large vessels for shipment to the United States.

Cuban exports of iron ore declined from 279,133 tons in 1939 to 210,068

in 1940. In Chile, El Tofo mine of Bethlehem Steel, located in the coastal belt near Atacama, suspended shipments in May, 1942, because of shipping difficulties. Production had been at the rate of 1,800,000 tons a year. Annual requirements of 100,000 tons of iron and steel products are to be met by a proposed new blast furnace and rolling mills near the coal field at Concepcion, supplementing the 24,000-ton steel plant at Corral, built in 1929.

In Peru, Chimbote, located 250 miles northwest of Lima, has been selected as the site for industrial plants for the manufacture of iron and steel products. Large fields of semianthracite are located inland from Chimbote, and large iron-ore deposits occur at Marcona to the south.

In Colombia, exploitation of iron deposits in the Rio del Paz district was announced by President Alberto Lleras Camargo, on Dec. 13, 1945. A loan was to be floated under a contract with the Minister of Finance by the Industrial Development Institute to finance the development program.

In Chile, Bethlehem Steel Corporation controls large deposits of iron ore. The first shipment since 1942 was received at the Sparrows Point plant on Aug. 24, 1945, amounting to 25,000 tons. Pomento Corporation signed two loan agreements for $33,000,000 from Export-Import Bank for the purpose of buying United States equipment materials and services for the construction of an iron and steel plant near Concepcion. The corporation, Compania de Acero del Pacifico, will produce pig iron, heavy and light structural steel, rail, galvanized sheets, wire, pipe and other products. The plant will operate with electric power.

Near the Persian Gulf occur undeveloped ore deposits having an average grade reported to be 65 per cent of iron. In Persia, 400 to 600 miles east of the Persian Gulf, iron-ore deposits believed to be of large size have not been explored.

In British India, an iron range located in the central provinces is believed to have deposits of iron ore surpassing in size those of the Lake Superior region of the United States. Iron-ore reserves in the Singhbhum-Orissa field were estimated at 8 billion gross tons on Nov. 20, 1945, excluding the Mayurbhanji titaniferous magnetite. India increased production 55 per cent between 1937 and 1944.

In Sierra Leone, British industry has developed large iron mines having export facilities for 5 million tons a year. In South Australia, at Iron Knob, a growing steel industry has been established.

World steel production in 1943, according to statistics published by the Lohdon *Metal Bulletin*, amounted to 146½ million long tons. This was 1 million tons higher than the previous year but lower than the peak volume in 1940. The United States produced 79,350,000 tons (in 1940, 59,806,000);

Germany, 20 million (in 1940, 28 million); Great Britain, 13 million (in 1940, 14 million); U.S.S.R., 12 million (in 1940, 18 million). In 1938, U.S.S.R. and the United States each produced iron ore amounting to about 19.5 per cent of the world total. In steel output, the United States accounted for 26.5 per cent and Germany 21.4 per cent of the total.

WORLD PRODUCTION OF IRON ORE, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1937	1938
United States	73,250,649	
France	37,839,000	32,904,045
U.S.S.R	26,000,000	27,000,000
Sweden	14,952,549	13,701,955
Great Britain	14,443,146	11,859,191
Germany	9,575,234	10,942,200
Luxemburg	7,786,254	5,059,443
British India	2,883,548	2,761,725
Algeria	2,427,230	2,985,582

WORLD PRODUCTION OF PIG IRON AND STEEL, IN GROSS TONS
(After American Metal Market)

Country	1937		1938	
	Pig iron	Steel	Pig iron	Steel
France	5,954,000	6,077,000	4,600,000	5,500,000
United States	19,161,000	28,350,000	42,320,000	59,806,000
U.S.S.R	14,756,000	18,156,000	15,300,000	19,500,000
Sweden	703,000	964,000	600,000	875,000
Great Britain	6,763,000	10,394,000	8,300,000	13,400,000
Germany	18,221,000	22,876,000*	20,700,000	25,150,000
Luxemburg	1,526,000	1,414,000	1,100,000	1,300,000
India	1,610,000	966,000		
Spain	433,000	463,000	500,000	500,000
Australia	1,000,000	1,160,000		

* Includes Austria.

National self-sufficiency in iron ore is held by four countries: the United States, the British Empire, France and colonies, and Spain and colonies. U.S.S.R. has iron ore adequate to meet domestic demands without appreciable excess or deficiency. Belgium and colonies, China, and Japan have inadequate iron ore to meet domestic demands. Germany, the Netherlands and colonies, and Italy are dependent almost entirely on foreign sources.

France and Sweden together had prewar exports of iron ore amounting to 58 per cent of the world total, whereas Germany imported about half of total

shipments from foreign sources. Ore imported by Belgium amounted to about half of that received by Germany. Great Britain imported about one-tenth of the world total. World production of iron ore increased from 124 million tons in 1914 to 197 million in 1939. In the same period, production in the United States expanded from 41.4 to 51.7 million long tons.

In Russia, a goal of 50 million tons of pig iron and 60 million tons of steel a year was stated by Premier Stalin on Feb. 9, 1946, as part of the fourth 5-year plan. These projected capacities compare with 4,220,000 tons of pig iron in 1913; 15,000,000 in 1940; and 18,000,000 in 1941; 4,230,000 tons of steel in 1913; 18,300,000 in 1940; and 22,000,000 in 1941.

Prices. The prices of Lake Superior ore at lower lake ports were in effect from 1940 through Sept. 1, 1945, at $4.45 to $4.75 a gross ton for the four standard grades, which was 5 cents a ton lower than in the 1929–1936 period and 50 cents lower than in 1937–1939. These prices applied as follows: Old Range Bessemer, 51.5 per cent of iron, natural, $4.75; Mesabi Bessemer, $4.60; Old Range non-Bessemer, $4.60; Mesabi non-Bessemer, $4.45. Eastern ores were 11 to 12 cents per long ton unit, delivered at furnaces, foundry and basic, 56 to 63 per cent.

On Dec. 30, 1945, the OPA ordered price ceilings for iron ore produced in Minnesota, Wisconsin, and Michigan increased 10 to 20 cents a ton, retroactive for the entire 1945 shipping season to underground mines producing ore for sale (19 million of the 82 million tons produced in 1944 were for sale). Old Range Bessemer increased to $4.95 ($5.45 on Aug. 1, 1946); Old Range non-Bessemer, to $4.80 ($5.30 on Aug. 1, 1946); Mesabi Bessemer, to $4.70 ($5.20 on Aug. 1, 1946); Mesabi non-Bessemer, to $4.55 ($5.05 on Aug. 1, 1946). High-phosphorus ore increased 20 cents to $4.55 a ton; manganiferous, silicious, and lump ores increased 20 cents a gross ton.

Brazilian ores, 68 per cent, were 7¼ to 7¾ cents, f.a.s. Brazilian ports.

Pig iron was quoted at $23.50 per gross ton up to Mar. 1, 1945, when the price increased to $24.50. For No. 2 foundry pig iron, the ceiling price was in effect from June 24, 1941, to Feb. 14, 1945, when an increase of $1.00 per gross ton established the price at $25 at Chicago; $26 f.o.b. Bethlehem, Pa. The price of pig iron was increased 75 cents a ton in October, 1945, and was quoted at $28 through Sept. 30, 1946.

The steel base price, Pittsburgh Billets, was $34 per gross ton on Apr. 2, 1945; $39 on Sept. 30, 1946; structural shapes, $2.35 per 100 lb. Ferrosilicon was priced at 6.65 to 8.10 cents per pound of contained silicon, 50 per cent grade, eastern zone; 75 per cent grade, 8.05 to 9.05 cents; 90 to 95 per cent grade, 11.05 to 12.30 cents. The prices of carbon steel were raised $2 to $2.25 in October, 1945, in order to meet higher costs.

Iron oxide was reported on Apr. 12, 1945, by *E & M J Metal and Mineral Markets* at 3 to 5 cents a pound, Spanish red, standard No. 1 quality; domestic earth, 2½ to 3¾ cents. *Oil, Paint and Drug Reporter* listed the following prices (1943–1944) for finished earth pigments: precipitated magnetic blacks, in barrels, less carlots, works, 8½ cents a pound; metallic browns, in barrels, 2½ cents; vandyke brown, 9 to 12 cents; sap brown, 12 cents; synthetic (pure) browns, 12 cents; synthetic (pure) red iron oxides, 9 to 9¾ cents; Venetian reds, 2.2 to 4 cents, depending on iron oxide content; natural yellow oxides, high iron, 5 cents; synthetic (pure) iron oxide yellows, 7.1 cents; domestic French-type ochers, 3.45 cents; burnt siennas, American-type, 3¾ to 5 cents; Italian-type burnt siennas, 8¾ to 10¾ cents; raw siennas, American-type, 4 to 10 cents; raw siennas, Italian-type, 8 to 10 cents; Turkey-type umbers, 4¾ to 5¾ cents. In Canada, the price of red iron oxide is 2 to 7 cents a pound. Carbonye iron amounting to 150 tons was reported in the government stockpile on July 17, 1944, by *The Wall Street Journal.*

According to the tariff act of 1930, the rate (corrected to Feb. 1, 1943) on iron and steel scrap was 75 cents per gross ton; pig iron not over 0.04 per cent phosphorus, 75 cents per ton; over 0.04 per cent, $1.125 per ton. The duty on ferrosilicon, from 8 to 30 per cent silicon, was 1 cent per pound of silicon contained; spiegeleisen, over 1 per cent carbon, 75 cents per ton.

Stainless-steel scrap was suspended from price control by the OPA on Nov. 16, to be effective Nov. 20, 1945. This affected Revised Price Schedule 8 and also Navy and ordnance castings (Armor), as defined in Maximum Price Schedule 41. These rulings followed policies approved by the Office of Economic Stabilization to permit "decontrol of goods and services when supplies balance demand" or when items are "judged to have little effect on the cost of living, the cost of business, or production of other commodities."

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KYANITE

(Indian)

Properties. Containing about three times as much alumina as feldspar, kyanite has three times the tolerant content of iron oxide. Kyanite occurs in crystals having glassy to pearly luster; its color ranges through blue, white, colorless, gray, green, brown, and black. About the hardness of quartz across the flat-bladed crystals, kyanite is much softer parallel to the long direction of the blades. Its specific gravity is 3.56 to 3.67 (quartz, 2.65). "Standard" kyanite contains 58.77 per cent of Al_2O_3 and 37.7 per cent of SiO_2.

The capacity to withstand high temperatures makes kyanite useful as a refractory; and in the form of porcelain, it has a high melting point, high insulating power when heated, a low coefficient of expansion, and resistance to the corrosive action of certain fluxing agencies and furnace gases. The volume change in burning is negligible.

In the production of ceramics, kyanite has the economic advantage over andalusite of a more constant source of supply. It is more readily decomposed than andalusite; and because of expansion on heating, it may be used to advantage in combination with diaspore or bauxite, which have high shrinkage, in the preparation of refractories. The expansion of kyanite counteracts the shrinkage of diaspore or bauxite. Kyanite decomposes to mullite and a liquid (silicious glass) upon heating, beginning at a temperature of about 1350°C.

Uses. War industry developed important applications for kyanite in the manufacture of special refractories. Little known before 1920, kyanite has developed as a cheap source of alumina for a low-alkali type of glass. It is proposed to provide finely powdered kyanite as an efficient source of alumina for improving the strength, viscosity, chemical durability, and thermal endurance of the glass.

In 1941, the Advisory Committee on Metals and Minerals, National Academy of Sciences, reported that metallurgical industries account for about half of the total kyanite refractories used in the United States. Only high-melting alloys require superrefractories (kyanite, alumina, spinel, chrome, and aluminosilicate). High-alumina refractories, at one-fifth the cost of kyanite, are equally serviceable at temperatures below 3000°F. in ferrous smelting. At higher temperatures, kyanite products have twice the life; in intermittent operation, these products have at least five times the life.

The chief ceramic use is in high-temperature kiln furniture for open-type firing tunnel kilns. A special situation exists in high-purity kyanite for production of low-alkali glass (borosilicate). Used mainly in the manufacture of brick and other refractories for glassworks, kyanite is also employed directly as a constituent of glass and of other ceramic products. As a substitute for kyanite, andalusite, in calcined form, was brought into use under the war emergency.

Kyanite refractories, although representing only a small percentage of the total output of refractories in the United States, have special properties of strategic importance, particularly the ability to bear high loads at high temperatures and to resist thermal shock. These refractories are made in prefabricated and burned shapes, such as brick, tile, and block. They are also employed in making plastics, cements, ramming mixes, and mortars. About half the domestic output is supplied the metallurgical industry. Alumina and magnesia—alumina refractories—have the same life as kyanite products but are more difficult to install. Fire-clay refractories are reported to have only one-tenth the life of kyanite in furnaces melting alloys with a high melting point. High-alumina refractories have only half the life of kyanite materials at temperatures above 1649°C.

Kyanite is employed in burner blocks in the superstructures of glass tanks; for plungers, rings, and tubes for feeding molten glass to forming machines; for saggers and other kiln furniture for the chinaware and pottery trade; and in porcelain.

Domestic Sources of Supply and Production. Kyanite can be concentrated efficiently from its ore by means of flotation, a high-grade product being recovered which is treated electromagnetically in order to separate kyanite and garnet into products of marketable grade.

Kyanite Products Corporation, the only large producer of refractory grade kyanite, is located 20 miles southwest of Farmville, Va. In 1941, it acquired properties for development in Virginia and South Carolina. Kyanite Products was purchased, in February, 1945, by Kyanite Mining Corporation, Cullen, Va. Yancey Cyanite Company, the only domestic producer of low-iron kyanite, shut down on Jan. 5, 1944. In 1944, domestic production of refractory and low-iron glass-grade kyanite did not meet requirements.

An attempt has been made, through research at Virginia Polytechnic Institute, to employ binders and plasticizers to agglomerate the fine-grained Virginia kyanite into briquettes for crushing or grinding in order to form products of large grain size comparable with those of large-grained Indian kyanite.

SHIPMENTS OF DOMESTIC KYANITE, IN SHORT TONS
(After U.S. Bureau of Mines)

1940	1941	1942	1943	1944
4,241	8,335	8,708	9,361	*

* Data not available for publication.

Production has been secured also in Georgia, where widely distributed occurrences of kyanite have been investigated by cooperative field studies of the Tennessee Valley Authority and the Georgia Department of Mines, Mining, and Geology. In Florida, beach sands near Pensacola having a commercial concentrate of kyanite (with rutile and zircon) were investigated by the U.S. Bureau of Mines in 1943 and recommended for production.

A. P. Green Fire Brick Company produces kyanite near Clarkesville, Ga. The company makes use of this kyanite in the manufacture of refractory products. Other domestic production has been secured at Clarkesville by Southern Mining and Milling Company and in York County, South Carolina, by B. J. Lochmund.

Mas-Celo Mines, working a large disseminated deposit at Burnsville, N. C., was the pioneer kyanite producer until 1942. Reorganized as Yancey Cyanite Company and financed by the Reconstruction Finance Corporation, the plant resumed production in 1943 at a daily rate of 12 tons of kyanite concentrate, until it again was shut down in January, 1944. In addition to refractory grades, extra-low-iron kyanite concentrate was also produced for use in glass, whiteware, and special ceramic products.

Postwar prospects for domestic kyanite are stated to be promising owing to improved mining and milling methods. The practice of mixing kyanite with topaz has resulted in producing refractories that have a high pyrometric cone rating.

Production increased in 1942 but was inadequate to supply demands. Lower shipments from India were caused by the lack of shipping facilities and by the threatened Japanese invasion of India.

The first commitment for the purchase of kyanite by the Metals Reserve Company for stockpiling was made in 1942. Ranking thirty-eighth among MRC stockpile items, kyanite valued at $224,920 was purchased, the inventory, on Oct. 31, 1944, being $185,949. At the end of 1943, government stockpiles held 5,240 tons, and 5,642 tons were stocked by the industry. Indian kyanite amounting to 3,515 short tons was held in government stocks by the RFC through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration.

The War Production Board announced, on Sept. 30, 1945, that Indian kyanite was added to the materials exempted from all inventory controls. This material, which was moved from Group III to Group II late in 1944 by the conservation division of the WPB, was returned to Group III as readily available for essential uses. This action was part of a second revision of the WPB General Inventory Control Regulation 32.

Conservation Order M-143, concerning Indian kyanite, was withdrawn by the WPB on Nov. 22, 1943, with inventory control being maintained to assure adequate supplies.

IMPORTS AND DOMESTIC PRODUCTION OF KYANITE, IN SHORT TONS
(After U.S. Bureau of Mines)

	1940	1941	1942	1943
Domestic production	4,241	8,335	8,708	9,561
Imports from India	7,658	14,285	6,524	9,972
Stocks	*	*	18,970	10,883

* Figures not available.

World Production, Imports and Exports. Imports from British India, the only important foreign source, in 1940 amounted to 7,658 short tons compared with 3,381 tons in 1939 and 6,211 tons in the first 9 months of 1941.

In the state of Kharsawan, about 100 miles west of Calcutta, kyanite occurs in large, well-rounded boulders. This material is hauled 10 miles by oxcart to the railroad for movement to the seaport. Germany was a major purchaser in prewar years, along with Britain and the United States. Sillimanite and andalusite are associated with the kyanite, with some free corundum and topaz. When calcined, Indian kyanite does not expand so much as the domestic product from Virginia, North Carolina, and Georgia. Indian kyanite, however, does expand much more than sillimanite, andalusite, and dumortierite.

Indian kyanite is imported by Charles F. Taylor & Sons Company, Cincinnati, Ohio; Golwynne Magnesite & Magnesia Corporation, New York City; and B. G. McNabb, Gary, Ind.

Prices. The price on Jan. 1, 1944, was $22 to $32 a ton, f.o.b. North Carolina and Georgia. On Apr. 12, 1945, *E & M J Metal and Mineral Markets* reported the price at $19 per long ton for raw kyanite f.o.b. point of shipping; $37.50 for 35-mesh; $40 for glass grade. The U.S. Bureau of Mines reported that prices in 1944 were set for the Kyanite Products Corporation, ranging from $24 per short ton for raw kyanite, 35-mesh, in carlots, to $42.50 for 325-mesh material, less than carlots, in 100-lb. bags. Calcined kyanite,

35-mesh, in carlots, was $31.50; 325-mesh, less than carlots, f.o.b. Cullen or Pamplin, Va., $47.50 per short ton. The U.S. Bureau of Mines reported that the average price, in 1941, of all domestic sales was $21.07 a short ton, f.o.b. mines.

Shipping rates on kyanite from Calcutta increased from $11.20 to $16.80 a short ton in 1941, when the cost of Indian kyanite delivered at Atlantic ports rose from about $25 to $30 a short ton, compared with the average price in 1940 of $22.10, plus a premium, for grades low in iron. A special calcined, finely ground product low in iron and ground to 325-mesh sold at $78 a ton. The price in 1943, delivered at Atlantic seaports, was $54 per short ton.

Domestic kyanite prices were revised upward, effective on Feb. 17, 1943, by the Office of Price Administration under Order MPR-327. Prices were set for Kyanite Products Corporation, as follows: raw kyanite, 35-mesh, in carlots, $19 per short ton; 325-mesh, less than carlots, in 100-lb. bags, $37.50; calcined kyanite, 35-mesh, in carlots, $26.50; 325-mesh, less than carlots, f.o.b. Cullen or Pamplin, Va., $42.50. Prices for all classes were raised $5 per ton on Nov. 2, 1943. The price was raised to $45 a ton for glass-grade kyanite produced by Yancey Cyanite Company.

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LEAD

(Ore, Bullion, Refined)

Properties. Undoubtedly used in Egypt before 3000 B.C., lead is one of the 16 industrial nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. Lead is an element having a wide range of applications based on its softness, fusibility, malleability, corrosion resistance, weight, and alloy properties. It is important in the preparation of chemical compounds. Its density is 11.34. (Pb, atomic number, 82; atomic weight, 207.21; melting point, 327.5°C.) The volume conductivity of lead is 7.8, and its mass conductivity is 6.1 compared with 100 for copper.

Antimonial lead ("hard lead") is formed by the addition of a small amount of antimony to increase strength and hardness. "Workability" and the capacity to withstand attack by chemicals, particularly sulfuric acid, has given lead its most important application in the manufacture of storage batteries.

The chief lead mineral is galena (lead sulfide), with the carbonate cerrusite and the sulfate anglesite of minor importance. Concentration processes of lead ore include jigs and shaking tables and modern flotation. In the form of base bullion, lead is reduced in the blast furnace, followed by refining by electrolysis or other methods. In order to avoid losses in smelting, fine-grained flotation concentrates are first sintered.

Uses. Not being on the critical list until 1945, lead expanded into fields formerly occupied by such metals as copper and tin. Chief applications were as follows: dry-charging batteries for shipment and reassembling abroad, as a protective coating for steel, in lead rings for sealing waterproof machine-gun wrappers, in cable sheathing, and for "lubricating" projectiles.

For alloys with silver and other metals, lead takes the place of tin in bearings. In producing turpentine, lead coatings are used for cups, gutters, and drums. In plumbing supplies, lead had an essential wartime application. Lead-antimony alloy was more widely applied under war conditions as name plates, covers, and other nonstructural uses; lead foil was much more widely employed in packaging. Recently, lead contributed to the development and production of a wide variety of alloys, improving chemical and physical methods of determining and controlling small amounts of added elements. Wider uses in solders have resulted in conserving tin-lead alloys,

which were more generally employed in the place of tin for coating copper conductors.

The second largest use of lead has been as a sheath in covering copper electric cable as a protection from air and water.

Predominant in the general chemical industry, lead has shared the expansion in that field under war requirements. In 1944, lead was adopted for dyes, the colors ranging from dull red to dark brown. There has been a steady increase in the use of lead in pigments, which have an extremely high covering power and resistance to weathering. Lead paint is one of the most durable surface finishes. White lead has uniform quality and whiteness. Red lead has been developed for use in storage batteries. Tetraethyl lead has been applied in greatly increased amounts in wartime to prepare high-octane gasoline for aviation.

Lead in the form of pigments found greater application in 1944 than ever before, particularly in the form of litharge and red lead. The more important applications are listed by the U.S. Bureau of Mines as follows: white lead (paints and ceramics), red lead (storage batteries, paints, and ceramics), orange mineral (color pigments and ink manufacture), and litharge (storage batteries, insecticides, ceramics, chrome pigments, oil refining, rubber, varnish, and linoleum).

Of its compounds, lead arsenate is a crystalline salt used as an insecticide; red lead is an oxide used as a pigment and, when mixed with linseed oil, as a cement; white lead, a mixture of carbonate and hydroxide of lead, is used as a pigment and in paint manufacture; sugar of lead (acetate), a crystalline salt, is used in medicine.

Normal uses of lead were not disturbed by the war to any important extent. These were under strict government control and include storage batteries, castings, bearing metals, solders, lead wool, cable covering, foil pigments, and oxides for paint, type metal, calking, and lead pipe. There are prospects that many of the new war applications will continue in use in the postwar period.

Postwar prospects appear promising in the normal applications of lead and in tempering gasoline, replacing tin for solders and bearing metals and as a protective coating for iron and steel. There is evidence that prices will not drop to depression levels. Total demand is expected to be strong through the rehabilitation period for storage batteries and paints and in electrical insulation. Annual consumption of more than 500,000 tons of lead is expected by the U.S. Bureau of Mines to continue into the postwar period for some years. Increased dependence on foreign sources is expected.

Lead is classed as a nonexpendable material (except in the chemical

industries, as red lead, white lead, and litharge) and has a much higher secondary recovery than zinc. About 80 per cent of the lead used each year may be recovered as scrap.

Scrap lead, amounting to more than half of the new lead produced each year in the United States, is a substitute for new lead ore. In paint manufacture, substitutes are employed in the form of lithopone, zinc-white, and titanium-white pigments. Low cost was a prewar factor in eliminating the need for securing substitutes. Under war conditions, lead was widely adopted as a substitute for more critical metals. It replaced tin in solders, babbitts, bearing metals, foils, and collapsible tubes; copper, zinc, and iron were replaced in certain plumbing supplies in the construction of industrial plant and equipment.

CONSUMPTION OF REFINED LEAD IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

	1941	1942	1943	1944	1945
Ammunition	32,959	48,025	64,023	31,479	29,315
Bearing metals	10,160	8,466	10,189	15,941	14,104
Brass and bronze	.....	5,294	5,748	7,845	7,069
Cable covering	141,161	128,535	117,802	110,417	86,158
Calking lead	32,380	9,047	8,618	9,411	13,374
Casting metals	9,243	3,106	3,072	4,425	5,322
Collapsible tubes	3,726	9,966	11,425	12,482	7,428
Foil	51,516	9,359	5,816	11,190	2,185
Pipe, traps, and bends	32,946	21,411	18,724	24,387	24,061
Sheet lead	35,480	31,700	27,738	31,546	30,624
Solder	35,630	13,371	15,472	22,390	27,475
Storage batteries	73,982	62,604	68,239	68,769	60,179
Terne plate	2,069	2,336	815	2,190	2,178
Type metals	2,975	943	812	1,269	1,401
White lead	83,230	56,476	36,809	54,333	35,611
Red lead and litharge	143,496	100,563	124,715	157,080	157,171
Tetraethyl lead	48,327	50,152	65,320	83,067	75,890
Chemicals and insecticides	8,861	6,298	8,172	10,703	8,567
Annealing	.....	5,229	5,987	5,719	5,525
Galvanizing	.....	484	819	1,073	988
Lead plating	.....	.....	941	494	1,130
Weights and ballast	.....	.....	9,269	22,964	9,539
Other	64,506	33,746	64,940	33,646	32,205
Total	812,647	607,111	675,465	722,820	637,499

Working stocks of white lead and pigments were reported on July 22, 1946, to have declined to a more acute level than at any time during the war. Shortage of lead seriously hampered the production of white lead, both the carbonate and sulfate. Additions of titanium contributed to the spreading of

lead supplies to a moderate extent. Inadequate supplies of white lead and lead pigments are expected to persist through 1950. When normal lead supplies are available, the annual consumption of white lead is estimated at 75,000 to 100,000 tons.

The Lead Industries Association estimated the uses of lead according to properties as follows: weight, 10 per cent; softness, malleability, and corrosion resistance, 30 per cent; alloying properties, 24 per cent; special properties of chemical compounds, 33 per cent.

Domestic Sources of Supply and Production. Under war conditions, the United States assumed the position of world metallurgical center as the only market available to many foreign producers. Lead production dropped 36 per cent in the period 1929–1939, according to the American Bureau of Metal Statistics. Domestic output in 1940 was 470,517 tons; in 1942, 467,367; in 1943, 453,313 valued at $67,996,950; in 1944 the value was $66,679,760; in 1945, $66,726,024, as reported by the U.S. Bureau of Mines. Lead production of 538,618 tons, in 1944, was reported by American Bureau of Metal Statistics, representing primary smelters and refiners; in 1945, 524, 328.

UNITED STATES PRODUCTION OF REFINED LEAD, IN SHORT TONS
(After U.S. Bureau of Mines)

Source	1939	1940	1941	1942	1943	1944
Refined lead:						
From domestic ores	420,967	433,065	470,517	467,367	406,544	394,443
From foreign ores	.....	.....	.....	.....	132	95
From foreign base bullion	63,068	100,114	100,450	99,472	62,936	70.225
Total from primary sources	484,035	533,179	570,967	566,839	469,612	464,763
Total from scrap	29,011	16,588	13,454	12,856	1,863	11,368
Total refined lead	513,046	549,767	584,421	579,695	471,475	476,131
Value, primary refined	$45,499,000	$53,318,000	$65,090,000	$71,422,000	$60,110,000	$59,490,000

CONSUMPTION OF LEAD IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

1939	1940	1941	1942	1943	1944	1945
415,031	633,989	812,647	607,111	675,465	722,820	637,499

Requirements increased from 1,085,000 tons in 1943 to 1,115,000 in 1944. The War Production Board estimated requirements in 1945 of primary and secondary lead at 1,150,000 tons compared with anticipated output of

970,000 tons. Lead requirements for 1946 were estimated by the Civilian Production Administration at 1,150,000 tons; lead supplies from domestic mine output and scrap piles in 1946 were expected to be 450,000 tons less than demand, with a maximum of 30,000 tons expected to be available from scrap. The 1946 deficit was estimated on Oct. 21, at 200,000 tons.

The output of refined lead at primary smelters and refineries in the United States, including soft lead from domestic and foreign ores plus antimonial lead and secondary metal at primary refineries, amounted to 471,475 in 1943; in 1942, 579,695 as reported by the U.S. Bureau of Mines. Output in 1945, from domestic mines (including Alaska), was estimated at 387,942 short tons, 7 per cent lower than domestic production of 416,861 tons in 1944. Production of 382,000 tons of refined lead from domestic ores was estimated for 1945, 3 per cent lower than 1944 and the smallest output since 1938.

Largest domestic lead-producing area continued to be the southeast Missouri district, which supplied 45 per cent of the United States total in 1945; 40 per cent in 1944. St. Joseph Lead Company was the major operator. The Tri-State region accounted for 6 per cent of total domestic lead in 1945; 7 per cent in 1944; 8 per cent in 1943. The largest producer in this district was Eagle-Picher Mining & Smelting Company. Western states (including Alaska) accounted for 50 per cent of the 1944 output; 46 per cent in 1945. Idaho, with Bunker Hill & Sullivan the major operator, followed Missouri as second largest producing state. In the East, New York and Virginia produced 5,230 tons in 1945; 6,340 tons in 1944; in 1943, 4,643 and an additional 200 tons from Tennessee.

Small-arms production, in 1943, consumed 178,000 tons, which was reduced to an estimated 140,000 tons in 1944. Allotments of Mexican and stockpile lead averaged more than 30,000 tons a month, August to December, 1944. Reduced stockpile supplies were accounted for as follows:

1. Less recoverable lead was produced by domestic mines.
2. Expiration of contracts with Australia and Canada resulted in shipment from those sources to England.
3. Since 1941, lead consumption exceeded current supplies as a result of substitution for such critical metals as copper and zinc.

The WPB designated lead on Mar. 1, 1944, as a metal sufficient for war purposes plus essential industrial demands, but supplies were insufficient in January, 1945, for greatly expanded war demand in addition to requirements of industry. The dangerously reduced stock position was due partly to labor shortage, which became increasingly acute after July, 1944. Domestic industry, including manufactures for export, is expected to absorb 800,000

tons of lead each year in the postwar period, as reported in November, 1944, by Philip D. Wilson, vice-chairman for metals and mining, WPB.

General Preference Order M-38 was sweepingly revised by the WPB at the end of 1944 for the purpose of further restricting consumption in an effort to ease the critical supply situation.

Order M-72 was revoked by the WPB, on Aug. 20, 1945, removing all restrictions on lead scrap. Controls expired on the production and distribution of all metals except lead, antimony, and tin, on Sept. 30, 1945, when the curb on semifabricated and fabricated lead was the final import control on metals to be removed by WPB. After that date, priorities were to be restricted to military needs and emergency requirements in order to meet special civilian conversion needs. Revoking WPB's Controlled Materials Plan left only the following controls in effect: the emergency AAA rating, MM rating for military needs, CC rating for emergency civilian requirements. Order M-38 was being maintained by the CPA at the end of 1945 as a distribution control and was to continue until lead supplies improved.

Direction 5 to Priorities Regulation 32 was issued in October, 1945, prohibiting dealers from receiving lead- or tin-base scrap unless they had disposed of an amount at least equal to their current inventory during the preceding 60 days, in order to prevent the accumulation of excessive stocks.

Effective Feb. 1, 1946, the CPA ruled that the premium-price quota plan would be relaxed in order to make lead producers who started mining operations after Oct. 27, 1943, eligible for the same premium payments as old producers.

Erwin Vogelsang, director of the tin-lead-zinc division, WPB, reported in May, 1945, that lead supplies, including imports, would fall short by 25,910 tons of minimum requirements for the second quarter of 1945, in spite of greatly curtailed quotas allowed for various uses of the metal.

Foreign lead was being drawn heavily from stockpiles to supplement domestic output, which was critically short on Dec. 1, 1944, and stockpiles were reduced below a safe level, as reported by the Lead Producers' Industry Advisory Committee, WPB. The lead stockpile, on Sept. 1, 1945, had increased from a low of 65,000 to 94,000 tons. Additional tonnages were expected to be released for production of pigments.

On Dec. 27, 1944, the WPB ordered a 40 per cent cut for civilian uses in paint, storage batteries, and other important items. Increasing shortages forced greater restrictions in March, 1945, for the use of lead in paints, varnishes, and lacquers. In August, 1945, more metal was being allowed by the WPB for red lead and white lead and for various chemical applications. Allocations for the month were about 21,000 tons; in September, 20,000.

Lead, antimony, tin, and uranium were the only strategic metals retained under government control for use and distribution after August, 1945.

The Combined Raw Materials Board announced, in September, 1945, that certain European countries would be permitted to purchase about 30,000 tons of lead from Latin America for delivery before the end of 1945, owing to the extreme shortage of lead in Europe. Sales to European countries by British Empire and Western Hemisphere producers were restricted to definite tonnage allocations. Australia, Canada, Mexico, and Peru were to sell lead to France, Belgium, Norway, and Holland. Less metal was available until 1946 from Mexico and Peru, owing to sales from those two countries to the Foreign Economic Administration for the account of the Metals Reserve Company.

Total deliveries of foreign and domestic lead, in February, 1945, were estimated at 80,000 tons against 90,000 tons required. Domestic production in the first quarter of 1945 was 123,239 compared with 136,557 tons in the same quarter of 1944, and consumption in the first quarter of 1946 was estimated at 277,000 tons. Total output from domestic ores in 1945 was 388,969 short tons, a monthly average of 32,414 compared with 34,738 in 1944. Output from all sources in the first 7 months of 1945 totaled 315,029 tons compared with 329,677 tons in the same period of 1944. These figures do not include foreign lead, which was allotted for July delivery by the WPB tin-lead-zinc division. At the end of July, stocks carried by the MRC were believed to amount to 88,000 tons. Stocks of lead in producers' hands at the end of July gained 3,693 tons over June, to 41,145 tons. Producers' stocks of refined lead were 36,464 short tons at the end of 1943; 16,788 at the end of 1944. Lead available in 1943 was 1,063,922 tons, compared with estimated requirements of 1,126,001. Surplus supplies from the stockpile amounted to 62,079 tons in 1943; in 1942, 241,572 tons.

On VE-Day (May 8, 1945) lead was a material in short supply and the WPB continued L and M orders in effect. Inventory controls at all levels of production and distribution were expected to last longer than most WPB orders, as a move to avoid inflationary pressure.

In June, 1945, lead was included by the WPB with a list of materials and products that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and it was anticipated that further changes in controls would be announced. On Aug. 30, 1945, the WPB cautioned prewar users of lead that the metal remained scarce in spite of the war's ending; sufficient supplies for all users were not in prospect for some time. The government stockpile was frozen Apr. 12, 1946.

The WPB announced the removal of import control of lead manufactur-

ers on Oct. 4, 1945. The products affected were collapsible tubes, tube disks, slugs or other semifabricated forms, lead foil, and lead acid-type storage batteries. On Oct. 10, the WPB, by amendment to Order M-384, eliminated end-use restrictions on lead in the production of chemicals. An over-all quota was established for the production of these chemicals.

The CPA reported on Mar. 28, 1946, that approval to a proposed new regulation to limit further use of both lead and lead chemicals had been given by the advisory committee of the lead pigment industry. On April 24, 1946, the CPA established a more favorable base period for quotas of lead-chrome pigments used in printing inks, paints, and ceramics. Amendment of L-354 shifted the period to the first 3 months of 1946. Producers were limited to 77 per cent of their consumption of lead during the first quarter of 1946. Unless authorized by CPA, disposal of surplus lead was barred Mar. 21, 1946.

Foreign and secondary lead amounted to 62,624 tons in 1944; in 1943, 54,322. Labor shortage was given as the reason for small 1944 output by scrap collectors and secondary smelters. F. E. Wormser, Lead Industries Association, stated in January, 1945 that although 500,000 tons of scrap lead were scattered over the United States, they were not available for converting into metal because of the man-power shortage. Stocks of lead-base scrap and residues amounted to 69,463 short tons at the end of July, 1945; at the end of April, 72,711; at the end of October, 79,099. This includes the following materials: battery-lead plates, solder and tinny lead, common babbit, soft and hard lead scrap, cable lead, type metals, drosses and residues. Total output of the secondary lead industry was 44,385 short tons in October, 1945. Consumption of refined soft lead gained 11 per cent in 1943 compared with a 9 per cent decrease in primary refineries. Government stockpiles were reported by *The Wall Street Journal* on July 17, 1944, to be holding 34 tons of lead bullion, 174,101 net tons of refined lead, 5,983 tons of lead ore. The government stockpile dropped from the peak of 273,000 tons, early in 1943, to 65,000 tons at the end of March, 1945; in November, 1944, 115,000.

Lead was one of the commodities first purchased by the MRC, in 1941. Ranking fifth in cost of deliveries to the MRC stockpile, lead was purchased to the extent of $119,628,573 (excluding payments under the premium price plan). Inventory value was reduced to $26,363,977 on Oct. 31, 1944. Primary refined lead amounting to 82,335 short tons on Sept. 30 and 86,242 short tons on Oct. 31, 1945, were reported in the government stockpile by the Office of Metals Reserve. Lead was in such short supply that distribution controls were continued after Nov. 30, 1945, by the CPA, which was ready to turn over lead to private industry in order to help meet requirements for reconversion as soon as supplies were demonstrated to be ample. The MRC

foreign pig stockpile at the end of 1945 was estimated at 72,000 tons, with 24,500 tons allocated for January, 1946.

At the close of 1944, the lead industry had met all demands for essential uses; stocks on hand, Dec. 31, 1944, were 19,536 tons compared with 37,690 tons on Jan. 31, 1944 (not including stocks owned and held by the MRC), the lowest to be reported in several years.

In May, 1945, the need for increased lead production was stressed by J. A. Krug, WPB chairman, and Paul V. McNutt, War Man-power Commission chairman. It was stated that VE-Day did not reduce war demands and essential civilian requirements for lead. Several thousand more miners were required to increase the scale of lead-mining operations.

Distribution controls on lead continued through December, 1945. Consumption was reported to be little changed at about 65,000 tons a month of primary metal, made up of about 40,000 tons from domestic production and the balance from foreign pig stockpiles of the OMR. Consumption of primary and secondary lead in 1946 was estimated at 1,060,000 tons, requiring 245,000 tons to be imported at the 1944 level.

Submarginal domestic sources of lead, a deficient mineral, are available in terms of prewar consumption under emergency conditions and at a high price, adequate for less than five years. For the postwar period, greater dependence on foreign sources has been indicated. Elmer W. Pehrson, U.S. Bureau of Mines, reported estimated reserves of 5 million tons in 1944; this was available at a 6-cent price under prewar operating conditions. Only one-third of this volume was measured and indicated. Total reserves under emergency conditions expanded to 6,600,000 tons, including the 6-cent metal, adequate for an estimated 12-year supply. As compared with the all-time peak of 1925, maximum war output in 1942 was 27 per cent lower, the reduction applying to all important lead-producing districts.

> We have less than a 35-year peacetime commercial supply of lead and twenty other minerals . . . which we shall have to import in larger and larger quantities. . . . We cannot afford another prolonged war in 20 or 30 years. The prodigal harvest that we have reaped to win this war has bankrupted some of our most vital mineral resources. We no longer deserve to be listed with the British Empire and Russia as one of the "have" nations. We should be listed with the "have nots," such as Germany and Japan. Even more alarming than the fact that we are coming to the end of some of our known resources is the fact that we are uncovering few, if any, unknown deposits of minerals.

This is according to the report by Harold L. Ickes, Secretary of the Interior, in December, 1945. Lead amounting to 2,278,000 tons was mined between Jan. 1, 1940, and Jan. 1, 1945.

Domestic lead production has been sharply lower than in the First World War, owing mainly to depleted ore reserves. Less than 20 per cent of the original domestic reserves remain in the ground. Domestic reserves of lead ore were increased in the 1930's by adapting differential flotation to the recovery of complex refractory minerals of the Rocky Mountain region and of the Illinois fluorite ores.

Sales of lead pigments in 1944 were substantially higher than in 1943. Litharge and red lead established new records as a result of greater demand for the manufacture of storage batteries. Lead pigments sold by domestic manufacturers are reported in short tons by the U.S. Bureau of Mines as follows: basic lead sulfate (sublimed lead), white, 5,253 in 1944 (4,752 in 1943); blue, 1,080 (845); red lead, 53,972 (53,378); orange mineral, 284 (79); litharge, 138,203 (113,091); white lead, dry, 46,466 (49,525); in oil, 39,-260 (36,642).

In the postwar period, the United States will be dependent on foreign lead, which has expanded in volume adequate to supply our own needs as well as those of Europe. For imported foreign lead, domestic pricing based on St. Louis will not apply, and domestic lead-treatment plants are not favorably located. The removal of premium prices will cause a radical drop in production from domestic sources and increased dependence of the United States on the lead output of Canada, Mexico, Peru, and Bolivia. War requirements led to expanded production, but the failure for many years to discover new ore deposits has led to declining supplies, both in the United States and in Mexico.

Industrial requirements of lead in 1946 were estimated at 1,300,000 tons, against an available supply of 835,000 tons. On Apr. 20, 1946, Washington announced a joint drive of industry and Federal agencies to increase lead output by more than 50 per cent. John W. Snyder, Director of War Mobilization and Reconversion, announced four emergency measures designed to increase both domestic and world supplies of lead by (1) intensified efforts to salvage scrap lead, (2) conservation and allocation to eliminate nonessential use of lead, (3) settlement of strikes, and (4) exploration of new sources of supply in both domestic and foreign areas.

The domestic lead shortage was caused by curtailed imports, inadequate recovery of scrap, and labor-management disputes leading to shutdowns of mines and smelters. In Japan, 15,000 tons of available lead had been uncovered, and all possible foreign sources of supply were to be investigated by the Reconstruction Finance Corporation and the Departments of State, War, and Navy. New domestic sources must be discovered in order to avoid more critical shortages of lead. A shortage of about 450,000 tons in 1946

was estimated on May 1, 1946, by Clinton H. Crane, president of St. Joseph Lead Company. The shortage continued acute at the end of October, 1946.

World Production, Imports and Exports. The United States holds first place in both mine production and smelter output of lead. Domestic consumption, however, is closely in balance with production; so exports are unimportant. Lead supplies are adequate to meet domestic demands without appreciable excess or deficiency. Exports, in 1938, amounted to 12 per cent of domestic output. Mexico and Peru have been the principal foreign sources of lead for the United States. Buying contracts with both these countries expired Dec. 31, 1945, and were not renewed, pending agreement on price increases.

Only the British Empire and Spain and colonies have lead available for export. Of other world powers, Germany, Italy, and U.S.S.R. have lead supplies inadequate for domestic requirements, or so located or of such grade (and cost) as to require draft on foreign sources. All other world powers (France, Belgium, the Netherlands and colonies, China, and Japan) depend almost entirely on foreign sources for lead supplies.

Europe is deficient in lead, in addition to many other metals and minerals. Consumption of this metal in the prewar years depended on imports to the extent of 50 per cent. Of the lead mined in all countries in 1938, 48 per cent of the exported metal was in smelted form. The largest exporter of ore was Yugoslavia, followed by Peru, Newfoundland, Australia, and Morocco. All of these, except Australia, are deficient in smelter capacity. The lead-export trade is controlled (80 per cent in 1938) by Mexico, Australia, Canada, and Burma, where domestic uses are limited.

Production figures for sources outside the Western Hemisphere were limited by censorship during the war years. There was an 11 per cent increase in output in Britain in 1940, against an estimated 11 per cent decline for continental Europe and Mexico. On Dec. 28, 1945, the Board of Trade reported that Britain's position, as far as raw materials were concerned, did not give rise to anxiety. Economy in the import of materials was required, particularly where these were of little aid to the export position. Lead was still restricted, consumption having increased in 1945 over 1944. The short position also applied to tin, but other metals were in adequate supply. Consumption of lead amounted to 162,056 tons and 50,859 tons of lead scrap in the first 9 months of 1945, compared with 205,385 tons of lead consumed in all 1944, as reported by the Directorate of Nonferrous Metals. Canada and Australia are the principal lead producers of the British Empire.

United States foreign trade in lead, 1943–1944, is shown in the following table. Imports continued at a high rate in 1944, although it was considerably

lower than in 1942, as reported by the U.S. Bureau of Mines. Of pig lead imported, Mexico supplied 75 per cent and Peru 25 per cent. Lead in ore and matte declined from Africa and Bolivia but increased substantially from Australia, Newfoundland, and Peru. Exports of pig lead amounted to 15,523 tons in 1944, 92 per cent going to U.S.S.R. Of the world supply of lead ore, about 80 per cent was controlled by or available to the United States at the end of 1942. World output declined in 1943.

Imported lead in the first 7 months of 1945 amounted to 129,861 tons of refined pig, 5,869 tons of which came from Canada, and 36,918 tons of metal in ore and matte (5,594 tons from Canada). Imported metal, in November, was 15,500 tons; in December, an estimated 22,500 tons.

IMPORTS AND EXPORTS OF LEAD, IN SHORT TONS
(After U.S. Bureau of Mines)

	1943	1944	1945
Imports:			
In ore and matte	153,176	195,939	64,000
In base bullion	9,094	320	8
Pigs and bars	488,066	446,137	230,000
In reclaimed scrap, etc	477	3,313	
Sheets, pipe, and shot	25	40	
In babbitt, solder, white metal, etc	69	18	
In type metal and antimonial lead	3,422	7,174	
Exports:			
Pigs and bars	2,003	15,523	
Foreign pig lead reexported	11,258	*	

* Less than 1 ton.

WORLD SMELTER AND REFINERY PRODUCTION OF LEAD, IN SHORT TONS
(After American Bureau of Metal Statistics)

	1939	1940	1941	1942	1943
United States	420,427*	429,020	482,988	496,642	446,582
Canada	195,569	220,088	228,027	243,839	224,493
Mexico	237,673	219,089	174,704	212,028	206,512
North America	853,669	868,197	885,719	952,509	877,587
South America	54,000	47,677	56,925	66,236	73,008
Europe	574,056	30,000†	30,261†	38,400†	41,600
Asia	113,269				
Australia	277,500				
Africa	25,817				
Total	1,899,311				

* Including foreign ores, 484,000 tons.
† Spain only (in 1945, 29, 909).

C. K. Leith compares lead resources of the Axis powers with those of the United Nations (see *World Minerals and World Peace*). Areas are grouped according to affiliations and controls at the end of 1942 (in thousands of metric tons per year, as of 1938–1940).

Capacity	Axis powers	Axis controlled	Total Axis	United Nations	Others*	World total
Lead refining	236	554	790	2,160	269	3,219

* Turkey, Spain, and Portugal.

Exports of lead in pigs and base bullion, in 1938, had lead content of about 855,000 tons. As tabulated by C. K. Leith, refined lead exports from 11 countries are shown for all shipments exceeding 2,000 tons, as follows (in thousands of metric tons):

1. *Mexico*	
To: United States	75.5
Germany and Austria	47.6
Britain	36.6
Belgium	21.9
Sweden	18.6
Netherlands	11.8
Denmark	11.0
Czechoslovakia	8.9
France	8.1
Finland	5.0
Switzerland	3.7
Total	254.3
2. *Australia*	
To: United Kingdom	179.3
Japan	3.5
Germany	3.4
Total	207.8
3. *Canada*	
To: United Kingdom	101.1
Japan	15.1
Brazil	3.2
Total	134.9
4. *Burma*	
To: United Kingdom	55.9
Japan	13.8
British India	6.5
Total	81.9
5. *Belgium*	
To: Netherlands	19.7
France	17.2
Germany	8.2
Switzerland	3.2
U.S.S.R.	3.1
Brazil	2.8
Total	64.8

6. *United States*	
To: Japan	26.3
Netherlands	3.3
Total	39.9
7. *Peru*	
To: Germany	8.2
Sweden	3.9
Total	28.7
8. *Tunisia*	
To: France	15.4
Total	19.7
9. *United Kingdom*	
To: Germany	5.5
Total	6.4
10. *Yugoslavia*	
To: Hungary	4.3
Total	5.6
11. *Germany*	
To: Italy	3.0
Total	3.0

Imports in 1940 of lead in ore, matte, pigs, and bars increased 592 per cent to 151,568 short tons. The 1940 world output was estimated at 1,700,000 metric tons compared with 1,723,000 tons in 1939, with substantial increases recorded by the following countries: United States, 404,257 metric tons; Canada, 172,880; Germany, 181,400; Spain, 27,000; India, 77,220; Australia (1939), 269,590; in 1945, 174,552.

Imports of pig lead in 1943 amounted to 243,000 short tons, plus a lead content of 70,328 tons in ore, concentrate, matte, bullion, etc. Pig-lead imports in 1944 increased to an estimated 275,000. Practically all imported lead is delivered at ceiling prices or less. British demand for the metal was reduced, and purchase contracts for lead from Canada expired in September, 1945.

In Canada, lead holds a stronger position than other base metals as a result of the inflated European demand and exhaustion of ore reserves in other countries. George C. Bateman, deputy for Canada on the Combined Production Resources Board at Washington, stated in April, 1945, that lead may become a semiprecious metal. Canada, holding fourth place among lead-producing countries, in 1942 expanded to the record figure of 256,071 short tons of refined metal. Output in other war years was as follows: in 1939, 194,285 short tons; in 1940, 235,925; in 1941, 230,084; in 1943, 222,177 valued at $16,681,078; in 1944, 152,291 tons valued at $13,548,327. In 1945, production of lead in all forms was estimated at 174,585 tons by the Dominion Bureau of Statistics. Over-all production of lead in Canada, Sept. 1, 1939, to Sept. 1, 1945, amounted to 1,270,100 short tons valued at $92,839,000.

Consumption of new lead in Canada in the first half of 1945 amounted to 106,782 long tons; 34,976 long tons of scrap were used in the same period. Exports of pig lead to the United States amounted to 162,500 tons in 1940–1944; to Britain in 1939–1944, 672,500; to other countries 79,000. Imports are largely compounds of lead tetraethyl, which was valued at $3,063,295 in 1942; in 1943, $3,568,496.

The only electrolytic lead refinery in Canada is located at Trail, British Columbia. Ore is shipped 185 miles to Trail from the Sullivan mine of Consolidated Mining and Smelting Company and from mines in the Kootenay district of British Columbia. Lead concentrate from other sources must be exported, the tonnage representing only a small part of Canada's output.

Lead valued at $162,000,000 was included in the total of $1,952,000,000 spent abroad for metals and minerals by the Department of Commerce in foreign financial and supply transactions, from July 1, 1940, through June 30, 1945. Inventories held abroad included a total of $87,000,000 in metals and minerals, of which $2,000,000 represented lead held by the MRC in Canada.

Mexico, largest lead producer in Latin America, reported an average yearly output, 1941–1943, of 200,000 tons. In 1938, Mexico followed the United States with second largest smelter output (16.1 per cent) and second largest production of lead ore (15.9 per cent). Lead ore and concentrate are shipped from mines in the states of Chihuahua and Nuevo Leon to smelters at Monterrey, Chihuahua, San Luis Potosi, and Torreon. Complex sulfide ore containing lead-zinc and some copper is worked in more than 100 small mines, which market 5 to 150 tons of ore and concentrate monthly with large American companies. Before the McKinley tariff was imposed, with its duty on the lead content of high-grade silver-lead ores, the Guggenheims built their first smelter below the Rio Grande. Such ores had previously been imported for smelting in Colorado. Production in 1945 was 224,925 tons.

Lead mining in Mexico, in the war years, was stimulated by contracts with MRC. On Jan. 1, 1945, the MRC negotiated new Mexican contracts at a price increased to the New York ceiling. The entire output in Mexico was expected to be purchased for United States consumption. Prewar exports of lead averaged about $22,000,000 a year. Of total output in 1941 of 170,783 metric tons, all but 1 per cent was exported, chiefly in refined form.

In Bolivia, annual lead production averages about 15,000 tons from the Huanchaca mine of Hochschild Company. Output in 1942 (12,360 tons) was lower than in 1941. Peru is an important producer of pig lead from mines of Cerro de Pasco Copper Corporation, where large ore reserves are reported. Other known deposits of lead-zinc ore have not yet been developed.

In Argentina, the only large lead producer is the Aguilar mine of St. Joseph Lead Company, with ore reserves reported to be adequate for several years. About half the lead output is treated at the Resistencia smelter of National Lead Company, where the annual output of pig lead for use in Argentina amounts to about 12,000 tons. The balance of lead concentrate is exported to the United States. Production in 1945 was 23,324 tons.

With capital available from raw-materials exports and from loans through the Export-Import Bank for making machinery and equipment purchases in the United States, certain Latin-American countries are attempting to utilize raw-material products locally by erecting processing plants for lead ores.

In Mexico, Peru, and Bolivia, lead was one of 17 minerals included in agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus as part of the foreign procurement program initiated late in 1940. U.S. Commercial Company, in May, 1945, negotiated purchases of 10,000 tons of lead from Canada and 10,000 tons from Australia in an effort to supplement supplies received from Mexico and Peru. American capital controls domestic lead production as well as a large part of Mexican and South American output.

Government foreign procurement, combined with private purchases, in February, 1945, was at the annual rate of about 300,000 tons of refined lead and lead concentrate. Imports of refined lead in 1943 amounted to 244,512 tons compared with 369,254 tons in 1942.

In Alaska, total mineral production to the end of 1944 has included gold (70 per cent), copper (25 per cent), and eight other minerals including lead (5 per cent). A vast postwar expansion in the output of lead can be secured through systematic development, as reported on May 7, 1945, by the U.S. Geological Survey.

In the Philippine Islands, lead ore and metal exported in 1939 amounted to 36 tons; in 1940, 143. The islands came under Japanese occupation early in 1942. Mine output in 1941 has not been reported.

In Australia, the Mount Isa deposits of lead-zinc ore, in production since the late 1930's, have been described as a dependable world source. Lead production is controlled by British capital in Australia, Burma, and Rhodesia.

Lead-zinc ore of the Buchans mine, Newfoundland, has developed into an important source of supply for the United States, production being controlled jointly by Canadian and American capital.

In Japan and Germany, as well as in U.S.S.R. and Italy, prewar commercial control of lead production was held by the government. Japan increased smelter capacity, 1939–1940, in preparation for larger imports of ore from Asia and the cutting off of foreign pig-lead shipments. Before the attack on

Pearl Harbor, large lead supplies had been stockpiled in Japan without the knowledge of the United Nations. Germany, entering on a war economy long before any of the United Nations, set up a board of control in 1937 to regulate the sale of lead and other metals. Domestic production was increased. Lead stocks and important ore supplies were secured with the conquest of Yugoslavia and Belgium.

Latest figures for Poland show lead output at the annual rate of 10,000 to 15,000 metric tons; German Silesia, 4,000 to 5,000. Lead refineries in Silesia treated high-grade ores produced locally and in various parts of Central Europe. In the prewar period, Silesia accounted for 40 per cent of Germany's lead; lead concentrate was imported from Australia and other foreign fields for refining in Silesia, shipments being made through the port of Gdynia and over the system of connecting waterways.

The Trepca lead-zinc mines of Yugoslavia, the largest in Europe, have been an important source of concentrate for the Axis countries under war conditions. England owned control in 1939. Yugoslavia nationalized these mines in October, 1944. The shares had not been confiscated by the German economic dictator, as was the case with shares of the Bor mines. Settlement late in 1945 was expected of the Bor ownership, which was regarded as a test case concerning ownership of other lead-zinc properties and concessions in the Danubian and Balkan states and Bulgaria, Poland, and Hungary. British capital formerly participated in the lead production of Spain.

The CRMB, in August, 1945, gave permission to certain countries (assumed to be Belgium, France, Holland, and Norway) to purchase 30,000 tons of lead from Canada, Mexico, Australia, and Peru, the last supplying 14,000 tons of the total.

Prices. The ceiling price of common lead at New York, Jan. 20, 1942, through Feb. 1, 1946, as reported by *E & M J Metal and Mineral Markets*, was 6.5 cents a pound; at St. Louis, in the same period, 6.35 cents. The New York price averaged 6.481 cents in 1942; in 1941, 5.793 cents; in 1940, 5.179 cents. The St. Louis price, in 1942, averaged 6.331 cents a pound; in 1941, 5.643 cents; in 1940, 5.029 cents.

The metal-content basis on 80 per cent lead ore at Joplin, Mo., was $76.54 a ton in 1944, later contracting to $76.01. The price advanced to $99.96 on June 3, 1946. Lead sheets, full rolled, were 9.5 cents a pound; clipped, 9.75 cents.

A weighted yearly price averaging 8.6 cents per pound in 1945 and 8 cents in 1944 for lead, including bonus payments on over-quota domestic production by the MRC, was the basis of calculations published by the U.S. Bureau of Mines. In 1943, under B-quota premiums, a total of 11.75 cents a pound

was paid on all lead in excess of the B base. The average cost of domestic lead was 8 cents a pound, as reported in November, 1944, by Philip D. Wilson. The weighted average prices for all grades in 1942, including MRC bonus payments to marginal producers, was 6.7 cents.

The tariff was cut in half on Jan. 20, 1943, on two important classes of lead imported from Mexico. In January, 1945, the price paid by the FEA for Mexican lead increased from 5.45 to 5.85 cents a pound. This tariff reduction was extended to Canada, Peru, Australia, and Argentina, under the "most favored nation" policy, reducing the tariff to ¾ cent a pound for lead in ore and to 1 1/16 cents for pig lead.

The Lead Industries Association estimated that domestic output of less than 200,000 tons a year would have been possible at the ceiling price of 6.5 cents a pound, the average in 1944 (including premium payments) being 8.25 cents. Domestic producers received a price averaging 2 cents a pound higher than producers in Mexico and more than 3 cents higher than Canada and Australia, indicating the higher United States cost of production. The price to Mexican and Peruvian producers averaged about 6.5 cents a pound delivered at New York, in the war period.

Price stability of lead has been a notable achievement since 1941, in contrast to an increase of about 100 per cent in the First World War.

The premium-quota plan effective on Feb. 1, 1942, provided for payment by the MRC of a premium on all domestic production of lead in excess of monthly quotas established by the WPB and the Office of Price Administration and approved by the MRC. This premium reflected the difference between the ceiling and the equivalent of 9 cents a pound for lead at New York, subject to prior termination of the national emergency before July 31, 1944. The basic A premium has been held at 2¾ cents a pound. Congress extended the effective period of the plan to July 31, 1945, and again to June 30, 1946, under the Hayden-McFarland bill, S-502.

The premium-price plan was broadened in February, 1943, to cope with changing conditions in the lead industry. The B premium was added, subject to the joint recommendations of the WPB and the OPA, in order to raise the maximum premium to 5½ cents a pound. The premium was payable, over the basic A premium, on quotas made available only in those special cases where the basic A premium would not provide revenue adequate to secure the necessary maximum production. Premium rates were as follows: On production in excess of basic A quota, 2¼ cents; on production in excess of B quota, 2¾ cents; on production in excess of special quota, as specified. The Stabilization Administration announced on Feb. 11, 1946, that a price ceiling on lead would be maintained.

Duties on lead, according to the tariff act of 1930 and the revenue bill effective on June 21, 1932, revised to Feb. 1, 1943, as affected by reciprocal trade agreements, were as follows: ore, on lead contained, ¾ cents a pound; in bullion or base bullion, pigs, bars, etc., 1⅛ cents; sheet, pipe, shot and wire, 2⅜ cents; lead pigments, 20 per cent; white lead, 2.1 cents; litharge, 2¼ cents; red lead, 2¼ cents; orange mineral, 2½ cents.

The London price for lead was quoted in August, 1945, at £30 per ton compared with £25, which had been the official maximum spot-delivery price in 1939–1944. The British Ministry of Supply increased the official price of lead, delivered to British users, to the equivalent of 7 cents a pound U.S., as announced in January, 1946. On Apr. 8, 1946, the price ceiling on lead was advanced from £39 to £45 ($180 U.S.) per ton. The British had been buying lead at prices in excess of the United States ceiling of 6.5 cents a pound. British action in raising the consumer price of lead was in contrast to the announcement on Mar. 30, 1946, by Economic Stabilizer Chester Bowles, that increased subsidies would be made to lead producers to offset increasing labor and other costs.

The export price of lead pipe was advanced on Feb. 1, 1946, £14 per long ton to £55 10*s*; sheet lead, £55, f.o.b. United Kingdom port. Before the price advance, the British rate for lead pipe had been $6 below the United States market; the increase amounted to $45 per ton above the United States price, or 9.97 cents a pound. Lead sheet prices, formerly $41 under the United States level, advanced to $9.40 above, equal to 9.88 cents a pound.

On May 29, 1946, the OPA authorized a 20 per cent industry-wide increase for producers of lead, scrap, and secondary products in a broad pricing adjustment designed to offset rising costs of materials and labor. The new prices went into effect on June 3.

The OPA stated that in addition to these price increases, adjustment soon would be announced to provide "compensating" increases for metallic lead products, also effective June 3. Subsidy payments under the premium-price plan were continued, the increased base prices allowing a reduction in subsidy payments on lead and copper of about $7,500,000 a year.

Lead: the price increased from 6.5 to 8.25 cents, at New York; 8.10 cents at St. Louis.

Secondary lead: the same increase, 1.75 cents a pound.

Primary and secondary antimonial lead: increased 1.75 cents a pound.

Lead scrap and battery lead scrap: increased 1.55 cents a pound.

Lead oxide: allocation control was reestablished July 1, 1946.

The OPA on Aug. 24, 1946, permitted adjustment in dealer premiums for resellers of both primary and secondary lead to restore their average per-

centage markups in effect on Mar. 31. Similar permission to raise their maximum prices was given to resellers of lead products.

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LITHIUM MINERALS

(Amblygonite, Lepidolite, Spodumene)

Properties. The lightest of all metals, lithium occurs in spodumene (aluminum-lithium silicate), the chief source of lithium salts, with an average content of 4 to 7 per cent of Li_2O. The element deteriorates rapidly in air; so it cannot be used for structural purposes. Important applications have been developed in alloys containing minor amounts of lithium, its use in copper, bronze, and steel castings reducing the amount of scrap and rejected material. (Li, atomic number, 3; atomic weight, 6.94; melting point, 186°C.) Its boiling point is 1400°C.; its relative hardness, 0.6; its specific gravity at 20° is 0.543.

Amblygonite contains an average of 9 per cent of Li_2O. Lepidolite (lithium-mica) contains an average of 4 per cent of Li_2O. Other minerals, containing 3 to 9 per cent of Li_2O, that are occasionally mined as sources of the element, are triphylite, lithiophilite, petalite, and zinnwaldite.

In chemical properties, lithium is closely related to the other alkali metals, sodium, potassium, rubidium, and cesium. All alkali metals are silver white, have brilliant metallic luster when fresh and unoxidized, but tarnish at once on exposure to the air, becoming covered by an oxide coating. Lithium is the lightest element that retains a solid form at ordinary temperature. It is soft and ductile, entering into a great variety of chemical combinations. A non-luminous flame is rendered vivid carmine red by lithium.

Lithium, either alone or as an alloy with other alkaline-earth metals, acts as a refining agent on molten metals. It imparts characteristic properties to the alloy when lithium is only a minor constituent, adding strength and ductility and giving improved uniformity. Lithium is the only known material that, when combined with hydrogen and other gases, produces an initial alloy in a superrefined state. It densifies the grain in the metal and eliminates porosity in high-pressure castings. Tests were being made of lithium in bearings for the automotive industry, it was reported on Apr. 1, 1946.

Lithium has been found to be widely distributed in minute quantities in some 140 different minerals. Amblygonite (fluphosphate of aluminum and lithium) is white to pale green, blue, gray, yellow or brown; it is hard, subtransparent to translucent, usually occurring in pegmatite. Lepidolite (hydrated fluosilicate of aluminum, potassium and lithium) ranges in color

from white to pink, usually occurring in massive aggregates of small plates or scales in pegmatite. Spodumene (aluminum-lithium silicate) is hard and gray to purple in color; it occurs in pegmatite as cleavable masses or large prismatic crystals that have been found weighing up to 37 tons and measuring up to 40 ft. in length.

Uses. Lithium salts have been widely used in steel for war materials. Essential military applications were in the electrochemical, aircraft, electrical-manufacturing, and foundry industries. The new lithium vapor process renders steel machine parts bright and free from scale while in heat treatment. Minute quantities of metallic lithium increase the hardness, toughness, and tensile strength of bearing-metal alloys, copper electrodes, and lead cable sheaths. Lithium metal is added to copper-base alloy melts as a scavenger.

Lithium has been employed with electric-furnace carbon steels for steel castings, replacing aluminum as a deoxidizer to produce sounder castings. Both steel and copper castings with which lithium is included can be poured at lower temperatures and with high fluidity. It is stated that lithium produced in the form of wire and rods permits chemists to utilize the metal by feeding it into kettles at controlled speeds.

Expanded use of lithium in the form of lithium-hydride has been made for producing hydrogen gas for baloons. Lithium, an efficient degassifier and deoxidizer, is used in the form of master alloys to produce tin bronze, silicon bronze, and pure copper castings of high uniformity and optimum physical properties. Master copper alloy contains 4 per cent of lithium.

Lithium compounds, which have wider application than either the metal or the alloys, have been used effectively in the glass and optical, ceramic, chemical, and air-conditioning industries. Both lithium metal and lithium amide can be used as an intermediate in building molecules for carbonols, nicotinic acid, and other organic compounds. The high yield of hydrogen from lithium borohydride and lithium diborane gives these derivatives important possibilities in chemical research to determine new applications.

Lithium chloride, one of the most hygroscopic inorganic compounds, is essential in air-conditioning units as a drying agent. Blast furnaces have their efficiency increased by 10 per cent when the air is dried. Minor uses have been developed in the production of optical, pharmaceutical, electrical, and textile materials.

Spodumene and lepidolite have been used largely for inflating life rafts, in making certain types of glass in the ceramic industry, and for drugs. It was reported in June, 1945, that spodumene had been used as a substitute for glass-grade kyanite. Lepidolite is essential in the manufacture of borosilicate glass for electronic tubes and boiler gauges. As a ceramic raw material,

spodumene-feldspar mixtures have lower melting point than has feldspar alone. Spodumene has been proposed as a substitute for the more costly prepared lithium carbonate in pottery bodies, glazes, and enamels. Amblygonite is used in opaque glasses.

Lepidolite and, to a less extent, the other commercial lithium minerals are added in important proportions to glass batches, particularly as opacifying agents in making opal and white glasses. Lepidolite is also employed in the production of flint glass, with a consequent lowering of the coefficient of expansion of the glass which results in less breakage from sudden heating and cooling. Lepidolite glass is characteristically harder, tougher, and more brilliant, owing to increased index of refraction, and the polished surfaces are more resistant to atmospheric corrosion. Lithium and fluorine contained in the lepidolite serve as valuable fluxing agents in facilitating the melt in glassmaking, for which scaly varieties of the mineral, light purple in color, are employed.

In electrical welding of aluminum and magnesium and their alloys, lithium chloride or lithium fluoride is usually employed in the flux. Lead-lithium, the best known of the alloys (Bahn metal) contains only 0.04 per cent of lithium, which increases the hardness at high temperature. Other alloys, including aluminum and magnesium, are reported to have superior properties. Bahn metal is used as railroad bearings.

Manufactured salts of lithium are employed in the preparation of mineral waters, lithia tablets, and medicine and for many minor uses. Lithium hydroxide is used, with potassium hydroxide, as the electrolyte in the Edison alkaline storage cell. Lithium chloride is used in signal lights to produce a crimson flare. In 1944, lithia was reported to be one of the most promising substitutes (with strontia and the fluorides) for lead in glazing pottery. This application may compensate for the loss of military uses in the postwar period. Markets for lithium ores and compounds are reported to be expanding rapidly, and a variety of new postwar applications is expected to be established.

One pound of lithium burned with hydrogen would serve as fuel for a year in a furnace requiring more than 4,000 tons of coal to produce the same amount of heat, stated Dr. W. G. Pollard, University of Tennessee physicist, on Sept. 5, 1946, in discussing the chain-reacting pile at Oak Ridge, Tenn.

Domestic Sources of Supply and Production. Listed as essential by war agencies of both the United States and Britain, lithium has various applications of military importance. War demand for lithium salts led to an increase in 1942 from 500 to 2,000 tons a month in mill capacity for the production of low-grade spodumene ore as a domestic source of lithia. This ore required

beneficiation, for which froth flotation gives excellent results. By-products of the process are low-grade feldspar and mica concentrates.

The United States has the largest known reserves of lithium ores. The lithium chemical industry supplies products having a high degree of purity. Production is secured from pegmatites and from brines. The most productive area has been in the Black Hills of South Dakota. In North Carolina, disseminated spodumene occurs over a large area near Kings Mountain. Searles Lake, California, is an important source of crude lithium sodium phosphate, the crude brines containing up to 0.032 per cent of LiCl.

Two mills, located at Kings Mountain, N. C., and Tinton, S. D., were completed in 1943 and 1944 with government assistance. These plants concentrate spodumene for the production of lithium salts. The Tinton flotation plant was inactive at the end of 1944. At Kings Mountain, satisfactory operation was reported close to capacity of 1,000 tons monthly. Two mines in the Black Hills were the main source of spodumene in prewar years.

Lepidolite and amblygonite were produced in California and New Mexico until several years ago, when operations were terminated. The U.S. Bureau of Mines listed lithium producers in 1941, as follows: American Potash & Chemical Company, Searles Lake, Trona, Calif.; Black Hills Keystone Corporation, Lawrence Judson, and Maywood Chemical Company, all of Keystone, the Black Hills Tin Company, Tinton, B. M. Dilly, Custer, all of South Dakota; United Feldspar & Mineral Corporation, Kings Mountain, N. C.

A new lepidolite producer, in 1944, was the Brown Derby mine in Colorado, operated by the Hayden Mining Company. The mineral occurs there with microlite in lepidolite. To be of commercial grade, a minimum of 6 per cent is required. Production of lithium minerals and compounds (including dilithium sodium phosphate) from domestic sources reached record levels in 1944. The output of spodumene was 87 per cent higher than in 1943, and a gain of 187 per cent was shown for dilithium sodium phosphate. Lithium minerals were in adequate supply, except lepidolite for the glassmaking industry, which depended on imports from South-West Africa.

The Solvay Process Company was prevented by wartime restrictions on purchase of machinery from completing its milling unit at Kings Mountain, N. C. It was the major producer in 1944, followed by Black Hills Tin Company. Increased output of dilithium sodium phosphate at Searles Lake, California, was followed by installation of a flotation process. At the Kings Mountain plant, production was terminated in February, 1945, after contracts with the Army expired at the end of 1944.

California, South Dakota, and New Mexico had a total output, prior to

1936, of about 70,000 tons of lithium minerals having an average value of $18.60 a ton. In 1941, one of the three principal shippers of lithium minerals and salts was American Potash & Chemical Company, Trona, Calif., which produced lithium-sodium phosphate (lithia-mica) from brines.

The first commitment for the purchase of lithium (amblygonite and spodumene) for stockpiling was made in 1943 by the Metals Reserve Company. Lithium ranked fortieth in cost of deliveries for the government stockpile, and purchases had a total value of $91,846, of which $30,275 remained in the inventory of the MRC on Oct. 31, 1944. In August, 1944, the War Production Board announced that lithium had moved into an easier supply position and spodumene and dilithium sodium phosphate were being added to the government stockpile. Spodumene amounting to 1,571 short tons was reported in government stocks held by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration. No stocks of amblygonite were being held.

Allocation of spodumene was established on Dec. 5, 1942, by General Conservation Order M-253. This order was revoked by the WPB on Sept. 30, 1944.

SHIPMENTS OF LITHIUM ORES AND COMPOUNDS FROM MINES IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

	1940	1941	1942	1943	1944
Ore	2,011	3,832	5,405	8,155	13,319
Li_2O content	113	209	299	463	848

World Production, Imports and Exports. Imports of lepidolite and spodumene were required for essential products in 1943. The total of 832 short tons received included 390 tons of lepidolite from South-West Africa; the balance was spodumene received from South America (Brazil, 276; Argentina, 166). Additional imported lepidolite was required in 1944, owing to shortages of domestic supplies. Importers of lepidolite included Corning Glass Company and General Electric Company.

Of prewar world output of lithium ores, the United States accounted for more than half, followed in importance by South-West Africa, Australia, Sweden, and Germany. War demand led to starting production in Argentina, where its occurrence in commercial quantity had not been previously reported. Minor output has been secured in Canada, Spain, Portugal, and Southern Rhodesia, and deposits of commercial value are known in U.S.S.R.,

Madagascar, and India. Germany had used the zinnwaldite of Bohemia and Saxony, before 1927, in making lithium-alloy metal for the manufacture of bearing metal and a hard aluminum alloy, "scleron." Chemical plants for the treatment of lithium ores were located in prewar years in Britain, France, and Germany.

Prices. Lithium metal was quoted on May 10, 1945, by *E & M J Metal and Mineral Markets*, at $12.50 a pound, 98 and 99 per cent, minimum lots of 5 tons. In the period 1932–1942, the price remained at $15; 1930–1931, $18; 1929, $96.

Lepidolite, ordinary grades, lump, 3 per cent Li_2O, f.o.b. mine, was $24 to $25 a short ton; these rates applied for the period 1940–1945.

Amblygonite, 8 to 9 per cent Li_2O, was $40 to $50 per ton in May, 1945; December, 1939, to December, 1941, $40; December, 1938, to July, 1939, $35 to $40.

Spodumene mill concentrates were $5 to $6 per unit of Li_2O, 6 per cent minimum, or $30 per short ton in carlots, f.o.b. North Carolina. The price was quoted at $5 from December, 1937, through December, 1941; in 1930–1931, $50 to $60.

The following lithium compounds were quoted in January, 1942, by *Oil, Paint, and Drug Reporter:* lithium bromide, $1.90 per pound, in 100-lb. barrels; lithium carbonate, $1.25 per pound, in 250-lb. barrels; lithium chloride, $1.65 per pound, in 25-lb. jars; lithium fluoride, $2.10 per pound, in barrels.

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MAGNESITE

(Dead Burned)

Properties. The normal carbonate of magnesia, magnesite consists of magnesium metal combined with carbonic acid. Breunnerite, or spathic magnesite, forms the variety known as crystalline magnesite. Its hardness is 3.5 to 4. It is a massive crystalline rock varying in color from white, gray, and black to pink or red. It resembles sedimentary rock in its bedded occurrence.

Pure magnesite (amorphous or cryptocrystalline) is commonly a white, very fine-grained, compact, minutely crystalline rock that occurs in veins. The following three types of magnesite deposits are recognized:

1. Veins in serpentine (as in California and Greece).
2. Replacements of dolomite or limestone (as in Washington, Quebec, and Austria).
3. Sedimentary rock (as in Kern County, California).

Caustic magnesite is produced by calcining crude magnesite at a temperature of about 1200°C. It contains 2 to 5 per cent of carbon dioxide and deteriorates on exposure to the air, from which it takes up additional carbon dioxide. Plastic magnesia is caustic magnesite that is adaptable to forming magnesium oxychloride cement (Sorel cement).

Dead-burned magnesite requires higher temperatures of burning, from 1550 to 1900°C. This calcining reduces the carbon dioxide content to less than 1 per cent, the product remaining inert in the presence of air. Magnesite is fired in vertical-stack kilns using wood, coal, oil, or coke as fuel and in rotary cylindrical kilns fired with oil or powdered coal.

Uses. Dead-burned or calcined magnesite, a wartime key product that filled important industrial needs, is used in making eight standard types of bricks for metallurgical purposes, as a refractory material for primary linings for basic open-hearth furnaces. Wartime construction of hearths favored rammed magnesia grain bottoms, because the speed of this installation was greater than a furnace lining built up a layer at a time with dead-burned magnesite. Although there is no technically satisfactory substitute for magnesite brick, the lower price of chrome brick has led to its use for the same purpose.

Successful experiments, in 1944, demonstrated that basic roofs are more refractory but less stable under load than silica roofs. Postwar competition is expected to be active in brickmaking grades of imported dead-burned

magnesite and domestic sea-water magnesia. The former is lower in price, but the latter offers greater purity and better control over the final product.

Postwar basic brick is expected to benefit from increased supplies of high-grade synthetic magnesia. Electrically fused magnesia shapes are becoming available in increasing quantity. Imports are expected to be held at 35 to 40 per cent of domestic consumption.

In 1940, there was a great increase in the use of both magnesitic dolomite refractories and magnesia refractories derived from dolomite. Dolomite continues to be used as a substitute for magnesite refractories, which were replaced in 1918. Crushed dolomite, both raw and calcined, is used in large quantities in maintaining basic open-hearth furnaces; it is added alone or mixed with slag.

Magnesia is one of the important insulating materials. It is also the basis of Epsom salts and other medical supplies, fertilizers, and rubber. Formerly, it was used to a larger extent in making Sorel cement for stucco and flooring. Caustic magnesite has an essential use as oxychloride cement flooring in explosives plants, due to its nonflashing properties; material for this purpose increased 60 per cent in 1940; a decline was reported in 1944.

Many materials compete with magnesite in the building trades, but few are acceptable substitutes for such applications as stucco, plasterboards, plasters (base-coat, sanded, finished, and molding), lathe, wallboard, partition tiles, and insulating materials. Dolomite and sea water rival with magnesite and brucite as sources of magnesia products. Magnesia, obtained by calcining brucite, can be used for the same purposes as that produced from magnesite.

Domestic Sources of Supply and Production. High-purity magnesite produced in California, in 1940, supplied most of the caustic magnesite for flooring, amounting to 16,261 tons. Expansion of the magnesite industry as a whole in the United States was due to increased demand resulting from the program of national defense and to smaller imports. In California, the major source, production was increased. At Chewelah, Wash., a flotation plant was being completed; and early in 1941, operations started in Nevada for opening deposits to supply raw material for both metallic magnesium and refractories. The record 1917 output of 316,638 tons has been exceeded in each year since 1939.

Strong demand for dead-burned magnesite and dead-burned dolomite, in 1944, resulted from the high level of activity of metallurgical furnaces. Reduced demand for magnesite and magnesium chloride was caused by curtailed output of magnesium metal. Output was valued at $6,071,596 in 1943; in 1944, $4,407,461.

DOMESTIC PRODUCTION, SALES, AND IMPORTS OF MAGNESITE IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

	1939	1940	1941	1942	1943	1944
Crude:						
Mine output	198,980	333,166	374,799	497,368	754,832	561,450
Imports	569	22	*	*	*	1,039
Sold by producers	1,123	2,133	4,536	6,835	4,090	*
Caustic-calcined:						
Imports	2,218	928	864	578	290	559
Sold by producers	10,157	16,261	30,225	41,889	191,792	139,243
Dead-burned dolomite:						
Imports	*	*	64	449	739	40
Sold by producers	86,077	867,909	1,069,887	1,229,357	1,276,725	1,290,790

*Not reported.

Oxychloride Cement Association was formed in July, 1944, representing suppliers of magnesium chloride (Dow Chemical Company and Westvaco Chlorine Products Corporation) and a supplier and grinder of caustic-calcined magnesia (Westvaco and F. E. Schundler & Company).

World Production, Imports and Exports. In prewar years, magnesite was imported from Austria and Greece. The sharp reduction in shipments from German-occupied territory, in 1940, led to increased imports of dead-burned magnesite from Manchuria, primarily because of economic advantage. Imports from Manchuria continued to arrive until late 1941; since then, imports have consisted largely of dead-burned magnesite from U.S.S.R.

In 1944, Canada produced magnesitic dolomite and brucite valued at $1,125,433; in 1943, $1,260,056; in 1942, $1,059,374; in 1941, $831,041; in 1940, $897,016. Argenteuil County, Quebec, is a major source of an intimate mixture of magnesite and dolomite, which is sold as caustic and dead-burned magnesite, in the form of bricks, as finely ground cement, and in combination with chrome as an ingredient in certain types of refractories. These deposits and crystalline limestone from which brucite concentrates are produced, located near Wakefield, Quebec, are reported to be ample for domestic requirements and for a large export trade.

Aluminum Company of Canada, in 1941, erected a plant for the production of brucite. Magnesia obtained from this source is suitable for high-grade basic refractories. Before dolomite was developed near Haley's, Ontario, for producing magnesium metal, brucite from Wakefield was employed for that purpose at the plant of Dominion Magnesium, Ltd. Exports of calcined and dead-burned magnesite amounted to 537 tons in 1942; in 1943, 396 valued at $16,398.

Brazil has two potentially large deposits of high-grade magnesite. The Brumad deposit is located 85 miles from the railroad at Contendas, state of Bahia. Extensive high-grade deposits, estimated at upward of 100 million tons, outcrop along a mountain range of serpentine. The Josi de Alencar deposit, state of Ceara, is located 270 miles by railroad from the port of Tartaleza. Production for domestic use amounted to 6,000 tons of caustic magnesite in the first 7 months of 1942.

Germany, Japan, and U.S.S.R. are the only world powers in a position to produce sufficient magnesite for their own requirements and additional amounts for export. The United States has adequate resources for satisfying domestic demands, without either excess or deficiency. Britain and Italy are deficient in domestic supplies. France, Belgium, the Netherlands, Spain, and China are almost entirely dependent on imported magnesite. Of world production in 1934, U.S.S.R. accounted for 482,000 metric tons; Austria, 258,382; United States, 91,601; Greece, 70,388.

This was one of the six raw materials produced in Europe in supplies adequate for exporting, compared with critical shortages of other metals and minerals. The other items available for export were potash, mercury, sulfur, gypsum, and synthetic nitrogen.

In Venezuela, magnesite deposits have been recorded but are undeveloped.

In South Africa, prewar consumption of magnesite was chiefly for making refractory bricks and in the manufacture of carbon dioxide, Epsom salts, and cupels. Disorganization of world supplies resulted in the exporting of South African magnesite to Britain for the construction of aircraft and the manu-

MAGNESITE IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

	1942	1943	1944
Crude magnesite:			
Cuba	.....	.....	47
U.S.S.R.	.....	.....	992
Lump caustic-calcined magnesite:			
Canada	.....	....	3
Cuba	412	174	
Other countries	.....	.....	556
Ground caustic-calcined magnesite:			
Canada	100		
Cuba	59	106	
United Kingdom	7	10	
Dead-burned and grain magnesite and periclase:			
Canada	425	147	780
U.S.S.R.	6,723	9,086	5,396
United Kingdom	580		

facture of incendiary bombs. British sources in Greece and other Mediterranean countries were cut off. Magnesite of suitable grade was produced in eastern Transvaal. Production amounted to 15,474 tons in 1943, valued at £31,205; in 1944, 5,938 tons valued at £11,622, compared with prewar output valued at less than £4,000.

Other sources of magnesite include Czechoslovakia, Yugoslavia, Italy, Australia, and India.

Prices. The price of dead-burned grain magnesite, sold by Northwest Magnesite Company, f.o.b., Chewelah, Wash., remained unchanged from 1939 through Sept. 30, 1946, at $22 a short ton; California, $25, as reported by *E & M J Metal and Mineral Markets.* California caustic-calcined, bulk, 85 per cent MgO, was $52.75; 95 per cent, granular, $57; dead-burned, $40.50.

Mined and synthetic magnesias, sold by Westvaco Chlorine Products Corporation, were quoted as follows: artificial periclase, 94 per cent MgO, $65; 90 per cent, $35; mined periclase, bulk, 83 per cent MgO, $38.24; 90 per cent, $40.50; sea-water periclase, bulk, 85 per cent, $36; 90 per cent, $36.50; 93 per cent, $72.50; calcined (sea-water) magnesia, bulk, $54; powdered, $60; white caustic, 95 per cent, $40; 85 per cent, no color standard, $37.50; magnesite brick, 9-in. straights, f.o.b. works, $76 per ton.

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MAGNESIUM

Properties. The third most abundant of the engineering metals, surpassed in volume by only aluminum and iron, magnesium is one of the eight elements that account for about 98.5 per cent of the composition of the outer 10 miles of the earth's crust, of which magnesium represents about 2.09 per cent. Although abundant in nature, magnesium is difficult to reduce to metallic form. It is one of the 16 nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. (Mg, atomic number, 12; atomic weight, 24.32; melting point, 651°C.; density, 1.74.)

Only silver, copper, and aluminum have a higher electrical conductivity; in mass conductivity, it is second only to aluminum. Magnesium metal can be used to replace aluminum in various applications. Specific gravity of magnesium alloys varies from 1.76 to 1.86. Beryllium and lithium are the only metals having greater lightness.

Major recovery has been from sea water, brines, and salt deposits. Carnalite, an important constituent of Michigan and other brines, contains 34 per cent of magnesium chloride. Sea water has a carnalite content of 0.4 per cent (0.13 per cent of magnesium). Dolomitic lime is used to precipitate magnesia from sea water. Other sources include brucite (41.6 per cent of magnesium), magnesite (28.7 per cent of magnesium), hydromagnesite (26.5 per cent of magnesium), dolomite (13 per cent of magnesium), serpentine (25.8 per cent of magnesium), and olivine. Brucite has been produced in Nevada since 1934 and, since 1940, in Canada where deposits are the largest known in the world. The supply of raw materials is inexhaustible for the manufacture of magnesium.

Magnesium became available only when important chemical discoveries made its extraction possible, and its large-scale use in bulky cast form has been widely applied in industry, particularly under the urgency of critical war demands. High strength and low weight have made it an essential structural metal for aircraft. It is 37 per cent lighter than aluminum. It resists alkalies but is anodic and the most corrosive of the metals, being attacked by most acids. Its surface oxidizes easily; other unfavorable factors include a low modulus of elasticity and incapacity for free and easy cold-working.

The sole American producer of magnesium was, until recently, the Dow Chemical Company, which employed a process electrolyzing fused magne-

sium chloride obtained from Michigan salt brines. New salt wells in Michigan supply brine three times as rich in magnesium salts as that from the original Midland area. Production from sea water was started in 1941. Domestic sale increased from 50 tons in 1915 to more than 2,000 tons in 1934.

The Pidgeon thermal-reduction process, requiring the lowest capital cost, operates on the reduction of calcined dolomite and ferrosilicon, the silicon stealing the oxygen from magnesium oxide. Lime is then added in order to remove the silicon dioxide formed. Similar techniques are used for other metals as well as magnesium, only minor changes being required in making magnesium available for more general application. Three thermal reduction processes involve reduction of magnesia with carbon (in United States), reduction of magnesia with calcium carbide (in Britain), and reduction of calcined dolomite with ferrosilicon (in Canada, United States, and Italy).

In the Hansgirg carbothermic process, thermal reduction provides for the distillation of magnesium in an internally heated electric furnace similar to that developed for the electrothermic reduction of zinc. Oxygen is removed from magnesium oxide ore by means of coke, an inert gas keeping air out of the furnace. Hot volatilized metal is instantly cooled by a stream of cold natural gas in order to prevent an explosive reaction with carbon monoxide.

The first electrolytic plant to produce magnesium metal was erected near Bremen, Germany, in 1886. In the United States, new interest in producing magnesium developed in 1915, when imported metal from Europe was no longer available. The oxide process was abandoned in 1927, in favor of the chloride process, which had advantages of lower operating cost and a higher purity of plus 99.8 per cent.

The magnesium industry consists of three stages: conversion of raw materials into primary metal largely through the use of electric power, semifabrication of the metal into various forms, and final processing.

Uses. Incendiary and oxidizing characteristics of magnesium were employed in the First World War for fire bombs and flares and for open flashlights in night photography. The metal was used in the Second World War in many new applications, both military and civilian. Different types of bombs not using magnesium were also introduced, which had the effect of curtailing magnesium consumption to about 15 per cent of capacity before the end of 1944.

Lightness combined with flammable properties are advantages of magnesium-bomb casings. When a magnesium bomb explodes, the casing also burns. The "Goop" fire bomb was first used in May, 1945, against Japan in

what was described as the greatest contribution to the success of fire raids on the Pacific front. The "Goop," or M-74, bomb weighs 10 lb. and contains magnesium powder coated with asphalt particles, jellied gasoline, and other ingredients.

In the Second World War, the expanded world demand for magnesium is without parallel in the history of the use of metals. One group of uses is based on the chemical activity of the metal, either in finely divided condition or at high temperatures; the more important application was based on engineering properties of magnesium alloys. Magnesium-rich alloy structural products used 64 per cent of production in 1940, and 32 per cent was employed for alloys of aluminum, zinc, and other metals. The balance was utilized for pyrotechnics and chemicals and for other purposes. Magnesium compounds hold an essential place in the chemical and processing industries.

Of magnesium structural products, the aircraft industry took 75 per cent in 1940; the automotive industry, 10 per cent; tool and equipment industries, 6 per cent; textile, foundry-equipment, and other industries, 9 per cent.

The War Production Board allocated about 75 per cent, in 1942–1943, to the aircraft industry and the incendiary-bomb program and for export to Britain. The remainder went to the production of pyrotechnics and ordnance materials for the Army and Navy, to the aluminum industry, and for exports to U.S.S.R., Canada, and Latin America.

Distribution of output in 1944 was as follows: incendiaries, 40 per cent; aircraft construction and many parts in war weapons, 30 per cent. In military equipment, the use was being increased to improve performance. Magnesium sulfate, recovered from serpentine in Augusta, Ga., is used for the manufacture of fertilizer. Brucite is employed in the manufacture of furnace refractories, and small amounts are used in petroleum refineries.

In 1943, potential new-use requirements were many times the supply. Capacity for fabrication was expanded to approximate the estimated requirement of 362,500 tons, on the basis of a 1 to 3 balance with the 1,200,000 tons of aluminum estimated for aircraft production. This figure proved to be excessive; and at the end of 1944, WPB stockpiles were twice as great as required. Early in 1944, increased military demands were expected to lead to large increases in sheet and extrusion capacity and expansion of forging capacity.

In aircraft construction, magnesium alloys make possible a more rigid structure with fewer reinforcements than is obtainable from the same weight of other material. This gives promise of increased use of magnesium for structural purposes. Progress has been made in alloy casting.

In aircraft-engine construction, magnesium forgings and castings are

employed in amounts up to 50 per cent of the total weight of nonferrous alloys. Magnesium is used for extruded socket launcher tubing because of its rigidity, lightness, and ease of fabrication. In slightly more than two months, several million pounds of magnesium metal wire were fabricated for tubing.

In the United States, the first large magnesium forging was produced in December, 1944, and regular output was scheduled before the end of 1945 by Wyman-Gordon Company. Britain, Russia, and Germany, for a number of years, have made use of heavy presses for large forgings. In 1944, castings made from high-strength alloy formed 80 per cent of fabricated magnesium products. Superior weldability is an important property.

A new anodic coating for magnesium alloys was announced in September, 1944. In high resistance to corrosion and abrasion, it was claimed to be superior to those finishes produced by the acid dichromate and chrome pickle treatment.

The Truman Committee reported in March, 1944, that a large part of the magnesium industry would be written off as a war loss unless hundreds of new peacetime uses could be found for the metal. Postwar planning was discussed by Dr. W. H. Dow in October, 1944. He believed that plants built for the war emergency could maintain capacity for production of such materials as magnesium wheels for automobiles, wheelbarrows, and roller skates and in the manufacture of cigarette machines, printing presses, knitting machines, bread-slicing machines, various household appliances, portable hand tools, radios, office machines, and cameras. Magnesium compounds are expected to depend on the volume of industrial production for stimulated output in relieving shortages of goods and services of many kinds. A 60-lb. canoe and a 70-lb. rowboat were reported to be in production in December, 1945.

At the second annual meeting of the Magnesium Association, the vice-president, T. W. Atkins, called for prompt action in disposal of government-owned magnesium plants, on Oct. 2, 1945. Many labor- and energy-saving applications for magnesium were discussed for "this magnesium age." Household appliances, office equipment, and sporting goods; elevator cages, trucks, buses, aircraft, and railroad cars; weaving machines, adding machines, and typewriters were cited as among the hundreds of magnesium applications either in actual production or on the drawing boards. Magnesium forgings for aircraft were expected to compete with other metals. Strong magnesium forgings are available to be applied by other industries as soon as postwar price reductions can be adopted.

Dow Chemical Company reported to Congress that postwar consumption of magnesium, estimated at 30,000 tons a year, will be distributed as

follows: 45 per cent for the manufacture of aircraft; 11 per cent for the manufacture of automobiles, trucks, and buses; 21 per cent for industrial machinery, tools, and manually handled equipment; 8 per cent for furniture and other consumers' goods; 5 per cent as an alloying element for aluminum; and 10 per cent for use in the chemical industries and in photography. No export demand of consequence was anticipated.

Domestic Sources of Supply and Production. An Army and Navy program, announced late in 1944, was formed to ensure the national ability to turn overnight from peacetime to war production of magnesium. The armed services' requirements specified (1) peacetime demand for magnesium sufficient to promote aggressive development in production and (2) a means of rapidly increasing magnesium output if industrial mobilization on an all-out basis is ever necessary again.

The Magnesium Association was to act as a permanent industrial advisory committee on economic planning and research in the interest of national preparedness. The Army Industrial College announced that close liaison between industry and the armed services would be continued through the postwar period and beyond. Magnesium is one of the eight major minerals that may be expected to last more than 100 years, on the basis of known usable domestic reserves. Inexhaustible supplies of the metal are available from brines and ocean water.

Magnesium metal, first produced commercially in 1915 in the United States, continued in limited supply until it was learned that great quantities (up to 20,000 tons a year) were being produced in Germany. The youthful magnesium industry is now faced with a grave problem of overexpansion for peacetime requirements, after production had been boosted from 3,000 to 300,000 tons a year. Dow accounted for 30,000 tons in company-owned plants, and the balance was provided by government-operated facilities. Under war conditions, all metal was for government purchase. In peacetime, it cannot be demonstrated that a sufficient market is available for civilian magnesium products to justify the use of plants employing much higher cost production methods. Maximum postwar demand for this metal has been estimated by the U.S. Bureau of Mines at 30,000 tons a year.

The government stockpile amounted to about 5,000 tons on VJ-Day, equal to a 20-month supply for the Dow plants alone. In view of this problem, independent operators asked for large allowances in taking over government facilities for peacetime operation. Retooling would be required on a large scale for civilian production. Demand for higher quality fabrics at lower cost led designers for textile machinery to turn to the use of lightweight materials, such as magnesium.

The only domestic source of primary magnesium, in 1940, was the natural brine ($MgCl_2$) treated by Dow Chemical Company, Midland, Mich., with output of 6,261 tons, in 1940; in 1941, 16,295; in 1942, 48,963 tons, following construction of a second Dow plant at Freeport, Tex., and two others in Michigan. In 1943, output jumped to 183,584 short tons valued at $69,700,600; in 1944, 168,337. Sales of domestic metallic magnesium in all forms were reported by the U.S. Bureau of Mines as follows: 5,325 short tons; in 1940, 6,412; in 1941, 15,528; in 1942, 47,420; in 1943, 170,267.

ESTIMATED POSTWAR MAGNESIUM OXIDE AVAILABLE AND REQUIRED, IN SHORT TONS
(After U.S. Bureau of Mines)

Grade	Available from producers	From idle magnesium plants	From imports	Postwar requirements
Refractory:				
Maintenance Brick	278,000	346,000	50,000	100,000 60,000
Caustic-calcined	26,600		3,000	20,000
Pure grades	4,700	.....	.....	5,000
Total	309,300	346,000	53,000	185,000

Metallurgical production in 1944 was reported by the American Bureau of Metal Statistics at 183,265 tons. The rate touched a peak in January, 1944, and dropped to about 15 per cent of capacity by the end of the year. Secondary recovery was reported at 922 tons, in December, 1944. In 1943, Dow controlled 44 per cent of operating-plant capacity and secured 61 per cent of the total domestic output. The Senate war contracts committee reported on June 13, 1945, that 90 per cent of magnesium production was from government-owned plants.

The Pidgeon ferrosilicon reduction process was adopted in 1942 in an effort to supply quick, dependable metal output with small electric-power requirements.

The Permanente plant of Todd-California Shipbuilding Corporation, located near San Jose, Calif., started operations in 1941 with an annual capacity of 12,000 tons. The plant of Basic Magnesium, Inc., at Henderson, Nev., using the method of English Magnesium Electron, Ltd., was built by the Defense Plant Corporation at a cost of $133,000,000. It was located at a shipping distance of 950 miles from the ore supply at Gabbs, Nev. Anaconda Copper Mining Company took over 52½ per cent control in October, 1942, and operated at capacity of 56,000 tons a year. Reduction of output was started on Oct. 1, 1944, when four of the ten units remained in operation.

Complete suspension followed on Nov. 16, 1944, and the feeder plant was closed down at Gabbs also. Liquid chlorine and caustic production were continued at the plant.

At Basic Magnesium, part of the plant was turned to storage use; part was adapted to production of other war materials, following installation of $5,000,000 worth of new equipment. Anaconda was released on May 17, 1945, from all connection with management and operation of the plant and mines. The plant had attained a production in excess of capacity, with total output amounting to 83,161 tons of marketable or alloyed magnesium metal.

Listed on page 288 are the 16 magnesium plants completed in the United States, 92 per cent of the total productive capacity being represented by government-owned plants all of which were shut down by Jan. 1, 1945.

Curtailed output started in March, 1944; and at the end of the year, the following 11 plants were shut down: Amco Magnesium, Ford Motor, Permanente, Electro Metallurgical, Dow Magnesium (Velasco, Ludington, and Marysville), International Minerals & Chemical (Carlsbad and Austin), Mathieson Alkali, and Basic Magnesium.

The largest and most successful operator was Dow Chemical Company, which furnished operating experience for the new plants and secured the low cost of 12 cents a pound on some of its production compared with Office of Price Administration ceiling prices of 20½ and 22½ cents a pound. The cancellation of war orders for magnesium led Dow to plan a $51,000,000 expansion program at Freeport, Tex., for the purpose of taking up the slack in production and employment. Dr. A. P. Beutel, general manager of Dow's Texas division, stated on Oct. 4, 1945, that the proposed expansion would provide for the manufacture of plastics for new products. Efforts were being made to lease part of the government-owned plants used in producing magnesium for war purposes.

Permanente Metals was developed by Henry J. Kaiser, making use of a new process. Running up higher costs in early stages of production, the plant was given a $2,700,000 subsidy by the WPB averaging 16 cents a pound on the first production of 7,500 tons. Profits of Kaiser shipbuilding operations were used to repay Reconstruction Finance Corporation loans amounting to $28,000,000.

One of the largest magnesium mills, for the fabrication of plate, sheet, rod, bar, tube, forgings, and extrusions, was operated by Revere Copper and Brass, Inc. Permanente Metals Corporation operated its California plant, at Moss Landing, for the recovery of magnesium oxide from raw sea water and dolomite to be used in making magnesium metal and refractories and for other purposes. Magnesium oxide was recovered from sea-water bitterns at

the Bald Eagle magnesite mine, in California, by Westvaco Chlorine Products Corporation. The oxide was used in making periclase oxychloride cement, as a rubber catalyst, as a fertilizer, in Epsom salts, and in various specialty uses.

GOVERNMENT-OWNED MAGNESIUM PLANTS USING PIDGEON PROCESS
(Dolomite)

Operator	Location	Annual capacity, short tons	Government investment
Magnesium Reduction Co. (National Lead Co., operator)	Luckey, Ohio	5,000	$ 4,700,000
New England Lime Co	Canaan, Conn.	5,000	4,800,000
Amco Magnesium Corp. (American Metal Co., operator)	Wingdale, N. Y.	5,000	7,000,000
Electro Metallurgical Co	Spokane, Wash.	24,000	16,100,000
Permanente Metals Corp	Manteca, Calif.	10,000	6,200,000
Ford Motor Co	Dearborn, Mich.	20,000	10,400,000

GOVERNMENT-OWNED MAGNESIUM PLANTS USING BY-PRODUCT LIQUORS
(Dow Electrolytic Process)

Diamond Magnesium Co. (Diamond Alkali Co., operator)	Painesville, Ohio	18,000	$ 14,600,000
Mathieson Alkali Works	Lake Charles, La.	27,000	48,600,000
International Minerals and Chemical Corp.	Carlsbad, N. M.	30,900	3,800,000
International Minerals and Chemical Corp.	Austin, Tex.	12,000	14,600,000

GOVERNMENT-OWNED MAGNESIUM PLANTS USING SEA WATER
(Dow Electrolytic Process)

Dow Chemical Co	Freeport, Tex.	9,000	$ 8,200,000
Dow Magnesium Corp	Velasco, Tex.	36,000	55,100,000

GOVERNMENT-OWNED MAGNESIUM PLANTS USING NATURAL BRINE AS CELL FEED

Dow Chemical Co	Midland, Mich.	*	
Dow Magnesium Corp	Ludington, Mich.	190,000	$ 16,800,000
Dow Magnesium Corp	Marysville, Mich.	36,000	21,600,000
Basic Magnesium, Inc. (Basic Refractories, operator)	Las Vegas, Nev.	56,000	140,000,000

* Privately owned and operated.

Postwar conversion of magnesium metal plants to the production of magnesium oxide is expected to lead to increased competition. Postwar supplies of magnesia are expected to be in considerable excess over demand.

The change-over to magnesia manufacture can be accomplished without radical alterations, except for those plants where the ferrosilicon process is employed.

Three DPC magnesium plants, two of them operating since Dec. 31, 1944, at 50 per cent of capacity, were ordered by the WPB on May 21, 1945, to return to full production schedules. The facilities involved are located at Painesville, Ohio (operated by Diamond Magnesium Corporation), and at Luckey, Ohio (operated by Magnesium Reduction Company). The plant at Velasco, Tex. (operated by Dow Magnesium Corporation), had been in stand-by condition since Dec. 1, 1944.

Sixty-three plants were either producing or preparing to produce magnesium at the end of 1943. They represented an investment of about $515,000,000, including $90,000,000 representing about 92 per cent of total production facilities financed with government funds. Fabricators of magnesium structural products increased from 59 in 1942 to about 85 in 1943, as reported by the U.S. Bureau of Mines. Out of 20 plants installed for the production of magnesium powder, 16 were in operation. It was reported that more than 37 companies were producing sand casings; 13, permanent mold casings; 14, die castings; 3, extruded products; and 3, forgings.

Cutbacks in the first half of 1944 totaled about 39 per cent of installed capacity; and in November, seven plants were closed down and total output was reduced to about 15 per cent of rated capacity. In 1944, primary magnesium-producing facilities were curtailed to this extent as a result of the mounting stocks of ingot combined with decreased requirements for war materials. Curtailed production of primary magnesium for the year, at 157,100 short tons, was 14 per cent lower than in 1943; total 1944 output, making no allowance for melting losses, was 161,935 tons (in 1943, 190,025) of all primary magnesium in raw, crystal, and ingot forms. These latter figures represent metal produced directly from Dow-type electrolytic plants and "ingot equivalent" of the raw and crystalline magnesium obtained from plants using other processes.

Surplus ingot increased to about 24,000 tons in January, 1944, production being secured from 85 per cent of installed capacity; at the end of 1944, from 17.4 per cent of capacity. The WPB recommended that a reserve be accumulated equal to about two months' requirements. A series of cutbacks was started in February, 1944, and continued throughout the year as new metal continued to exceed requirements.

Incendiary bombs, for which a large part of earlier production was used, were in ample supply early in 1945, and magnesium metal was plentiful for all war requirements with only 50,000 of the total 300,000-ton capacity in

use. Incendiary bombs required about 65,000 of the total 183,584 tons produced in 1943, when consumption was 259 per cent higher than in 1942. In the latter year, consumption was equally apportioned to the aircraft industry and to casings for incendiary bombs. Production was down to 4,618 tons in July, 1945, an increase of 34 per cent above June production; in August, primary magnesium output was 4,532 tons, and secondary metal was 698 tons.

Rapid expansion in requirements of the aircraft industry in 1940 resulted in magnesium consumption 310 per cent higher than in 1938. In 1942, consumption was 43,375 tons, including 22,788 tons of magnesium-base alloy structural products, which again jumped 259 per cent in 1943, when the WPB maintained allocation control of the total domestic output in order to secure material for military use in aircraft and incendiary bombs.

Of the estimated eightyfold expansion represented by productive capacity of magnesium metal in 1944, the reduction of MgO with carbon accounted for about 8 per cent; reduction of calcined dolomite with ferrosilicon, 22 per cent; the balance came from the electrolysis of magnesium chloride, which accounted for 85 per cent of the 1943 output.

Natural magnesium compounds, including brucite, were reported by the U.S. Bureau of Mines as follows: in 1941, 137,357 tons; in 1942, 369,257; in 1943, 612,574 valued at $21,605,241. New ingot magnesium was reported as follows: in 1941, 15,528 short tons; in 1942, 47,420; in 1943, 170,267 valued at $69,960,802.

Recovery of secondary magnesium reached a high figure of 1,750 tons, in March, 1944, and 1,136 tons in April. This resulted from melting accumulated scrap in facilities previously used for alloying primary metal. Secondary magnesium recovered in 1942 was 6,283 tons; in 1943, 11,404 tons valued at $4,798,803.

MAGNESIUM COMPOUNDS PRODUCED IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Product	1943	1944
Precipitated magnesium carbonate	55,207	52,918
Pharmaceutical-grade magnesia and magnesium hydroxide	3,888*	4,694*
Magnesium chloride	640,708	525,223
Magnesium sulfate	26,710	25,316

*Not including magnesia made from magnesium hydroxide.

Magnesium chloride was produced in smaller volume in 1944, as a result of curtailed output of magnesium metal. Higher rates were reported for pharmaceutical-grade magnesium oxide and hydroxide, resulting from

greater requirements for the production of synthetic rubber in 1944. Small declines were reported by the U.S. Bureau of Mines in the 1944 output of precipitated magnesium carbonate (for magnesia insulation) and magnesium sulfate.

In 1944, techniques were provided by the U.S. Bureau of Mines enabling industry to reduce metal losses by recovering valuable constituents from magnesium drosses, powders, and dust. Losses on government-owned plants can be repaid only if postwar applications of magnesium for aircraft are adopted, in addition to broad uses proposed for railroad equipment, automobiles, refrigerators, and household appliances.

As a stockpile item, magnesium ranked twenty-first in cost of deliveries to the Metals Reserve Company, at a total cost of $6,104,401. Metal having a market value of $149,000 remained in the inventory on Oct. 31,1944. The Civilian Production Administration announced on Nov. 30, 1945, that no primary ingot remained in the government stockpile of the Office of Metals Reserve, which held secondary or processed magnesium on Oct. 31, 1945, amounting to 1,108 tons. This metal was in adequate supply for industrial needs. The first commitment by the MRC for the purchase of magnesium for stockpiling was made in 1942.

The WPB announced the second expansion program early in 1942, increasing capacity to 362,500 tons. Magnesium General Preference Order M-2-b was issued by the WPB on Nov. 14, 1941. This was to conserve and direct the distribution of magnesium until the end of 1942, when an amended order eliminated all references to preference ratings and the supply of all metal and magnesium products was allocated directly to users for an indefinite period. In order to facilitate the handling of magnesium scrap and its reprocessing, provision was made for stricter segregation of scrap in accordance with A.S.T.M. alloy designations.

On Jan. 13, 1944, the WPB issued an amended order which simplified procedure governing allocation and use of the metal and magnesium products and the segregation and disposal of scrap. Prior approval of the WPB was not required before foundries could accept the return of rejected or spoiled castings. Magnesium scrap was defined as not including sawings, grindings, sweepings, dross, and sludge containing less than 20 per cent of magnesium by weight. The aircraft scheduling unit of the Aircraft Resources Control Board was empowered by WPB Directive 34, on Jan. 17, 1944, to grant authorizations to deliver magnesium products going into aircraft and aircraft equipment.

Magnesium was designated by the WPB as sufficient for war uses plus essential industrial demands on Mar. 1, 1944. Production in the first quarter

of 1944 averaged more than 20,500 tons a month, which was closely in line with the indicated needs of industry, as reported by the WPB.

In June, two high-cost government-owned plants were shut down by the WPB, one located at Manteca, Calif. (operated by Permanente Metals Corporation), and one at Wingdale, N. Y. (operated by Amco Magnesium Corporation). Monthly production schedules at four plants had been reduced by Aug. 1, and a fifth plant shut down in order to bring surplus stock of the metal more in line with stockpile requirements. This reduced monthly output by 3,760 tons.

In October, 1944, the WPB removed all government controls on the use of magnesium for civilian products, except as to quantity of any article produced on its size. Magnesium was one of three metals (with aluminum and mercury) on which a report was given by Chester Bowles, OPA, on Aug. 23, 1945. Price controls had been suspended on those, in addition to some 400 other items on which government wartime restrictions were no longer in effect. Price ceilings were soon to be removed on scrap magnesium and magnesium castings. All forms of magnesium metal were exempted from inventory control by the WPB on Oct. 26, 1945, through the addition of magnesium to Table III of Priorities Regulation 32.

The Surplus War Property Subcommittee of the Senate Special Committee to Study Problems of American Small Business started an investigation of the light-metals industry in February, 1945. At that time, the output of magnesium had been cut back to about 15 per cent of rated capacity, while stockpiled metal was estimated at "double the necessary reserve" and "enough to last for ten years of peacetime consumption." The companies owned by Dow and Kaiser were stated to be equipped to supply total metal requirements. The largest of the government-owned plants, Basic Magnesium, Inc., was described as "the worst contract the Government ever made."

In September, the Senate subcommittee issued a report recommending extensive study of the light-metals industry. Abundance of magnesium was stated to be essential to United States leadership in aircraft production, which would be necessary for future progress and for the prevention of future wars. Government-owned facilities were stated to represent about 90 per cent of primary magnesium capacity. Disposition of these facilities should be made according to policies determined by the Congress under the Surplus Property Act of 1944. The first objective of disposal, under the act, was to assure the most effective use for the common defense.

The magnesium industry consists of three stages: conversion of raw materials into primary metal largely through the use of electric power, semi-fabrication of the metal into various forms, and final processing. Government investment of $400,000,000 was made in 13 primary magnesium metal

plants, 11 fabricating plants, and various equipment in 14 privately owned plants. An employment peak of about 50,000 was reached in 1944. The ability of magnesium plants to compete against the low-cost operations of Dow depended on securing electric rates, as well as other basic items of cost, as low as Dow's. A monopoly position was gained, in 1927, by Dow Magnesium through the withdrawal of other producers. Permanente Metals Corporation was too new a competitor and on too small a scale to demonstrate its effectiveness. Maintenance of successful competition in the future would depend on government policies of plant disposal and of promoting equal conditions of competitive opportunity.

Although the outlook for new and expanded peacetime uses of magnesium was "one of the most brilliant in the history of American industry," certain obstacles stood in the way of increasing applications under the postwar economy: (1) costs of magnesium higher than of competing metals, (2) the need for technical education of processors, (3) slowness of manufacturers and consumers in adopting newer materials, (4) restrictive effects of control of the industry by one or two producers. In 4 years, Dow had increased total assets from $48,000,000 to $140,000,000.

The Army and Navy Munitions Board recommended to Congress an optional stockpile of magnesium. Purchases of metal for stockpiling could be divided among new and present producers, giving them a cushion of production while commercial markets were being developed. Between 50,000 and 100,000 short tons of primary magnesium ingot may have been made surplus with the ending of the war. It was proposed to stockpile ingot to whatever extent it would be useful for national defense, the remainder to be marketed under regulations of the Surplus Property Board.

The Surplus Property Administrator, W. Stuart Symington, stated in his fifth report to Congress on disposal policy for individual industries, on Dec. 7, 1945, that all government-owned magnesium plants should be withdrawn from production. These accounted for about 92 per cent of total capacity, of which one-third were recommended to be held in stand-by condition for national defense. The 10 per cent owned by private capital (three plants having a rated capacity of 30,000 tons) was stated to be adequate for commercial requirements in the next few years and should be operated to meet estimated civilian needs.

The remaining 60 per cent of plant capacity should be sold or leased "for purposes other than magnesium production," dismantled, or converted into warehouse space. The plants recommended to be held in stand-by condition for emergency use had cost the government $105,400,000. These six plants, having a total rated capacity of 97,000 tons of magnesium metal a year, are as follows:

Dow Chemical Company, Freeport, Tex.
Dow Magnesium Corporation, Velasco, Tex.
Diamond Magnesium Company, Painesville, Ohio.
Magnesium Reduction Company, Luckey, Ohio.
Electro Metallurgical Company, Spokane, Wash.
New England Lime Company, Canaan, Conn.

Of these six plants, the two in Texas were under certain prior rights to Dow under its government contract. All Dow magnesium operations were consolidated in May, 1946, under a separate executive board with Dr. J. D. Hanawalt as general manager. The sea-water plant at Freeport, closed since the end of the war, was to reach full capacity in July.

Capacity to be sold or leased and "adapted to other uses," because of high production costs, included seven plants built by the government at a cost of about $264,000,000. These were as follows:

Basic Magnesium, Inc., Las Vegas and Gabbs, Nev.
Dow Magnesium Corporation, Ludington and Marysville, Mich.
International Minerals & Chemical Corporation, Austin, Tex.
Permanente Metals Corporation, Manteca, Calif.
Amco Magnesium Corporation, Wingdale, N. Y.
Ford Motor Company, Dearborn, Mich.
Mathieson Alkali Works, Lake Charles, La.

These plants, producing metal at costs ranging from 18.7 to 73.3 cents a pound, compared with the Dow cost of 12 cents, were termed the least desirable owing to high-cost operation, location, and size.

World Production, Imports and Exports. World output of magnesium metal expanded from 1,800 tons in 1925 to 103,000 tons in 1941; in 1942, 140,000; in 1943, 269,000 metric tons (eight times the rate in 1939). In Germany and Japan, the 1943 output had dropped to 28 per cent of total world production; Axis nations in 1944 were reported to be using increased percentages of magnesium in planes and other war equipment.

German domestic sources were magnesite deposits in Bavaria and potash mines of Hanover and Saxony, which produced magnesium and potash-magnesium salts. Production was principally a by-product of the potash industry. Germany maintained world leadership in production until 1943. Axis and Axis-dominated nations produced an estimated 52 per cent of world supplies in 1942. The ratio was greatly changed in 1943–1944 by expanded facilities of the United Nations. Postwar destruction of Germany's nonferous smelting industry was reported in November, 1945. The entire capacity for manufacturing magnesium in Germany was to be destroyed or removed to other countries as reparations.

In Great Britain, it was reported early in March, 1944, that high production costs led to closing down one plant and curtailing operations at two others. Magnesium Control Order 4 was issued by the Minister of Aircraft Production late in 1942. This stabilized prices for all unfabricated magnesium, magnesium alloys, billets, and slabs. Nonferrous Metals Control reported, as of Aug. 1, 1945, easing controls on raw and fabricated magnesium. Other orders remained in effect.

British magnesium production was started in 1935 by Murex, Ltd., using dolomite, and by Magnesium Electron, Ltd., using an electrolytic process under patent rights held in Germany and similar to the method employed by Basic Magnesium, Inc. Lowest costs in the Empire were secured by Magnesium Electron, operating at an annual rate of 5,000 tons. A third operator, Magnesium Metal Corporation, employed the Hansgirg process, similar to that used by Permanente Corporation. Sea-water magnesia was utilized by International Alloys, Ltd., in a process similar to the Pidgeon ferrosilicon method. In 1942, production of magnesium from magnesite was started by Lancaster Metal Subliming Company, using a direct thermal reduction of the oxide.

In Canada, dolomite was the source of magnesium produced by the Pidgeon process in a government-owned plant having an annual capacity of 3,650 tons, located at Haley's, Ontario. In 1944, the output was 5,290 tons valued at $2,575,695; in 1943, 3,577 tons valued at $2,074,652; in 1942, 404; in 1941, 2.5. Magnesium produced in Canada, Sept. 1, 1939, to Sept. 1, 1945, amounted to 13,042 short tons valued at $6,854,000. The plant at Haley's started production in August, 1942, the process for extracting magnesium having been developed in the laboratories of the National Research Council. Brucite, a source of metallic magnesium, has been mined at Gracefield, Quebec, for use in the manufacture of basic refractory brick in the lining of smelter furnaces and as an ingredient in chemical fertilizers. Canada has three magnesium foundries, located at Toronto and Renfrew, Ontario, and Montreal, Quebec. The War Assets Corporation reported the sale, on October 30,1945, of the Haley's magnesium plant to Dominion Magnesium, Ltd., for $1,400,000.

Magnesium metal in the form of powder was first produced in Canada at Trail, British Columbia, by Consolidated Mining and Smelting Company, using magnesite produced at Marysville, Fort Steele mining district. In 1941, magnesium sulfate produced in Canada amounted to 265 tons; in 1942, 1,140 tons valued at $38,760.

In Australia, magnesite was used for the production of magnesium by Broken Hill Proprietary Company, which started operating a new plant

in July, 1941. Output was stated to be almost 50 per cent of the 1,000-ton rated capacity, in 1942.

In France, German cooperation was given throughout the war years in the production of magnesium. Both dolomite and sea-water brine from the Mediterranean were used as sources of magnesia.

In Scandinavia, the magnesium plant at Heroya, Norway, was destroyed soon after its completion by an air raid in July, 1943, as reported by the U.S. Bureau of Mines. Production figures for Sweden are not available. On Mar. 1, 1944, that country abolished all restrictions on uses of magnesium and magnesium alloys, semifinished products, and magnesium ashes, scrap, and waste.

In Hungary and Austria, magnesite deposits were listed as a main source available to Germany for producing metallic magnesium. Hungarian Magnesium & Electron Company was reported in 1942 to have secured a license from I.G. Farbenindustrie, A.G., for producing magnesium metal.

Japanese sources are not reported. In 1943, two new producers were established with production scheduled for late 1944. One of these was to operate in Kwantung, China, and the other in Japan (a merger of Toa Light Metals Company and Okura Magnesium Mining Company).

Magnesium resources of the Axis powers are compared with those of the United Nations, based on comparable capacity at the end of 1941, with an-

WORLD MAGNESIUM CAPACITY IN 1941

Axis powers	Axis occupied and controlled	Total Axis	United Nations	World total
48	13	61	42	103

WORLD PRODUCTION OF MAGNESIUM, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1940	1941	1942	1943
Australia	.....	200	430	500
Canada	.....	.....	367	3,243
France	2,000	3,000	3,000	3,000
Germany	25,000	35,000	50,000	50,000
Italy	500	2,500	5,000	5,000
Japan	3,000	5,000	12,000	15,000
Norway	.....	100	2,000	2,000
Switzerland	750	1,000	1,500	1,500
United Kingdom	6,500	12,000	16,500	17,000
U.S.S.R.	1,500	4,000	5,000	5,000
United States	5,680	14,780	44,418	166,544

nual capacity in thousands of metric tons (see *World Minerals and World Peace*), in the table shown on page 296.

Prices. The prices of magnesium ingots were in effect from 1943 through Sepr. 30, 1946, at 20½ cents a pound for 99.8 per cent, carload lots; 100 lb. or more, 22½ cents a pound; extruded sticks, carload lots, 27½ cents; 100 lb. or more, 29½ cents. The New York price in 1940 was 27 cents. Dow Chemical reduced the price from $5 a pound in 1915 to $1.81 in 1918, to 69 cents in 1927, and to 26 cents in 1934.

In Britain, prices were maintained through 1944 at 1*s.* 6*d.* a pound for ingots, 1*s.* 10*d.* a pound for sticks, and 4*s.* a pound for powder.

The OPA suspended magnesium mill products from price control under Maximum Price Schedule 41, on Nov. 15, to be effective Nov. 20, 1945. This ruling followed policies approved by the Office of Economic Stabilization to permit "decontrol of goods and services when supplies balance demand" or when items are "judged to have little effect on the cost of living, the cost of business, or production of other commodities."

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MANGANESE

(Ore, Ferro-grade, Electrolytic)

Properties. An abundant but structurally complicated and peculiar metal, manganese is twelfth among the elements in primary abundance. (Mn, atomic number, 25; atomic weight, 54.93; melting point, 1260°C.) Manganese metal is grayish white, resembling cast iron; it oxidizes rapidly. Its specific gravity is 8. It ranks in atomic weight next to iron, that metal being also closely associated in nature with manganese, which occurs frequently with titanium, chromium, vanadium, nickel, cobalt, copper, and zinc. Manganese is one of the 16 industrial nonferrous metals used essentially as alloying constituents.

Production is obtained chiefly from the oxides, which usually occur in irregular masses. Of 103 minerals in which manganese occurs, only seven are considered common ores: pyrolusite, the most common and most important, which contains 63 per cent of manganese when pure (hardness, 2 to 2.5; specific gravity, 4.8); psilomelane (hardness, 5 to 6; specific gravity, 3.7 to 4.7); manganite (hardness, 4; specific gravity, 4.2 to 4.4); braunite (hardness, 6 to 6.5; specific gravity, 4.8); rhodochrosite (hardness, 3.5 to 4.5; specific gravity, 3.45 to 3.6); rhodonite (hardness, 5.5 to 6.5; specific gravity, 3.4 to 3.7); and wad, a soft earthy mixture of water and manganese oxide.

Manganese has the lowest secondary return of all the strategic metals. Little is produced in the form of the pure metal, being largely converted from the ore into ferromanganese, spiegeleisen, and ferroalloys. Only richest manganese ore can be used as a purger for the oxide formed by melting the iron preparatory to purifying it and making it into steel. It is also applied as a desulfurizer and gives desirable qualities to steel. Manganese is essential for making the low-carbon metal that comprises most of the steel tonnage. It has no substitute in producing steel, along with iron ore and coal.

Manganese ores having a minimum content of 45 per cent of manganese are required for most commercial purposes. The iron and steel industry uses ore of uniform composition, lacking those impurities which are deleterious to the finished product. In the blast furnace, the ore is objectionable if it is too soft and friable. Ferro-grade ore (35 per cent plus of manganese) is used in making ferromanganese (75 to 82 per cent of manganese, 5 to 7 per cent of

carbon); ferruginous manganese ore (10 to 35 per cent of manganese) is used in making spiegeleisen (15 to 30 per cent of manganese); manganiferous iron ore (5 to 6 per cent of manganese) is used in the manufacture of pig iron where a small manganese content is desired.

The chemical industry requires manganese for the purpose of liberating oxygen easily. The most valuable manganese mineral for this purpose is pyrolusite, which has the highest content of available oxygen. For chemical use, ore having a minimum of impurities is required. Metallurgical ore accounts for about 90 per cent of world consumption, the remainder being of chemical grade.

Uses. Larger quantities of manganese ore are required than of any other strategic mineral commodity except iron and coal. It is one of the 23 minerals and metals most vital in war production. There is no substitute for manganese in deoxidizing, desulfurizing, and recarbonizing steels. High-grade manganese is used for these purposes, at the rate of 11 to 14 per cent of the steel produced. The domestic steel industry used 600,000 tons of manganese in 1943. Standard ferro grades, the form in which manganese is generally added in steel manufacture, are manufactured from high-grade ore having a minimum content of 48 per cent of manganese.

Manganese steel, tough and resistant to abrasion, is used extensively in the electrical industry. Compared with ordinary steel, it is a much poorer conductor of heat and electricity. Manganin, a copper-manganese-nickel alloy, is widely used in heating coils and electric furnaces, owing to its high resistance to electricity. In steel rails, manganese increases the life of ordinary carbon steel five to six times.

Manganese steel had an essential use for combat service in both World Wars in the fabrication of combat suits. These weighed 28 to 32 lb. Although heavy, they were less bulky than substitute materials of laminated nylon for flak suits and glass-cloth combat jackets. Nylon flak suits for airmen weighed slightly more than 18 lb.

Manganese is added to steel in the form of either ferromanganese or spiegeleisen. In the first form, it is used more efficiently and completely and makes up 85 to 95 per cent of the manganese employed in the steel industry. Ferro grades contain about 80 per cent of manganese; standard-grade spiegeleisen, about 20 per cent. Lower grade ores can be used in making spiegeleisen, which was employed in the war years as a substitute for the ferro grades. In the First World War, 16 per cent of the manganese used in the manufacture of steel was in the form of spiegeleisen, decreasing to 4 per cent in the 1920's. A limited amount of ferromanganese can be replaced with ferrosilicon. Molybdenum steel has been substituted for high-manganese

steel, but no other material can replace the functions of manganese in the metallurgy of steel.

Manganese steel is tough and nonmagnetic, finding a wide range of uses in mining, milling, digging, rock crushing, road working, and dredging and in certain types of tool steel. The usefulness of electrolytic manganese is increasing. Manganese alloys are employed in fabricating many materials having important mechanical and electrical properties. Manganese is added to bronze and alloyed with aluminum in order to give toughness and resistance to corrosion.

Silicomanganese production, in 1943, was largely increased to replace both ferromanganese and ferrosilicon in the manufacture of killed steels. For this use, many developments have taken place in the preparation of low-grade ores from rhodochrosite in Montana and dioxide-type ore at Las Vegas, Nev. Processes have been developed for reclaiming low-grade manganese ores of the Cuyuna Range, Minnesota. Standard manganese products can now be recovered from blending low-grade high-iron imported ore with high-grade manganese nodules.

The low lime content and the high percentage of combined water in manganese make it useful as a depolarizer in dry batteries. Battery-grade manganese is produced in Montana, Africa, and Puerto Rico. Other applications are in the manufacture of welding rods and as a protective coating for steel.

The chemical industry uses 5 to 10 per cent of the manganese produced, the remainder being employed in metallurgy. It is employed as a coloring material in the manufacture of dyes, paints, and varnishes and as a decolorizer in making glass, porcelain enamel, gray and black brick, pottery, and tile. Chemical-grade ores are used largely in the manufacture of dry batteries, battery ore containing a minimum of 75 per cent of MnO_2. The salt, manganese sulfate, is used as a starting point in the manufacture of manganese carbonate, manganese phosphate, and manganese driers. Manganese salts are employed in photography, in disinfectants, and in bleachers. In limestone soils, manganese sulfate is used as a fertilizer.

Domestic Sources of Supply and Production. The production of substantial tonnages of ferro-grade concentrates from low-grade domestic manganese ores was made possible by solving the difficult concentration problem. Two classes of manganese give satisfactory results in the flotation of low-grade ores: (1) oxides, including pyrolusite, psilomelane, manganite, and wad, and (2) carbonates, including rhodochrosite and manganosiderite.

Under contract with the Treasury Department and the Metals Reserve Company, Montana and eight other states supplied 1,342,500 long tons of

manganese ore in 1940. Small reserves of high-grade ore are located in Montana, estimated at a 2-year supply; submarginal and highly speculative resources good for 100 to 500 years, at the 1935–1939 rate of consumption, are estimated by Elmer W. Pehrson, U.S. Bureau of Mines.

Since 1914, domestic mines have shipped more than 2,300,000 tons of high-grade manganese ore and more than 7,000,000 tons of low-grade. The indicated reserve of domestic ore has been multiplied more than one hundred times, it was stated in April, 1946, by J. C. Adkerson, president of American Manganese Producers Association.

Efforts have been made to increase production through the beneficiation of low-grade domestic resources. About 97 per cent of the high-grade ore used in 1940 was imported. The MRC on Dec. 28, 1942, had accumulated 741,295 short tons of foreign ores; 147,558 tons of domestic ores were held in stockpiles located in 13 states (chiefly Maryland and Pennsylvania). In addition, 15 small-purchase depots held 4,875 tons of high-grade ore and 298,973 tons of low-grade, chiefly at Las Vegas and Butte. At the close of 1943, stockpiled ore totaled 1,525,000 tons. On July 17, 1944, *The Wall Street Journal* reported that government stocks held 1,073,468 tons, including 6,548 tons of manganese iron ore, 4,960 tons of ferromanganese, and 200 tons of electrolytic manganese.

Manganese, of the 42 metals and minerals purchased by the MRC, ranked seventh in cost of deliveries to the government stockpile and was one of the first two commodities secured in 1940. Total deliveries to the MRC as of Oct. 31, 1944, amounted to $83,959,286, of which sales to fabricators were valued at $37,161,169. The Office of Metals Reserve on Oct. 31, 1945, held 939,543 long dry tons of metallurgical grade (1 million tons on Aug. 31) and 400,000 lb. of electrolytic manganese; on June 1, 1946, 1,452,359 tons of manganese ore. No battery- or chemical-grade ore was being held. The estimated civilian deficiencies were to be held under orders of the Civilian Production Administration and the remainder was to be made available for the permanent postwar stockpile. Substantial quantities of manganese ore were held by the procurement division, U.S. Treasury Department, but figures were not made public.

The postwar outlook for domestic manganese has not been improved by war activity, which depended on imported high-grade ore, and its use is subject to control by activity in the steel industry. Under war conditions, more than 100,000 tons of exceptionally high-grade manganese nodules were produced annually in the area of Butte, Mont. In the prewar period, however, domestic output represented only 3 per cent of wartime requirements, at the rate of less than 40,000 tons a year.

Output was reported in 1943 as adequate for all essential needs; and in 1944, domestic production increased to almost 20 per cent of requirements. Major producers, in 1944, were as follows: Anaconda Copper Mining Company, Anaconda, Mont.; Domestic Manganese and Development Company, Butte, Mont.; and Dominion Manganese Corporation, Waynesboro, Va. The leaching and nodulizing plant of Manganese Ore Company, Las Vegas, Nev., was shut down on Sept. 30, 1944, by the War Production Board as a high-cost subsidized operation. Adequate material from other sources was available for producing standard ferromanganese.

Manganese ore containing a minimum of 35 per cent of manganese was produced in greater quantity in 1944 than in any year since 1918. Domestic production in the war period was as follows: in 1944, 243,000 short tons; in 1943, 205,173; in 1942, 190,748; in 1941, 87,794. Manganiferous ore (5 to 35 per cent of manganese) was produced amounting to 1,430,887 short tons valued at $3,700,716, in 1941. Shipments of manganiferous ore amounted to 1,660,000 tons in 1944, largely from the Cuyuna iron range. In 1944, spiegeleisen output was estimated at 170,000 tons; in 1943, 149,036; in 1942, 186,026. In 1944, ferromanganese output was estimated at 704,000 short tons; in 1943, 702,484; in 1942, 661,338. Production and shipments of ferromanganese amounted to 530,566 and 527,468 short tons, respectively, in the first 10 months of 1945 compared with 574,924 and 587,544, respectively, in the same period of 1944.

Submarine warfare made vitally important the use of domestic manganese, of which widespread deposits are available, the average grade being 20 per cent or lower. The U.S. Bureau of Mines examined about 1,000 domestic occurrences in 1940–1944. Exploration of 46 properties indicated 26,528,000 tons of ore averaging about 12 per cent. The properties tested were located in 15 states. The source of domestic output was as follows: Batesville, Ark. (normally, the most important); Artillery Peak, Ariz.; Franciscan formation, California; Butte and Philipsburg, Mont.; Three Kids, Nev.; Olympian Peninsula, Washington; New Mexico; Utah; and Virginia.

Methods have been developed making possible the production of high-grade concentrates from domestic manganese to secure for the United States self-sufficiency for a long war, even with no foreign ore available. The charge had been made, in 1937, of the "criminal folly" in encouraging the mining of "scanty supplies of domestic manganese" by maintaining a price that was double the world price. The domestic manganese industry secured the protective tariff on the basis of national self-sufficiency regardless of external factors. In the light of conditions during the Second World War, it appears that national policy was founded on sound judgment, leading to the exploita-

tion of a domestic resource of low-grade and submarginal-grade ore that may be classed as an essential asset.

Electrolytic manganese production from low-grade domestic ores now is a fully developed and economically feasible manufacturing technique, as reported by the Bureau of Mines. Three years of processing ore from the Three Kids Manganese mine, Clarke County, Nevada, is reported to have shown it commercially suitable for treatment. Reserves at the Three Kids mine are reported at 1,225,000 tons of 19 per cent manganese ore suitable for mining by low-cost, open-pit methods, and 1,879,000 tons of 10.6 per cent ore available for underground mining. The acceptability and possible advantages of using electrolytic manganese leached from low-grade ore by cathodic deposition of pure manganese from dilute sulfuric acid solutions in steel, instead of the usual manganese, have been determined by tests undertaken with 34 different steel plants. The tests indicated the superiority of this manganese in the manufacture of stainless steel. Near Chamberlin, S. D., deposits of carbonate nodules averaging 16 per cent of manganese are estimated to contain 8 million tons of manganese available for surface mining. Electrolytic manganese is made at Knoxville, Tenn., and at Boulder City, Nev.

DOMESTIC MANGANIFEROUS RAW MATERIALS SHIPPED BY PRODUCERS IN THE UNITED STATES,* IN SHORT TONS
(After U.S. Bureau of Mines)

Year	35 per cent or more	10 to 35 per cent	5 to 10 per cent
1939	18,580	239,544	469,703
1940	30,416	358,406	914,526
1941	73,952	512,162	918,725
1942	177,966	265,663	1,500,613
1943	195,096	468,862	1,251,275
1944	241,170	296,981	1,190,476

* Not included: manganiferous zinc residuum and battery ore.

SPIEGELEISEN PRODUCED AND SHIPPED IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Year	Production	Shipped from furnaces	Imports
1939	91,491	129,755	38,264
1940	114,119	119,512	15,585
1941	177,915	181,177	4,233
1942	186,026	186,163	*
1943	149,036	150,136	*
1944	165,530	155,325	*

* Data not available.

FERROMANGANESE PRODUCTION AND IMPORTS, IN GROSS TONS
(After American Metal Market)

Year	Ferromanganese production	Manganese imports	Manganese *content of ore*	Ferromanganese *manganese content*
1939	270,111	627,129	313,810	33,414
1940	459,538	1,282,079	617,101	8,573
1941	518,486	1,530,876	736,568	5,085
1942	590,480	†	†	†
1943	627,218	†	†	†
1944	608,000*	†	†	†

* Estimated.
† Data not available owing to censorship regulations.

FERROSILICON PRODUCTION AND IMPORTS, IN GROSS TONS
(After American Metal Market)

Year	Total production	Imports
1939	323,534	1,036
1940	445,386	1,103
1941	651,432	5,527
1942	786,467	*
1943	824,509	*

* Data not available.

FERROMANGANESE PRODUCED AND SHIPPED FROM FURNACES IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Ferromanganese	1940	1941	1942	1943	1944
Produced	514,682	580,704	661,338	702,484	702,632
Shipped from furnaces	503,291	619,395	659,219	722,658	715,059

Domestic production of ore containing 35 per cent or more of (natural) manganese totaled 247,616 short tons in 1944, compared with 205,173 in 1943, and 342,573 short tons in 1918, which was the record year for the domestic manganese-mining industry. Of total output, Montana accounted for 65 per cent, Nevada ranked second, California third, and Virginia fourth. Mining of metallurgical-grade ore was active in nine other states, of which Arizona, Arkansas, and Washington were of chief importance. The only other states accounting for output amounting to more than 1,000 tons in one year, during the war period, were Georgia, New Mexico, South Carolina, Tennessee, and West Virginia.

In 1941, ferruginous manganese ore shipped from mines in the United States amounted to 512,162 short tons; in 1943, 471,593; in 1940, 358,406. In 1944, ferruginous manganese ore containing 10 to 35 per cent of (natural) manganese and amounting to 297,136 tons, was shipped from 12 states, of which Minnesota and New Mexico accounted for 75 per cent. All but 155 tons was classified as metallurgical grade. Manganiferous iron ore produced in 1944 was recovered largely in Minnesota, with 4 per cent coming from Michigan. Manganiferous zinc residuum was produced from New Jersey zinc ores. The value, f.o.b. mines, of manganese ore shipped in 1944 was $9,014,875, as reported by the U.S. Bureau of Mines.

A tariff on manganese ore imported by the United States was first levied by the act of 1922, for the purpose of expanding domestic sources of supply in case of war. The tariff act was extended in 1930 to include low-grade ores. A trade agreement with Brazil, effective on Jan. 1, 1936, reduced the levy by 50 per cent. Imports increased in spite of these tax levies and domestic output diminished from 15 per cent of all ferro-grade used in 1925, which was the maximum volume provided from domestic sources. The steel industry has made unsuccessful attempts to have the import tax removed, considering it a source of impairing the position of American producers in competition with world markets.

As a means for ensuring against shortages of critical war supplies of manganese in time of national emergency, Brooks Emeny (see *The Strategy of Raw Materials*) has proposed three alternatives: (1) Retain a low tariff on manganese; (2) raise the tariff to exclude imports, except from Cuba, in order to encourage development of low-grade domestic resources; (3) stockpile up to 1 million tons of imported ferro-grade ore, which would not interfere with tariff policy nor depress domestic or world markets, if the ore were held for use in time of critical need.

We have less than a 35-year peacetime commercial supply of manganese and twenty other minerals . . . which we shall have to import in larger and larger quantities.

This was reported in December, 1945, by Harold L. Ickes, Secretary of the Interior.

We cannot afford another prolonged war in 20 or 30 years. The prodigal harvest that we have reaped to win this war has bankrupted some of our most vital mineral resources. We no longer deserve to be listed with the British Empire and Russia as one of the "have" nations. We should be listed with the "have nots," such as Germany and Japan. Even more alarming than the fact that we are coming to the end of some of our known resources is the fact that we are uncovering few, if any, unknown deposits of minerals.

WORLD EXPORTS OF MANGANESE ORE IN 1938, IN METRIC TONS
(After *World Minerals and World Peace*)
(In thousands of tons, not including shipments of less than 6,000 tons)

1. *British India*	
To: United Kingdom	175
Japan	115
Belgium	101
France	99
Italy	51
United States	26
Germany	19
Czechoslovakia	17
Poland	8
Total	659
2. *U.S.S.R.*	
To: United States	169
France	110
Germany	61
Belgium	35
Czechoslovakia	27
Poland	16
Norway	12
Netherlands	6
Total	439
3. *South Africa*	
To: Germany	268
Czechoslovakia	33
United States	31
France	18
Belgium	16
Netherlands	10
Total	376
4. *Gold Coast*	
To: United States	129
Norway	98
Canada	18
Britain	14
Total	329
5. *Brazil*	
To: Germany	48
United States	30
France	28
Belgium	17
Czechoslovakia	16
Poland	8
Total	147
6. *Cuba*	
To: United States	134
Total	134
7. *Philippine Islands*	
To: Japan	49
Total	53

8. *Rumania*	
To: Poland	30
Belgium	18
Total	48
9. *French Morocco*	
To: France	41
Total	44
10. *British Malaya*	
To: Japan	31
Total	31
11. *Chile*	
To: Norway	11
Germany	10
Total	21
12. *Netherlands East Indies*	
To: Germany	8
Total	11
13. *Egypt*	
To: Czechoslovakia	6
Total	6

World Production, Imports and Exports. Prewar sources of high-grade manganese used in the United States included the Gold Coast, South Africa, and Cuba. Imported ore containing a minimum of 35 per cent manganese, in 1940, amounted to 1,254,674 long tons, 104 per cent higher than in 1939. Of the total, 58 per cent was supplied by U.S.S.R., the Gold Coast, and British India. Production in 1940 totaled 2,213,000 tons from India, Cuba, South Africa, and five other countries. In South Africa, the high-grade ore has been largely depleted. Both India and U.S.S.R. have very large reserves of manganese ore, the output in 1938 being 2,273,000 metric tons for U.S.S.R. and 983,000 for India; South Africa, 552,000; the Gold Coast, 329,000; Brazil, 222,000. Of the total output in that year, U.S.S.R. accounted for 44.5 per cent; India, 19.2 per cent.

In British India, largest production is secured from Madras and the Balaghat district, central provinces. Some of the world's most valuable deposits, in the central provinces, are composed of manganiferous sediments, metamorphosed manganiferous silicates. Annual output of about 1 million tons of metallurgical-grade ore is the main supply for the United States, Britain, and Canada.

Only Russia and the British Empire are self-sufficient in manganese, with tonnage available for export. China has resources adequate for domestic requirements without appreciable excess or deficiency. Italy and Japan are deficient in domestic supplies. United States, France, Belgium, Spain, the Netherlands, and Germany are almost entirely dependent on imported ore; these countries, with Britain, accounted for 75 per cent of world manganese

shipments in 1938. Europe imports 90 per cent of the consumption of manganese.

Near Santiago, Cuba, manganese output in Oriente province averaged 4,000 tons a year, 1928–1932; 40,000 tons, 1933–1936; 120,000 tons, 1937–1940. Maximum production of 306,000 tons was attained in 1943. The outlook is unfavorable for postwar production, because of lower prices and ore reserves that are almost exhausted.

Brazil has the largest known manganese and manganiferous iron-ore deposits in the Americas, located in the states of Bahia, Minas Geraes, and Matto Grosso. The governments of these states collect export taxes on manganese, although the government of Brazil does not. In the Matto Grosso, bedded deposits of the Urucum property, near Corumba, have reserves of high-grade ore, as reported by the Ministry of Foreign Affairs, estimated at 30 million tons. This property contains 45 to 47 per cent of manganese and 7 to 11 per cent of iron. Considerable capital expenditure will be required for large-scale production, the scale of operation reported in February, 1945, being 2,000 tons monthly. Although the deposits are distant from tidewater, shipment over the longest railroad into the interior of Brazil has resulted in profitable operations.

A large part of production secured from widely distributed deposits of Minas Geraes is accounted for by Companhia Meridional de Mineracao, subsidiary of U.S. Steel Corporation. Production was reported in February, 1945, to average about 20,000 tons a month from open-cut operations. Ore reserves were estimated at 4 million tons. Other mines in Minas Geraes have combined monthly output of about 8,000 tons, restrictions on production being inadequate dock facilities at Rio de Janeiro and limited railroad facilities. Although the ore is of lower quality than generally demanded by the alloy industry, substantial output has been secured during the war emergency. Large deposits of better quality than at Urucum are quarried on a large scale near Corumba, Matto Grosso, with blocked-out ore reported at 2 million tons grading about 45 per cent of manganese and up to 10 per cent of iron. At these deposits, extensive development work is rapidly leading to well-established operations. In 1942, the largest producing center was in Minas Geraes, within 270 miles of Rio de Janeiro. Of 160,000 tons of Brazilian manganese purchased by the United States in 1942, only 49,000 tons were shipped during the year as the result of submarine activity and limited shipping space available.

In Mexico, the Gavilan mine of Homestake Mining Company and the Lucifer mine, both in Lower California, produced 5,000 tons in 1941 and more than 30,000 tons in 1944. It was reported that 1,077 tons were produced

for Mexican consumption in 1941. Field work directed by the U.S. Geological Survey and the Mines and Petroleum Department, Ministry of National Economy, Mexico, has indicated the potential expansion of manganese production from 65,000 to 80,000 metric tons a year. Undeveloped deposits are located in the states of Mexico, Guerro, Coahuila, San Luis Potosi, Zacatecas, and Chihuahua.

Manganese was one of 17 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus from Mexico, Brazil, and other Latin-American countries as part of the foreign procurement program initiated late in 1940. The MRC had negotiated contracts by the end of 1942 with 10 foreign countries for imports of manganese ore, in addition to contracts for domestic output. Deliveries to the end of 1942 amounted to $33,058,000, and the value of all contracts was stated to amount to $149,453,000 for manganese. Many smaller ore deposits were reported under development in Mexico, Cuba, and Chile in 1943–1944.

Chile increased production from 12,500 tons in 1939 to about 80,000 tons in 1943; completed contracts for shipments to the United States were expected to lead to suspending work at most of the mines located near Ovalle, Catalina, Antofogasta, and at La Marquesa mine, east of La Serena, Coquimbo. Production could compete only with difficulty in prewar years with the cheap ores of Asia, India, and Africa. The War Shipping Administration announced, on Aug. 4, 1945, that Chile had resumed shipping manganese ore after a 2-year lapse. Chile supplied 17 per cent of the manganese imported by the United States in October, 1945.

In the Philippine Islands, 17,949 metric tons of manganese ore were produced in 1939; in 1940, 29,019. Up to the time of the Japanese occupation early in 1942, ore was shipped to Japan and the United States. Imported ore is delivered to the United States at ceiling prices or less and, in February, 1945, was at the annual rate of about 1 million tons.

Prior to the Second World War, United States capital controlled the major output of the Philippines and Brazil. Total Cuban production is American controlled. Production of the Gold Coast is controlled by the American-owned African Manganese Mines Company, Ltd.

British capital controls most of the manganese produced outside U.S.S.R., both political and commercial. Included are the excellent and low-cost ores of Asia, Asia Minor, Africa, and India. The last is a source of high-grade manganese imported by the United States. India, the Gold Coast, and U.S.S.R. supplied about 60 per cent of United States imports in 1940, the balance coming from South Africa, Brazil, Chile, and the Philippines. British

manganese is imported largely from deposits located within the Empire, consumption amounting to 861 tons in 1944 and 385 tons in the first 9 months of 1945. Belgium and France depend on imports, chiefly from Africa.

The Gold Coast has one of the largest known manganese deposits, located in the Wasaw district. The grade averages 48 to 52 per cent of manganese. South African production is largely from the Portmasburg district, Cape Province. South Africa supplied 31 per cent and the Gold Coast 17 per cent of the ore imported by the United States in October, 1945.

Canada had domestic output in 1939–1944 amounting to only 1,067 tons. Consumption amounted to 81,824 tons in 1944, 36 per cent higher than 1943, when imports were 51,234 tons; in 1944, 85,795 tons valued at $2,370,109. Two Canadian manufacturers of manganese ferroalloys import metallurgical ore: Electro-Metallurgical Company, Welland, and Canadian Furnace, Ltd., Port Colborne, Ontario. Three Canadian manufacturers of dry batteries import chemical ores: Canadian National Carbon Company, Toronto; Burgess Battery Company, Niagara Falls; and General Dry Batteries of Canada, Ltd., Toronto, Ontario.

U.S.S.R. has the world's largest deposits of manganese, located in the Caucasus Mountains. In prewar years, ore was stockpiled in Siberia as a reserve for the steel industries there to safeguard against the possible loss of Caucasus mining areas near Nicopol. Russian trade in the late 1930's provided fairly equitable distribution of manganese among the major world sources of supply. Export taxes on manganese have been collected by the Russian government since 1914. Production, in 1941, was estimated at about 6 million tons. Ore imported by the United States in October, 1945, included 24 per cent supplied from U.S.S.R.

German supplies of manganese, in 1943, amounted to about 350,000 tons of metal content, largely from Nicopol, the Balkans, Hungary, and South Africa. The loss of these sources reduced German supplies to about 70,000 tons in 1944, sufficient for steel output of only 7 million tons compared with the 35 million tons produced in 1943. Batelle Memorial Institute reported, in February, 1945, that Germany's supply of manganese was inadequate but Japan was believed to have sufficient ore in stockpiles. The chief sources of supply for Japan were India, the Philippines, and British Malaya. Germany developed uneconomic low-grade deposits in prewar years and built up a large stockpile of imported ore.

Stockpiles of strategic materials were termed Japan's "most terrible secret weapon." Larger manganese supplies were secured in prewar years than had been estimated by United States experts. In addition to large imports from the Philippines and neighboring areas in Asia, manganese-steel

scrap was imported in volume. Manganese ore, widely distributed throughout Japan, in prewar years was produced only on a small scale and by primitive methods.

In 1944, the Foreign Economic Administration followed the policy of withdrawing from public purchase of foreign manganese when possible, returning the trade to former private channels if no impairment to the war effort resulted. World sources of manganese had increased rather than diminished, as of February, 1945, and war supplies were usually determined by available shipping rather than by production. Postwar demands will be greatly exceeded by foreign supplies of developed ore.

The removal of export controls on imported manganese ore and concentrates and manganiferous iron ore containing 35 per cent and more of manganese was announced by the WPB on Sept. 17, 1945.

MANGANESE ORE IMPORTS FOR CONSUMPTION, MANGANESE CONTENT 35 PER CENT AND OVER
(After U.S. Bureau of Mines)

Country	1939	1940	1941
U.S.S.R.	135,243	311,748	29,183
Brazil	42,713	168,241	315,937
Gold Coast	242,923	246,983	198,907
British India	89,545	189,473	386,908
Canada	157	129	
Cuba	105,936	130,646	243,405
Chile	49	7,849	16,344
South Africa	3,401	177,739	273,749
Other countries	7,162	49,271	66,443
Total	627,129	1,382,079	1,530,876

Prices. Ceiling prices quoted on Dec. 1, 1945, by *E & M J Metal and Mineral Markets* were 35.6 to 43.1 cents a pound of contained manganese, as to grade. Electrolytic grade, 99.9 per cent of manganese, was 37.6 cents. Current prices in the open market were reported at 73 to 75 cents per long-ton unit, Sept. 30, 1946.

The price of domestic manganese ore, on Feb. 1, 1944, was $1.10 to $1.20 per long-ton unit for 48 per cent grade, f.o.b. mines. Effective on Jan. 1, 1945, the price was reduced to $1 per long-ton unit analyzing 48 per cent of manganese, 6 per cent of iron, and 11 per cent of silicon, f.o.b. Western depots of the MRC.

Domestic prices on Cuban ore, Feb. 1, 1944, ranged from 87 to 91.5 cents per long-ton unit for 45 to 51 per cent of manganese and 78.8 cents per unit

for Brazilian ore grading 48 per cent, delivered at New York, prices including duty. On sales made on basing points that are also ports of discharge of imported manganese ore, the price was f.o.b. cars at shipside, at the dock most favorable to the buyer.

The MRC reduced the price to 85 cents, on May 15, 1944, on 48 per cent ore delivered at New York, Philadelphia, Baltimore, Norfolk, Mobile, and New Orleans (duty paid), subject to premiums and penalties; 91 cents at Western depots of the MRC (Fontana, Calif.; Provo, Utah; Pueblo, Colo.). These prices continued in effect through August, 1946. The former minimum contract of 500 tons was reduced on May 15, 1944, to a single 50-ton carload, at a price to be stipulated and the MRC to pay all freight to the nearest open stockpile.

Ferromanganese, 78 to 82 per cent, was quoted on Sept. 30, 1946, at $135 per gross ton, the price established on May 1, 1942. Spiegeleisen, 19 to 21 per cent, was $30 a ton in carload lots; silicomanganese, 3 per cent of carbon, $113 a gross ton; 2½ per cent of carbon, $116; 1 per cent of carbon, $133, through Dec. 1, 1945.

Chemical grades were quoted at $55 per ton in carloads, $60 to $65 in barrels, Brazil or Cuba, 80 per cent of MnO_2. Java or Caucasus ore, 85 per cent minimum, was $70 to $75; domestic, 70 to 72 per cent, $48 to $50 in carloads, f.o.b. mines.

Price stability of manganese and other steel-alloy materials was a notable achievement in 1941–1945, in contrast to the inflated prices that were in effect during the First World War. Maximum Price Regulation 248, effective on Nov. 9, 1942, fixed prices of all metallurgical grades except battery and chemical ore. The following long-ton unit rates were applied: 85 cents f.o.b. railroad cars, Mobile and New Orleans; 90 cents, Norfolk, Baltimore, Philadelphia, and New York; 96 cents at Fontana, Pueblo, and Provo.

Metallurgical grade with 40 per cent of manganese or less was exempted from the fixed prices in Amendment 1 to Maximum Price Regulation 248 (issued Nov. 10, 1942), replacing the previous standard of 35 per cent. Amendment 2, effective on Feb. 15, 1943, exempted from price control any ore sold to a processor using it in producing spiegeleisen or ferromanganese containing less than 75 per cent of manganese or who charged it directly in the production of steel or in foundry operations. Amendment 3 clarified the term "basing point" to mean that point which resulted in the lowest cost for the buyer.

Maximum Price Regulation 138 was revised on July 1, 1943, covering ferromanganese, all types of manganese alloys, and metal, whereas the original directive applied only to standard ferromanganese. Specific maximum

prices were set for spiegeleisen, silicomanganese, manganese metal, as well as standard ferromanganese.

John W. Snyder, Federal Loan Administrator, announced in May, 1945, that purchases of manganese ore by the MRC would be discontinued after June 30, since deliveries were insufficient to warrant continued operation of purchasing depots. Ore deliveries would be purchased until Dec. 31, 1945, at Batesville, Ark., and Grants Pass, Oreg. In the first 4 months of 1945, average deliveries at MRC depots did not exceed 125 tons. Contracts were lowered to 50 tons and the MRC would pay freight charges to the nearest open stockpile or to the nearest sales point designated.

The tariff act of 1930, as corrected to Feb. 1, 1943, set the duty on manganese ore at 0.5 cent per pound of manganese contained; ferromanganese, 1 cent per pound contained. The tariff, since Jan. 1, 1936, has been 1 cent per pound of manganese contained; previously, since Sept. 22, 1922, the tariff had been 1⅞ cents.

The Canadian government and Canadian consumers, in 1944, paid $46 per long ton for approximately 48 per cent manganese ore from India, at Welland, Ontario; Gold Coast ore, at Canadian ports, was $37. Chemical-grade (battery) ore was $60 to $85 (Canadian currency) a short ton, depending on mesh and origin, finely ground ore in bags, imported from Africa and Montana.

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MERCURY

Properties. Ranking first in military value among the elements having strategic applications, mercury is a key metal in producing munitions, electrical apparatus, and pharmaceuticals and in more than 3,000 different applications. It is one of the 16 industrial nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. (Hg, atomic number, 80; atomic weight, 200.61; melting point, 38.8°C.; boiling point, 357°C.)

Mercury is a heavy, silvery white metallic element that remains liquid at ordinary temperatures. It is resistant to corrosion and is a fair conductor of electricity and heat. Its thermal conductivity is about two-thirds that of silver. Its specific gravity is 13.59. In the periodic system, mercury is classified with beryllium, magnesium, zinc, and cadmium.

Cinnabar (mercury sulfide) is the ore from which about 95 per cent of world supplies of mercury are normally recovered. About twenty-five other mercurial minerals are known, but most of them are rare. Native mercury and calomel (mercury chloride) are minor sources. Cinnabar has a specific gravity of 8.1 and a hardness of 2 to 2.5. Its color is a deep cochineal-red. Containing 86 per cent of mercury, cinnabar occurs in calcite and siliceous veins, stringers, and irregular masses in altered limestone and other porous rocks, in volcanic breccia, and in andesitic lavas from Silurian to Pliocene in age. The mercury content generally ranges from 0.3 to 3 per cent. Mercury ore is treated at the mine, and the liquid metal is shipped in iron flasks each containing 76 lb.

Mercury-mining operations are usually confined to shallow depths, and broken ore is limited to small tonnages. Favorable prices led to the reopening of properties that did not require heavy expense for equipment. Smelting equipment is of two types: (1) the furnace method, in general use, by which ore is directly exposed to the flame and the mercury passes through condensers by a continuous operation, and (2) the retort method, by which ore is heated in a closed vessel and the mercury passes into condensers by intermittent operations.

Uses. Mercury is one of 23 minerals and metals most vital in war. Strategic uses include electric batteries, fulminate primers, scientific applications, and antifouling ship paint. Fulminate of mercury, a powerful detonator, was formerly indispensable as a primer to set off the main charge

in explosive shells but has been largely replaced for munitions by lead azide and silver compounds. Mercury has few substitutes for various scientific work mainly because of its liquid form at ordinary temperatures, high specific gravity, and electrical conductivity. As a source of antiseptics and other medical supplies, the poisonous quality of the metal and its compounds is essential.

A new use for mercury in the manufacture of mercurial salts (red mercuric oxide) for Ruben dry-battery cells was announced in January, 1945. This is a cell $\frac{3}{8}$ in. in height which contains mercuric oxide and layers of zinc and paper in the form of a spiral. It has a life five times that of the standard flash-lamp battery. Wide applications of this battery were made by all branches of the armed forces, particularly in small radios such as the walkie-talkie. This was regarded as being a major development for war application in signal devices, as well as offering important peacetime uses. Large-scale military production of the new dry-cell battery and the use of mercury for chemical-warfare purposes resulted in maximum consumption of mercury in the first 4 months of 1945.

The Ruben dry-battery cell was applied as the power unit of several miniature devices of great strategic value in munitions. In the VT fuse (variable-time radio-proximity fuse), mechanical accuracy was made possible for antiaircraft fire and for shooting down the Nazi V-1 bombs launched across the English Channel. A radio transmitter, receiver, and detonating mechanism were embedded in the nose of the shell. Accuracy of fire, which led to such records as bringing down 79 per cent of all V-1 bombs launched in the last week of July, 1944, was made possible by broadcasting a continuous radio wave which reflected back from the target to be picked up by the shell's receiver. The shell was automatically detonated at the instant when the greatest damage to the target would result.

About 30 per cent of the total consumption of mercury was, formerly, in metallic form, and the remainder was used in chemical compounds which resulted in complete loss of the metal. The pigment vermilion is mercury sulfide, employed in paints and printing inks; the oxide is used in antifouling paint for marine applications. For the latter purpose, the Navy made large purchases in 1941–1945. Some antifouling paints contain no mercury. The paint requires about 11 oz. of red oxide of mercury to each gallon, the salt water converting the oxide to poisonous bichloride, which kills marine growths. Mercuric nitrate, formerly employed in the manufacture of felt, was replaced by a substitute in 1941, because of danger to the health of the workers. Cadmium red is used as a substitute for vermilion pigments and copper oxide in painting merchant-ship bottoms, but not for naval use.

The use of mercury as a catalyst for war materials led to greatly expanded requirements, and this application is expected to be employed in other fields in the postwar period. In the manufacture of low-melting-point bismuth solder, the addition of 10 per cent of mercury and 0.6 per cent of gallium gives a fairly strong alloy that melts at about 57°C. Mercury is also important in the electrolytic preparation of chlorine, caustic soda, acetic acid, and acetone. In the mildewproofing of both fabrics and leather, in shine control for the pulp and paper industry, in boiler compounds, and in wood preservatives, there has been general acceptance of organic mercury compounds.

Other applications include the following: in the manufacture of mercury salts, thermometers, mirrors, and lamps (mercury-vapor and fluorescent); in the manufacture of electrical and chemical apparatus; in automatic electrical contacts and switches, mercury arc rectifiers, thermostats for oil burners, and cathodes for electrolytic chemical processes. Mercury is essential in control devices for regulating traffic lights, electric signs, and various industrial instruments. Increasing use is made in mercury-vapor boilers to replace steam in generating power. Commercial power plants, in 1935, were using about 10,000 flasks of mercury, requiring about 35 lb. of mercury per horsepower. These installations using both mercury vapor and steam are reported to operate at an efficiency exceeding that of diesel engines. Mercury boilers are economical only in large installations, the smallest in the United States having a capacity of 10,000 kw., requiring about 65 tons of metallic mercury.

Metallic mercury enters into the manufacture of scientific and industrial instruments, bearing metals and solders, and mercury cathodes for electrolytic cells in producing chlorine and caustic soda. About 1 lb. of mercury per ton of caustic soda manufactured is lost in the process. In the manufacture of glacial acetic acid, the mercury used is converted to a salt and acts as a catalyst for the reaction. The foremost use, up to 1890, was in the recovery of gold and silver from their ores by amalgamation; cyanide and flotation have now largely replaced this method. It used to be said: "You need a quicksilver mine to run a gold mine." Mercuric fulminate in blasting caps remains an essential material in all mining operations. Prewar uses were mainly in the heavy chemical industries, and for dental, medical, and pharmaceutical purposes, the most important drugs being calomel and corrosive sublimate.

Postwar uses of mercury are not expected to lead to large-scale substitutions by other materials unless unfavorable costs develop. For certain purposes, there has been a trend to substitutes, particularly for blasting caps and in the felt industry. Substitutes have also been adopted for certain pharmaceutical purposes. The Ruben battery is expected to be a major peacetime

application. In addition to the greatly expanded application for the Ruben battery, notable gains have been shown for electrical apparatus and instruments and control devices.

Domestic Sources of Supply and Production. Mercury was one of the materials placed under export control by the President on July 2, 1940. This resulted in diverting many shipments to the British Empire from Japanese consignment. Higher prices led to increases in domestic output and eased the critical problem of supply. Established producers expanded operations; idle properties were reopened; and production was started at new properties. The rate of domestic production is a function of price, a time lag of one to two years being required for output to respond to stimulated market demands.

In 1943, production exceeded domestic output for any year since 1882 (peak output was 79,395 flasks in 1877), as reported by the U.S. Bureau of Mines. Price increases, in November, 1944, were followed by an acute shortage of "free" metal. It was necessary to draw from government stockpiles to meet war requirements. Average monthly production in the war period was as follows: in 1942, 4,237 flasks; in 1943, 4,327; in 1944, 3,108; in 1945, 2,550. Mercury production dropped to 1,200 flasks in October, 1945, less than the average monthly output for any year since 1933.

Consumption in 1943 was 54,500 flasks; in 1944, 42,900; in 1945, 63,900, of which about one-third came from domestic sources. Consumption in May, 1945, was 8,900 flasks compared with the previous record of 6,200 flasks in October and November, 1942. Monthly consumption, in September and October, 1945, was 3,100 flasks; in November, 2,500.

DOMESTIC PRODUCTION OF MERCURY (METAL), IN FLASKS
(After U.S. Bureau of Mines)

1939	1940	1941	1942	1943	1944	1945*
18,633	37,777	44,921	50,846	51,929	37,688	30,600

* Preliminary.

Mercury was recovered from many new developments of small deposits located in the Western states in 1943, when two-thirds of domestic output was supplied by California, where the New Idria mine was of foremost importance. In 1944, the Abbott mine, Lake County, increased production by 89 per cent and moved into third place; fourth place was held by the Mt. Jackson mine, Sonoma County, 1943–1944. In the second and third place as producers, in 1943, were the Hermes and Bonanza mines, both located in

Oregon, but lower output was reported in 1944. In 1945, California produced 72 per cent of total domestic mercury, followed by Oregon. There were not more than three producers each in Oregon, Idaho, Arizona, Arkansas, Texas, and Alaska.

As evidence of the greatly expanded domestic mercury-mining industry, S. H. Williston reported that of the 17 mines producing in 1945, only one had appreciable output, from old dumps, in 1936. Furnace feed, in 1937, had a grade averaging 6 lb. per ton, which was about one-third the average grade reported in 1945. Mercury mines in California produce about 70 to 75 per cent of the nation's total.

Mercury and tungsten were the only strategic mineral products in which the United States was self-sufficient in the war period. Mercury is rated as a deficient mineral, however, owing to the fact that commercial reserves of ore are adequate for only 3 years at the prewar rate of usage, as estimated by Elmer W. Pehrson, U.S. Bureau of Mines. The United States now has less than 5 per cent of the original reserves. Submarginal and highly speculative resources are good for 5 to 25 years at the annual rate of consumption, 1935–1939. These submarginal resources are considered to be available in terms of prewar consumption under emergency conditions only and at a high price.

Although the Pehrson estimates have been sharply criticized by mercury producers, as well as by other branches of the domestic mining industry (blocked-out reserves at three Western mines were stated to exceed 75,000 flasks), the sharp decline in output, 1944–1945, appears to demonstrate that various factors are unfavorable for domestic competition with foreign producers of quicksilver. Postwar demand is expected to be about 50 per cent greater than prewar consumption, owing to the broad uses indicated for the Ruben battery.

At the close of 1943, demand was sharply lower, and the War Production Board announced that mercury was available for 2 years at the current rate of consumption. Government purchasing was withdrawn in January, 1944, when inventories in government hands amounted to 69,852 flasks. Government stocks had increased to about 100,000 flasks at the end of September, 1944. Attempts to increase production in line with stimulated demand, in December, 1944, were prevented by the labor shortage. The WPB announced, on Dec. 1, 1944, that the Metals Reserve Company would release mercury from the government stockpile for filling orders for war materials and for essential civilian requirements.

The mercury-conservation order, in effect since Dec. 28, 1941, was eased in September, 1943, and finally withdrawn in February, 1944. General Import

Order M-63 was issued by the WPB in July, 1944, withdrawing all restrictions on mercury.

Conservation Restriction Order M-78 was issued on Jan. 23, 1942, restricting the use of mercury for certain purposes and discontinuing its use for certain others. Further restrictions were imposed in August, 1942. Increased supplies made it possible to relax M-78 on Sept. 9, 1943, and the use of mercury was allowed for antifouling paint, for preparations for developing film, for thermometers, for the treatment of green lumber, for wall switches, and for vermilion, wood preservatives, mercuric fulminate for commercial blasting caps, and industrial and scientific thermometers. Order M-78 was revoked on Feb. 2, 1944.

The MRC started stockpiling mercury in 1941. The inventory, on Oct. 31, 1944, was valued at $6,049,450, the total cost of deliveries to the MRC being $19,655,110. Mercury amounting to 63,638 flasks was being held in stockpiles of the Office of Metals Reserve on Oct. 31, 1945, and the Civilian Production Administration estimated, on Nov. 30, 1945, that mercury supplies adequate for the needs of industry were available. The total value of government stocks showed mercury ranking thirteenth among metals and minerals accumulated by the MRC. In order to accommodate essential war orders, mercury was ordered released from the stockpile in December, 1944. Spot mercury purchases by the MRC from current domestic production was started in April, 1942; in July, purchase depots were set up. The MRC projected purchase agreements to the end of 1944, subject to prior termination, for the purpose of sustaining the price at satisfactory levels. The buying program was terminated on Jan. 31, 1944.

In Alaska, the purchase period was extended by the MRC to Dec. 31, 1944, and again to June, 1945, when the remaining material was sold to private industry at those depots located at Fairbanks, Anchorage, Seldovia, and Nome. The disposal included stocks of four other minerals, as reported by the Territorial Commissioner of Mines. In Alaska, the major producer, the New Idria-Alaska mine, had ore reserves amounting to 66,000 flasks, as reported on June 31, 1944, by the U.S. Bureau of Mines.

Mercury was one of three metals (with magnesium and aluminum) reported to be in good supply on Aug. 23, 1945, by Chester Bowles, Office of Price Administration. Government wartime restrictions were removed on prices and production of mercury, as well as on some 400 other items.

Stocks held by consumers and dealers at the end of July were three times those on Jan. 1, 1945. Inventories of producers were also at high levels. Mercury was in adequate supply for industrial needs on Nov. 30, 1945, as reported by the CPA.

The exclusion of mercury imports from both Spain and Italy caused a major setback in securing adequate supplies of this material for Second World War requirements. Dependence on domestic supplies became a critical factor after shipments from Europe were stopped by the submarine blockade and by the occupation of Italy by the German army, a fact that emphasized the need for conserving domestic resources for some future emergency. The record of the Second World War demonstrated the fallacy of the statement by Brooks Emeny, in 1934 (see "The Strategy of War Materials"): "Our relations with the two other world producers would [not] seem to warrant much concern over our strategic situation in . . . regard [to mercury]."

DOMESTIC CONSUMPTION OF VIRGIN MERCURY, IN FLASKS OF 76 LB.
(After U.S. Bureau of Mines)

Uses	1943	1944	1945	1928
Pharmaceuticals	14,563	8,358	11,133	14,000
Dental preparations	556	442	513	
Fulminate	3,142	1,890	1,133	6,500
Munitions (other than fulminate)	1,286			
Agriculture (includes disinfectants and fungicides)	1,632	3,930	2,863	
Antifouling paint	2,702	2,439	1,661	
As a catalyst or in electrolytic preparation of				
Chlorine and caustic soda	691	657	632	1,000
Acetic acid	1,995	1,981	1,111	
Other	2,437	2,783	2,543	
Electrical apparatus	3,284	7,092	24,468	2,500
Industrial and control instruments	3,674	3,249	3,250	3,000
Amalgamation	24	29	183	500
Laboratory use	360	265	309	500
Redistilled	5,384	6,613	9,647	
Other	11,241	2,236	2,635	7,000

Harold L. Ickes, Secretary of the Interior, said in December, 1945:

We just haven't got the mercury . . . to afford another prolonged war in 20 or 30 years. The prodigal harvest of minerals that we have reaped to win this war has bankrupted some of our most vital mineral resources. We no longer deserve to be listed with the British Empire and Russia as one of the "have" nations. We should be listed with the "have nots," such as Germany and Japan. Even more alarming than the fact that we are coming to the end of our known resources is the fact that we are uncovering few, if any, unknown deposits of minerals.

World Production, Imports and Exports. World output in 1940 included about 70,000 flasks each for Spain and Italy, of which Germany im-

ported less than 42,000 flasks for use in the installation of new plants for the manufacture of artificial rubber. German consumption, at least for 1940–1941, was approximately two and one-half times the average prewar rate.

United States imports, in 1940, amounted to 4,708 lb. of mercurous chloride, oxide (red precipitate), vermilion red, and other preparations, the total value of imported mercury compounds being $54,084 compared with $48,643 in 1939. General imports amounted to 19,819 flasks in 1944; in 1945, 71,508. An all-time record was made by imports in 1945, 49 per cent higher than the 47,805 flasks valued at $8,543,953 imported in 1943. Exports, amounting to 1,038 flasks in 1945, usually represent very small quantities shipped to some 50 countries.

MERCURY IMPORTED INTO THE UNITED STATES, IN FLASKS
(After U.S. Bureau of Mines)

Country	1940	1941	1942	1943	1944	1945
Canada	...	785	7,400	15,382	1,565	1,720
Chile	...	.....	1,409	2,660	981	750
Honduras	...	.....	.....	.....	.....	23
Mexico	127	6,851	29,917	29,457	17,221	13,083
Peru	...	.....	.....	107	52	185
Spain	40	104	.....	.....	.....	55,747

In prewar years, mercury was supplied chiefly by Spain, Italy, United States, U.S.S.R., Austria, Mexico, and China. It was one of the six raw materials exported from Europe. Prewar output was at the annual rate of 5,500 metric tons. Italy accounted for 44.4 per cent of world output in 1938; Spain, 28 per cent, followed by the United States and U.S.S.R. Production was also reported from Czechoslovakia, Japan, Chile, and Peru.

Spain, Italy, and China are the only world powers in a position to produce sufficient mercury for domestic requirements and to have additional supplies for export. United States and U.S.S.R. have a deficiency in domestic supply. Great Britain, France, Belgium, the Netherlands, Germany, and Japan all are dependent on imports from foreign sources.

In Spain, mercury deposits are owned by the state and are under absolute political control. The Almaden deposits have been traced for 7 miles and to a depth of 3,000 ft., the deepest mine workings being down 1,700 ft. The metal content averages 5 to 7 per cent compared with slightly more than 1 per cent in Italy and about 0.4 per cent in California. Wages paid mercury miners in Spain were reported in 1945 to be less than one-tenth of those prevailing in California. Mining and roasting costs in Spain were the equivalent of only $14 a flask. Present mine capacity is estimated at 10,000 flasks a month, giving

irregular employment to about 2,000 men. Records of mine production date back to 1546 and show the value of total output exceeding $250,000,000. Not only are the Almaden mines the world's largest, but they have been worked longer than any other mineral deposit with the possible exception of the Rio Tinto and Tharsis tin and copper deposits in western Spain.

In Italy, private producers control mercury deposits, but the state licenses all exports. Elsewhere, nationals of producing countries control the output. Italian mines held 26,500 tons of mercury in stock on Sept. 30, 1945, when it was reported that production had been resumed. In Europe, the commerce of mercury, unlike most other minerals, is largely local.

U.S.S.R. placed an urgent order in the United States in 1942 for large supplies of mercury. The Donets basin, principal source of Russian mercury, was occupied by the German army. Exports from the United States to Russia were officially reported at almost 21,000 flasks, October, 1942, through February, 1943, and additional shipments were made to the end of August, 1943.

Mercury was one of 17 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire surplus of exportable mercury from Mexico and other Latin-American countries, as part of the foreign procurement program initiated late in 1940.

In Mexico, production increased from 11,653 flasks in 1940 to an average of 18,000 flasks a year for the period 1941–1943. The entire 1941 output was exported except for 8 of the 877 metric tons. Combined output of 7,200 flasks a year was secured in the war period from Nuevo Mercurio and Sain Alto mines, state of Guerrero. The price break in 1944 resulted in suspending operations by marginal producers.

Canadian output from newly developed deposits in British Columbia was estimated to be ample for total empire requirements, amounting to 22,240 flasks valued at $4,559,200, in 1943; in 1944, 9,682 flasks valued at $1,333,516. Total production of mercury in Canada, Sept. 1, 1939, to Sept. 1, 1945, amounted to 54,640 flasks valued at $10,419,622. Canada is in a position to maintain production higher than the 1943 rate, if demand holds. The Pinchi mine, Omineca mining division, has mill capacity of 1,200 tons per day, larger than any other single producer in North or South America. Limited market outlets held production to a daily maximum of about 400 tons, and operations ceased in July, 1944, the MRC contract having been canceled in September, 1943. The Takla mine produced from November, 1943, to September, 1944, when the contract with the MRC was canceled. The Takla is located on the Pinchi fault, 85 miles northwest of the Pinchi mine. Good ore possibilities are reported elsewhere along this major regional structure. Canada imported 27 flasks in 1943; in 1944, 466.

MERCURY PRODUCTION IN CANADA, IN FLASKS
(After Dominion Bureau of Statistics)

1940	1941	1942	1943	1944
2,024	7,057	13,630	22,240	9,682

Requirements of Australia and New Zealand are normally supplied by domestic production, the Puhipuhi and Ngawha deposits in Aukland being of some importance. These cinnabar occurrences are developed by open-cut methods, and the product is refined before shipment. Future supply from these, as well as from North and South American deposits, is believed to be a direct function of price.

World output of mercury in 1938 was distributed as follows (after *World Minerals and World Peace*): Italy, 66,800 flasks; Spain, 42,100; United States, 18,000; U.S.S.R., 8,700; Mexico, 8,500; Czechoslovakia, 2,900; Germany, 1,750; nine other countries, 1,730.

In Alaska, postwar expansion in mercury output (one of nine minerals accounting for 5 per cent of total mine output from the territory) can be secured through systematic development, as reported on May 7, 1945, by the U.S. Geological Survey.

In February, 1945, Metal Traders, Inc., New York, N. Y., announced that Almaden mines of Spain would supply mercury to the United States as soon as shipping space could be provided. Spain and Italy, controlling 87 per cent of world supply, began marketing mercury in 1928 through Consorzio Mercurio Europeo Bureau de Venta, Lucerne, Switzerland. World quotas and markets were allocated at annual meetings. This mercury cartel established uniform prices and a quota system in which Italy held about 40 per cent and Spain about 60 per cent of world markets. In both countries the producers were either owned or controlled by the government. Prices were largely the result of cartel policy of taking maximum profits in world markets. The major prewar market was in London (until early in 1940), where production from Italy and Spain was sold. Mercury produced in the United States and Mexico was sold chiefly in the New York market.

Axis powers secured almost the entire Spanish-Italian output after 1939. Japan acquired a substantial mercury stockpile before Pearl Harbor and purchased "bootleg" mercury and other metals at inflated prices in Mexico until late in 1941. The large amount of metal in transit from Spain to New York, in March, 1945, had a depressing effect on prices.

In 1944, the Foreign Economic Administration followed the policy of withdrawing when possible from public purchase, returning the trade to former private channels if no impairment to the war effort resulted.

Prices. The price of mercury (quicksilver) on Jan. 1, 1946, was $108 per 76-lb. flask, 100 or more flasks compared with $106.87 in November; $101.39 in October; $95.84 in September; $123.20 in August; $140.72 in July; $156.84 in April; and $165.55 in February. Average prices quoted by the *Engineering and Mining Journal* in 1946 were as follows: $99.40 in June; $98.308 in July; $97.556 in August; $96 on Sept. 30.

American Metal Market records yearly average prices as follows: in 1944, $120.26; in 1943, $196.28; in 1942, $198.32; in 1941, $186.78; in 1940, $179.54; in 1939, $107.09; in 1938, $75. Prewar control of mercury prices was in the hands of the Spanish-Italian cartel, which doubled the rate in the first week of September, 1939.

The United States purchased Spanish mercury at upward of $250 a flask, prior to 1944; in London, the price of Spanish quicksilver was maintained at the equivalent of $279. Following the Allied occupation of Italy and France, supplies were purchased from Spain at the prevailing market quotation down to $110 a flask.

The Metals Control, London, reported the price of quicksilver at £69 15*s.* per flask, on September, 1945.

A duty of 25 cents a pound was set for mercury by the tariff act of 1930 and the revenue bill effective on June 21, 1932, as corrected to February, 1943, with revisions resulting from all reciprocal trade agreements. Specifications call for a minimum of 99.5 per cent of mercury, the antimony and arsenic content not to exceed 0.3 and 0.1 per cent, respectively.

The tariff on mercury imports made it possible, in prewar years, to produce a small part of domestic requirements in competition with Spain, Italy, and other low-cost areas. The view is offered by opponents of the tariff that domestic mercury resources should be conserved for use in time of national emergency, depending on low-cost foreign material for normal peacetime requirements.

No organized exchange existed in prewar years for marketing domestic mercury, which was dealt in largely by brokers using methods similar to those employed in marketing antimony, manganese ore, and tungsten. San Francisco was the primary market where mercury was handled by agents and brokers; shipments were made to New York for distribution to large consumers on the Atlantic seaboard.

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MICA: AMBER PHLOGOPITE AND MUSCOVITE

(Block, Splittings, and Films)

Properties. Essentially silicates of alumina with potash and hydroxyl, the micas are common rock-forming minerals. Mica contains various characteristic elements. Unique properties giving special value for application in industry include perfect cleavage, transparency, and lack of color in thin sheets. No other mineral and no artificial substance combine similar properties of flexibility, elasticity, toughness, nonconductivity of heat and electricity, and resistance to chemical decomposition, high temperatures, and sudden temperature changes. Their hardness is 2 to 3 ("silver amber" mica has the same hardness as copper).

A mica crystal, or book, is capable of being split into extremely thin films. A single book may yield two or three different qualities. Spotted or stained muscovite mica has dark inclusions (usually iron oxides) which reduce the quality but leave the material efficient for use in low-voltage electrical apparatus. Color alone is not a sure criterion of value. The power factor of clear mica, of green or other dark colors, varies widely. Any clear ruby-colored mica is satisfactory for use in condensers. Mica that is unsuitable for condensers may have other important strategic uses.

Both block and punch micas of strategic quality, prepared in accordance with domestic standards, were in huge demand for war requirements. Blocks were required to be sound, level, and reasonably free from splits, knife cuts, creases, wavy laminae, and rock punctures, with edges not shattered or opened.

Specifications of strategic mica were modified to make acceptable slightly stained, good-stained, and heavy-stained grades for strategic applications, owing to the high degree of flexibility. The staining is due to minute air bubbles. For high-grade condenser uses, a low power factor is essential; for generators, dielectric strength and resistance to heat are required; for aviation spark plugs, flexible phlogopite having high heat resistance is used. Mica will withstand temperatures up to 600°C. without appreciable change.

Muscovite (white, greenish, ruby, or smoky-brown potash mica) is the most valuable and most extensively mined. The highest grades are clear or slightly red stained. Phlogopite (amber to greenish magnesia mica) is less transparent than muscovite and is graded according to color ("light silver,"

"dark silver," and "wine amber"). Muscovite and phlogopite, the two varieties of commercial sheet mica, occur only in pegmatite dikes. Because of its low dielectric strength and hardness, black phlogopite has little value for electrical uses.

Other varieties of mica include the following: biotite (magnesia-iron mica), which grades into iron-rich phlogopites having black color, brittleness, and lack of ready cleavage, chiefly used as grinding scrap; vermiculite (hydrated biotite), marketed under the trade name "zonolite," as heat-insulating, sound-deadening, and paint materials; lepidomelane (high in ferric iron), used as scrap; lepidolite (lithia mica) and zinnwaldite (lithia-iron mica), both of which are sources of lithia, the former being used in glass manufacture. Roscoelite (vanadium mica) is an ore of vanadium, of which it contains an average of 1.5 to 5 per cent. Mica, although one of the commonest minerals, rarely occurs in deposits having commercial value.

Block mica of strategic value must be free of imperfections, such as cross grains, cracks, reeves, and ribs, which cause the mineral to split unevenly. It must be free of mineral inclusions, such as black spots, mineral stains, or streaks, which reduce electrical resistance and raise the power factor. Mineral staining renders the mica unfit for use in electrical condensers.

Foreign production of mica for the export trade is chiefly in the form of sheet, of which there are three grades: (1) uncut punch, (2) uncut larger than punch, and (3) splittings. The last are used in the manufacture of "boards." These are made by cutting and gluing together mica films according to any specified thickness, size, and shape.

Uses. Mica is an essential mineral in modern war. In the electrical industries, muscovite and phlogopite are indispensable because of their unique value as insulators in all forms of electrical equipment and appliances, particularly for aircraft, automobiles, and radio. Increasing application is reported as an insulator in electronics equipment; limited application of flawless sheets is made in marine compass dials, boiler gauges, and iconoscopes of television transmitters. Major strategic applications were in aviation spark plugs, radio and condenser films, and bridges in radio tubes.

While high-grade ruby sheet mica from India continued to be the most suitable for radio condensers, a development essential to the defense program was the successful adaptation to this purpose of the hard, green "black mica" (dark-stained muscovite) produced in North Carolina, which supplies mica suitable for stove fronts and furnace peepholes. Georgia produces a flat, brown variety of muscovite which, formerly, was used as diaphragms in phonographs. Scrap, ground, and the poorer qualities of block mica are not classified as strategic.

Military equipment required increased supplies of high-grade block sheet and splittings. Mica sheets, washers, tubes, and plates were applied in a great variety of electrical equipment for essential war purposes. High-grade sheet was used for naval conning towers, goggles, and lamp chimneys. Built-up mica board was applied for many electrical purposes to replace the less available sheet mica. Built-up board is suitable neither for high-grade condensers for radio transmitters nor for high-tension magnetos.

The war program required mica in the following forms: transmitting, receiving, and trimmer condenser films; radio-tube bridges and supports; cigarette films and washers for aircraft spark plugs; and magneto condenser films. Cigarette mica consists of films less than 1.2 mils in thickness that can be rolled around a ⅛-in. spindle without cracking or tearing; the films must be free of pinholes and hairline cracks. Trimmer condenser films require a power factor of 0.03 per cent or less. Dielectric mica is required to withstand a minimum of 1,000 volts per mil of thickness of 4 to 6 mils when tested with 2-in. plate electrodes.

As an insulator for certain types of electrical equipment, only high-grade phlogopite is adaptable. It is needed in the manufacture of armatures for electric motors, for separating the copper segments of the commutators. High dielectric strength is required. The mica must be free from iron impurities, holes, or cracks.

Whereas the major consumption of nonstrategic ground mica is for roofing, paint, rubber, and wallpaper, the Army and Navy, in May, 1945, were making important use of this material for airfield landing mats. Lesser amounts were employed in the manufacture of such essential products as welding rod and glass-bonded electrical insulating material.

Mica powder, or fine flake, is made from muscovite, phlogopite, and biotite. Several plants manufacture this product, chiefly for the roofing and rubber trades. Corrosion-resistant paints use this powder, which also goes into resin varnishes for coating cans used as food containers. It is applied in ceramic-type insulation under the trade names "mycalex" and "mykroy" and in plastics and resin-bonded, molded insulation. In foundry work, mica powder is employed as a mold and core wash. Coarser grades find use in oil-well drilling, to prevent circulation loss of the drilling fluid.

Vermiculite, under the trade name "zonolite," had an important wartime application for thermal and acoustic insulation. When combined with bonding materials, vermiculite is fabricated into pipe covering, insulating blocks, plasters, tiles, and structural roof slabs. As a lightweight aggregate in concrete, vermiculite has been largely employed for cast slabs used in the construction of prefabricated houses and for the decks, roofs, and fire walls of

ships and buildings subject to bombing attack. In aircraft and automobiles, plastic insulation containing vermiculite is employed as soundproof material and as a heat insulator for covering boilers and refinery columns. A distinctive property of this variety of mica is the swelling, when it it heated, into an exceedingly lightweight, accordionlike form which has a specific gravity of only 6 to 8 lb. per cu. ft. It is comparatively refractory and has low conductivity for heat and sound. It is a substitute for rock wool and glass wool, having increasing application for insulating buildings, ovens, furnaces, and refrigerators.

Scrap mica, mainly required by the construction trades, is the product used, normally, in greatest quantity in the United States. Formerly, scrap was obtained from the waste produced in trimming sheet mica; in 1935, it made up 65 per cent of the domestic output of ground mica. The material is used for both wet- and dry-ground mica, including the by-product material recovered in washing kaolin or kyanite.

A new apparatus was developed by the National Research Council to test the power factor of mica as well as the presence of conducting veins and spots. Various lower qualities of mica were shown by tests to be as satisfactory as the standard grades. Bell Telephone Laboratories, in 1943, developed a direct-reading *Q*-meter and a point-electrode conductivity tester for the purpose of determining the power factor and the electrical conductivity of sheet mica. These instruments had the effect of conserving material for exacting electrical applications, which formerly had been rejected on the basis of visual inspection.

Although no satisfactory substitute has been found for mica in certain spark plugs and aircraft and in condensers, radio tubes, and certain electrical generating and motive equipment, it is reported that excellent electrical insulating qualities are offered by "alsifilm." This material, prepared from bentonite clay, can be made in very thin, translucent, flexible sheets. As a part substitute in high-tension condensers, "pertinax" was developed in Germany in the First World War. It is described as having only slight importance as a substitute for high-quality mica. In the Second World War, Germany was reported to have developed a commercially feasible process for making synthetic mica.

Lower grades of sheet mica for electrical insulation were replaced by treated paper or specially prepared fabrics. Shortage of supplies of clear mica led to successful use of low-grade, stained types for various purposes.

Domestic Sources of Supply and Production. The United States, normally both the world's largest tonnage producer and consumer of mica, has for some years been self-sufficient in scrap mica. Only 15 to 35 per cent of

domestic requirements of sheet mica are available within the country. In 1938, 18.4 per cent of world mica production was secured from domestic sources, consisting chiefly of scrap, ground, and waste grades. High-grade mica splittings were almost entirely imported from foreign sources, which also normally supply about 75 per cent of domestic requirements for the grade uncut larger than punch. Of the latter grade, domestic production was stimulated by high prices, in 1925, to supply more than 1 million pounds, which was only slightly less than normal domestic consumption.

More than 75 per cent of the sheet mica produced within the United States has been supplied by North Carolina and New Hampshire; minor amounts are secured from six other states (Colorado, Connecticut, Georgia, Maine, New Mexico, and South Carolina). Enormous unexploited reserves are stated to be available in Colorado. "With prices of mica that would induce capital to invest in mica mining, a domestic production, sufficient to meet the principal demands of this country for sheet mica, could easily be met and maintained for years," stated F. W. Horton, U.S. Bureau of Mines, in 1929, before the subcommittee of the Senate committee on finance.

In 1940, the built-up mica industry was working at capacity; consumption of sheet mica reached a new high level about double the 1939 figure. Domestic output of biotite in 1940 was insignificant; muscovite was lower than in the peak years 1920 and 1929.

Sales of scrap mica for grinding and other domestic grades increased in 1944, when five scrap-mica plants were built in North Carolina. Demand for ground mica was so active that several additional kaolin-producing plants in the Spruce Pine area of North Carolina added mica-recovery equipment.

The bulk of production in mica mining comprises scrap suitable for grinding and low-value punch grade. Recovery of usable block mica makes up a very small part of total output. Raw block mica commonly composes only 2 to 6 per cent of the total rock produced, most of which grades as punch and circle and only a minor amount as rectangular block.

The marketable product of domestic sheet-mica mining may run as low as 1 per cent. In India, the high uniform quality results from handling by skilled cutters and graders, whereas in the United States and Canada, poorer dressing often results in low prices and rejection of a large part of the output, which is sold as rough trimmed or poorly knife trimmed. Block muscovite is graded as clear, slightly speckled or stained, and heavily speckled or stained.

Muscovite and phlogopite are split to meet specifications calling for a thickness of not more than 1 mil (0.001 in.). The dark-colored, iron-rich micas are not satisfactory for splitting. Scrap that has no value in the form of sheet is ground into powder by both wet- and dry-grinding methods. The manufacture of mica powder is almost exclusively an American industry.

In 1944, domestic commercial shops installed a mechanical device for trimming mica by means of a fine-toothed band saw. A bevel or bias cut could be secured by inclining the mica at an angle to a base plate on the machine. The Bureau of Standards reported on two devices for making mica splittings by other than hand-knife methods.

The quantity of sheet and punch mica produced in 1942 increased 4 per cent over the previous year and advanced to an all-time record in 1943, when domestic output supplied 11 per cent of consumption of good-stained and better grades. A shortage of No. 5 or larger book-form muscovite splittings developed late in 1943, owing to reduced production in India and restricted shipping space. From the 300 mica mines operating at the start of 1943, the end of the year saw the number expanded to 635 mines. Domestic producers, in 1943, employed about 5,000 miners and rifters and supplied 15.7 per cent of the total requirements of better grades, equal to material available from India and Brazil.

The great increase in the production of stained mica in 1943 was due to the War Production Board program of substituting, wherever possible, larger quantities of lower grade material for clear mica. Stocks of strategic grades, on Dec. 31, 1943, were adequate for a 15 months' supply.

CONSUMPTION OF DOMESTIC MICA, IN SHORT TONS
(After U.S. Bureau of Mines)

Grade	1939	1940	1941	1942	1943
Uncut sheet and punch	407	813	1,333	1,381	1,724
Scrap	24,672	22,386	32,500	43,262	46,138
Sheet and scrap	25,079	23,199	33,833	44,643	47,862
Ground	30,924	27,984	43,419	46,979	51,582
Splittings	1,711	2,459	3,649	3,318	4,166

WPB Order M-101-a, effective Mar. 15, 1944, placed No. 5 (larger book-form muscovite splittings) under allocation. This grade was for use in the manufacture of tape for armature insulation in high-voltage generators, industrial motors, and small transformers. Smaller sizes of strategic mica were in greatly increased demand for the armed services in 1943. A critical need developed for nonstrategic sheet and scrap, which is produced in large volume at those mines supplying strategic grades. The WPB proposed, in 1943, that maximum prices be maintained in the postwar period in order to build up a stockpile adequate for 3 years.

The domestic mica-procurement program was directed by the WPB and financed by the Metals Reserve Company, which designated Colonial Mica Corporation as its agent in June, 1942, to purchase strategic mica; in Decem-

ber, 1942, Colonial Mica was designated as the sole buyer of domestic and Canadian strategic grades. Colonial Mica leased mining equipment and supplies at a 2 per cent monthly rental and supervised development, instructed miners in methods of trimming and grading, purchased strategic mica, and assisted the miners in marketing nonstrategic grades. The U.S. Bureau of Mines and Geological Survey carried on a series of surveys in various states, particularly North Carolina, New Hampshire, Georgia, South Dakota, New Mexico, and Idaho.

The WPB defined strategic mica, in Order M-101 as amended on Dec. 2, 1942, as block and punch mica in the rifted condition (partially or fully trimmed). It was of better quality than black or red-stained and free of cracks, pinholes, cross grains, reeves, and ribs and relatively free of clay staining. It was required to be hard, clear, reasonably flat, and capable of being evenly and easily split into laminations or sheets of uniform thickness over the entire area, yielding sheets at least 1 by 1 in. in size.

Muscovite and phlogopite mica were designated on Mar. 1, 1944, by the WPB as minerals insufficient for war uses plus essential industrial demands. Other mica was available in adequate supply. Government stockpiles were reported, on July 17, 1944, by *The Wall Street Journal* to have 128,000 lb. of phlogopite block mica, 288,000 lb. of phlogopite splittings, and 6,152,000 lb. of muscovite block mica. Mica for stockpiling was first purchased by the MRC in 1941. Ranking ninth among stockpile items in cost of deliveries, mica valued at $30,658,918 was purchased by the MRC. The inventory on Oct. 31, 1944, was valued at $8,171,034. Strategic mica held on Oct. 31, 1945, by the Office of Metals Reserve and accumulated during the war period as a safety factor against interruption of supply and sudden changes in war requirements was as follows (in pounds): phlogopite, 553,390; splittings, 241,251; muscovite splittings, loose, 3,317,724; book-packed, 470,897; block and film, GS and better, 3,090,342; standard and lower, 3,531,193. Strategic block mica held by the OMR on June 1, 1946, amounted to 7,505,281 lb.; splittings, 6,259,808 lb.

Certain grades of mica were included by the WPB, in June, 1945, with a list of materials and products that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and it was anticipated that further changes would be announced. The MRC was authorized by the WPB on Oct. 12, 1945, to release 107,590 lb. of mica from the government stockpile to manufacturers for the purpose of completing orders. In February, 1945, purchases were restricted by Colonial Mica Corporation to ruby mica.

Private trade channels were free, under certain conditions, to purchase

Brazilian mica, it was announced by the Foreign Economic Administration on Sept. 18, 1945. Arrangements for resuming private trade into British Africa and India were to be announced as soon as they were completed. Mica (except book-form splittings) was removed from import controls by the WPB on Sept. 17, 1945. Book-form splittings continued in short supply on Nov. 30, 1945, as reported by the Civilian Production Administration. As soon as supplies were reported to be ample, this grade was to be turned over to private industry in order to help meet reconversion requirements.

The FEA announced in September, 1945, that government purchase of mica in all foreign areas was to be terminated on or before Dec. 31, 1945. United States-United Kingdom purchases stopped in Brazil and India on Nov. 30; United Kingdom purchases in British Africa stopped on Dec. 31. Private purchases in Angola were permitted, but authority for imports continued to be required from the WPB, under provisions of General Imports Order M-63.

Submarginal domestic resources of block mica, a deficient mineral, are estimated by Elmer W. Pehrson, U.S. Bureau of Mines, to be adequate for 5 to 25 years in terms of prewar consumption, under emergency conditions and at a high price. For the postwar period, greater dependence on foreign sources has been indicated.

World Production, Imports and Exports. Mica is an essential imported material satisfying critical needs. At the outbreak of war in 1939, moderate stocks were held by domestic industry and shipments continued to come by sea and air in spite of wartime hazards, the volume being greater in 1944 than in the previous year, as reported by the FEA in April, 1945.

Economic deposits are confined to ancient, stable land masses: along the east portions of North and South America, Central and South Africa, and India. Europe obtains from abroad by far the larger part of mica requirements. Only the British Empire holds national self-sufficiency in high-grade mica, with production adequate for all requirements and additional amounts for export. Japan had adequate resources for satisfying domestic demands without appreciable excess or deficiency. Other world powers are almost entirely dependent on imports of high-grade mica. India supplied 77.3 per cent and Madagascar 9.1 per cent of the total output of block mica, splittings, and sheet in 1938; in that year, India ranked second in production of scrap, ground, and waste mica (13.7 per cent), following the United States with 70.9 per cent of world total.

British India was the source of about two-thirds of block and sheet muscovite imported by the United States in 1942–1943, amounting to about 5,000 tons a year. The United States supplies less than 2 per cent of normal

domestic requirements of muscovite splittings. The mica industry of India employs more than 100,000 workers, largely experienced coolie labor. Both primitive and modern production methods are employed. Mexico, with cheap labor available for the manufacturing process, imports Indian block mica for treatment and for reexporting to the United States.

In the Bihar and Madras districts of India, mica is roughly sorted before shipment to the factory, where books are split into sheets for cutting. The mica is then sized, dressed, and graded. The material is prepared for market as trimmed mica, splittings (for built-up mica), and ground mica (powder). In mica splitting, India holds a virtual monopoly. No machine has been developed to replace cheap hand methods.

Brazil, second in importance as a source of mica, was reported in May, 1945, to be producing high-quality mica in increasing quantity, mainly from weathered pegmatites in three districts of Minas Geraes. Selective mining methods are required in working the discontinuous and spotty deposits. Inspection and trimming are being carried on to provide material for export. Since 1936, output has increased greatly and, in 1942–1943, supplied about one-fifth of United States requirements of good stained and better grades; in 1944, about 12 per cent (1,000 tons) of United States requirements were supplied.

The charge has been made that large quantities of machinery were shipped to Brazil by the Reconstruction Finance Corporation, on the direction of the Board of Economic Warfare, for use in producing mica. On arrival in Brazil, the machinery was placed in storage when it was found that mica mining could not be converted to mechanized methods.

In Brazil, Japan and Germany outbid the United States, after 1937, for mica. Japan secured 625 tons of mica from Brazil in 1940.

The U.S. Purchasing Commission in Rio de Janeiro bought 1,000 tons of mica in the 18 months following Jan. 1, 1942. Mica blocks are exported for splitting, after cleaning either at the mines or later at Espera Feliz or Governador Valadares. At Rio de Janeiro, it is further qualified before being exported.

Mexico was reported, in February, 1945, to be supplying block mica and phlogopite in appreciable amount. Mica was one of 17 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus from Brazil, Mexico, and other Latin-American countries, as part of the foreign procurement program initiated late in 1940.

Argentina produces about 500 tons a year of block and film mica, of which only about 10 per cent is superior grade (clear to slightly stained),

the balance being inferior, stained quality. In 1943, supplies amounted to about one-eighth of United States requirements. Bolivia also produces mica. In Venezuela, mica deposits have been reported but were undeveloped early in 1945. Angola, Mozambique, and Madagascar are sources of supply of phlogopite (amber splittings).

Canada, stimulated by war demand, became a major source of phlogopite and muscovite. The Eau Claire deposits in Ontario were discovered late in 1941 and, for a time, produced about 20 per cent of all white muscovite mined in North America, with cutting and trimming plants at Bonfield, Mattawa, and North Bay. Output of muscovite in 1944 was 138 tons valued at $579,134, including high-priced Eau Claire production which exceeded the entire value of Canadian output in the previous year. Phlogopite or amber mica amounting to 3,204 tons worth $261,892 was produced. The total output of both grades in 1943 was valued at $553,856. Over-all production of mica in Canada, Sept. 1, 1939, to Sept. 1, 1945, amounted to 16,811 short tons valued at $2,543,400.

Canada and Madagascar are the two leading world sources of phlogopite. In 1944, Kingston Mica Mining Company was the chief producer of phlogopite in Ontario, rifted rough sheet being exported to the United States for trimming and punch use. In Quebec, Blackburn Brothers operated the Nellis mine, Hull township, and the Phosphate King mine, Templeton township. The total value of Canada's production of mica, largely phlogopite, was more than $10,000.000 (1886–1944).

The FEA reported in August, 1945, that mica was included in almost 350,000 tons of minerals and metals available in Norway for immediate shipment, in spite of the extended military occupation by the Nazis. It

WORLD PRODUCTION OF MICA, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Argentina	298	442	540	625	423
Brazil (exports)	435	1,117	867	866	796
Canada	969	819	1,582	3,310	4,025
India	10,104	8,654	10,584	8,729	10,500*
Madagascar	†	531	479	320	215‡
U.S.S.R.	†	11,000*	†	†	†
South Africa (Transvaal)	972	1,252	1,076	1,315	986§
United States (sold or used)‖	22,751	21,046	30,693	40,499	43,419

* Estimated.
† Data not available.
‡ July through December.
§ January through September.
‖ Includes mica recovered from kaolin and schists.

was estimated that in the last 4 months of the year, 1 million tons of metals, minerals, and fertilizers would move out of Norway. Exports of mica from Norway totaled 171 metric tons in 1937–1939. Sweden, in the same period, produced 325 tons. Portugal, in 1942, had an estimated annual output of 350 tons of scrap and 40 tons of sheet. U.S.S.R. is reported by the U.S. Bureau of Mines to have domestic output estimated to be adequate for its requirements, the major part of the muscovite being secured from deposits located in Siberia.

Japan secured a major part of domestic requirements of low-grade mica from Korea (Chosen), as reported in March, 1946, by the U.S. Department of Foreign Commerce.

Prices. Colonial Mica Corporation posted the following schedule for ruby mica, in effect Aug. 7, 1944, to Mar. 31, 1945: full-trimmed domestic ruby sheet, first and second quality, sheet to cut 1½ by 2 in. and larger, $8 a pound; domestic punch mica, 30 cents. After Dec. 31, 1944, green mica and black-stained mica were eliminated.

Colonial Mica prices were in effect from Apr. 1 to Sept. 30, 1945, as follows: full-trimmed ruby muscovite domestic No. 1 quality, $1.70 to $36.65 a pound, depending on size; No. 2, $1.25 to $26; No. 2 inferior, 50 cents to $16; No. 3, 25 cents to $6.25, f.o.b. nearest producer's rifting shop. North Carolina white mica, ground, was $80 per ton; ground roofing, 20-mesh, $23 to $27 a ton.

Ground mica increased $5 a ton in ceiling price, as announced by the Office of Price Administration in order to cover higher production costs, effective on May 28, 1945. Scrap mica, from which ground mica is made, continued to be exempt from price control in an effort to increase production. In the New England states and New York, however, the scrap-mica price was under OPA rulings. Premium and discounts were allowed up to 40 per cent, depending on quality and trim. Prices for nonstrategic grades were frozen as of March, 1942, under Supplementary Regulation 1 to the General Maximum Price Regulation.

On Sept. 30, 1946, the *Engineering and Mining Journal* reported that domestic producers quoted mica as follows: punch, 22 cents a lb.; 1½ by 2 in., $1.10; 2 by 2 in., $1.60; 2 by 3 in., $2.10; 3 by 3 in., $2.75; 3 by 4 in., $3.50; 3 by 5 in., $4; 4 by 6 in., $5. Wet ground, very fine, $90 per ton. Special grades command a premium. Bulk sales dry ground, $32.50 per ton; scrap, $28 per ton and up.

North Carolina vermiculite was quoted at $9.50 a ton, f.o.b. mines; Montana vermiculite was $12, as reported on Apr. 12, 1945, by *E & M J Metal and Mineral Markets.*

Prices in Canadian funds, 1943–1944, as quoted by Colonial Mica Corporation for Canadian muscovite, f.o.b. shipping point, per pound, ranged from 33 cents (No. 3 grade), 66 cents (No. 2), $1.54 (No. 1), 1 by 1 in., up to $13.20 a pound for No. 1 grade, 10 by 12 in. Prices for thins (under 7 mils) ranged from 50 cents to $2.50 a pound, according to size and quality. These prices were set up to meet Canadian conditions, particularly at the Purdy mine. Colonial Mica Corporation canceled contracts on Dec. 31, 1944, when the Indian system of grading was adopted by Purdy Mica Mines, Ltd.

Mica imported into the United States is dutiable under the following schedule:

Untrimmed small sheet, phlogopite, yielding rectangular pieces not over 1 by 2 in., 10 per cent ad valorem.

Unmanufactured mica valued at not over 15 cents a pound, 4 cents a pound, plus 25 per cent ad valorem.

Mica, cut or stamped to dimensions, shape, or form, 40 per cent ad valorem.

Mica films and splittings, not cut or stamped to dimensions, not over 12/10,000 in. in thickness, 25 per cent ad valorem; over that thickness, 40 per cent.

Mica films and splittings, cut or stamped to dimensions, 45 per cent ad valorem.

Mica plate, built-up mica, and mica manufactures, 40 per cent ad valorem.

Phlogopite waste or scrap, valued at not over 5 cents a pound, 15 per cent ad valorem.

Mica waste and scrap, valued at 5 to 15 cents a pound, 4 cents a pound plus 25 per cent.

Mica, ground or pulverized, 15 per cent ad valorem.

In 1940, prices of mica from British India held steady but advanced for high-grade material from Brazil, as reported by the U.S. Bureau of Mines. Good punch mica dropped in price in May, 1941, from 15 to 12 cents a pound compared with prices in August, 1939, of 5 to 7 cents.

Peacetime costs of producing domestic sheet mica are estimated at $3 a pound compared with $1.11 for Indian mica and 92 cents for Brazilian of comparable grade. The postwar domestic market is expected to revert to prewar levels. Maximum Price Regulation 347, covering mica, was suspended on Nov. 15, 1945, by the OPA, reflecting the mounting postwar supplies of mica, effective on Nov. 20. New ceilings may be imposed if the supply-and-demand situation makes necessary renewed control. These rulings followed policies approved by the Office of Economic Stabilization to permit "decontrol of goods and services when supplies balance demand" or when items

are "judged to have little effect on the cost of living, the cost of business, or production of other commodities."

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MOLYBDENITE

Properties. The common mineral molybdenite (molybdenum sulfide) has a hardness of 1 to 1.5 and a specific gravity of 4.6 to 4.9. It is bluish lead-gray in color, resembling graphite, and occurs in thin scales or foliated masses. It contains 60 per cent of molybdenum. The mineral occurs in large quantities only in granite, pegmatite, and other quartzose rocks, in the form of soft, pliable flakes or leaves. It is also found in semiamorphous form, filling small fractures. Wulfenite (lead molybdate) occurs in oxidized parts of lead-bearing veins.

Molybdenum is a soft, silvery-white ductile, metallic element resembling platinum. (Mo, atomic number, 42; atomic weight, 95.95; melting point, 2620°C.) One of the scarcer elements, molybdenum ranks about thirty-sixth in quantity in the earth's crust, in about the same order as antimony, mercury, and tin. Molybdenum is one of the 16 industrial nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys.

Metallic molybdenum has a specific gravity of 10.2. Its electrical conductivity is less than one-third that of copper; its tensile strength is 260,000 lb. per sq. in. Properties, which are retained at moderately high temperatures, are strength, toughness, and resistance to repeated shocks. In the annealed state, molybdenum can be drawn, stamped, folded, hammered, woven, etched, engraved, or machined.

The greater strength of molybdenum steels, as compared with ordinary steel, makes possible a substantial reduction in weight. Although inferior to chrome steel for tensile strength at high temperatures, molybdenum steel can be flame-hardened to increase greatly resistance to wear. Molybdenum added to cast iron increases the machineability and adds strength and toughness. Molybdenum is one of the most important competitors of nickel.

Uses. Under war conditions, molybdenum has been grouped with the 23 metals and minerals of most vital importance. It is used chiefly as an alloying element in steel to intensify the effect of other alloying metals, particularly nickel, chromium, and vanadium. The molybdenum content commonly employed amounts to 0.15 to 0.4 per cent.

Alloy steels containing molybdenum have been widely used by the aircraft industry, particularly a nitriding steel that also contains chromium and nickel. Crankshafts now require a molybdenum steel containing 3 per

cent of chromium. Hollow steel propeller blades and seamless steel tubing for aircraft have been important war applications. A similar alloy is being applied to modernize railway-locomotive construction. Molybdenum high-speed steels are being used in oil-well drilling and oil refining, being required in many oil refineries where ordinary steel is unsatisfactory.

Molybdenum steel is essential in certain types of armor-piercing shells and in armor plate. The automotive industry uses low-molybdenum steels, containing less than 1 per cent of molybdenum, which are also required for railway forgings and bolts. Rustless steels, high-grade structural dies, high-speed tool steels, and permanent magnets require high-molybdenum steels containing more than 1 per cent of molybdenum. The railroads have made molybdenum steel the standard for crankpins, piston rods, and crossheads. The property of retaining strength at high temperatures has made molybdenum steel useful for syphons, firebox sheets, and similar equipment.

In the strategic machine-tool industry, molybdenum was largely substituted for tungsten and was widely used as a substitute for nickel, manganese, and chromium. Molybdenum is essential as a toughener of cast iron, which required about 3 per cent of molybdenum used in the war period. The usual 18 per cent tungsten cutting steel was replaced by a high-carbon steel carrying only 1.5 per cent of tungsten, with 9 per cent of molybdenum, 4 per cent of chromium, and 2 per cent of vanadium. Nonferrous alloys of chromium-nickel-tungsten-molybdenum are employed in the manufacture of precision and surgical instruments.

For radio radar equipment, the use of pure molybdenum metal was of highly strategic importance. The metal can be welded to nickel but not easily welded to itself. The best welding results are produced by electric spot welds or electric percussion welds. Fansteel Products Company produces molybdenum rods and sheets by special processes. Wire and sheet fabricated of the new molybdenum alloys are suitable for electrical resistance, for contacts, and for heating elements.

The most extensive prewar use of metallic molybdenum was in the form of wire for filament supports and hooks in incandescent lamps and radio tubes; in the form of sheets, as the plate element in radio and power tubes; and in the form of ribbon, as a heating element in electric-resistance furnaces. Molybdenum electrical-contact points have a life fifty times greater than silver, which they replace; they have also replaced tungsten and platinum-iridium. Under war conditions, more than 95 per cent of consumption was in steels. The National Emergency Steels made use of many low-alloy formulas in which molybdenum was essential.

Increasing use of molybdenum is being made by the chemical and ceramic

industries, although only about 2 per cent of the total used, under war conditions, was for these purposes. Molybdenum salts are employed to promote adherence in ground coats for enamels to cover steel and iron and to produce pigments for dyes and inks. As a reagent, ammonium molybdate is employed in the determination of phosphorus in steel.

Molybdenum-conversion plants have been increased in size and have developed improvements in processing that made it possible for them to meet the demands of the steel industry at war. They produced ferromolybdenum, calcium molybdate, and roasted concentrates at an exceedingly high rate.

In 1943, the metallurgical industry used more than 5,000 tons of technical molybdic oxide as briquettes. This was mixed with pulverized limestone and sold to alloy-steel makers as calcium molybdate. The forms more commonly used for introduction into steel are molybdenum trioxide and ferromolybdenum. The process of making ferromolybdenum from technical molybdic oxide by thermit reaction was greatly improved in 1943. The thermit method is used in making molybdenum silicide from mixtures of technical molybdic oxide, aluminum ferrosilicon, lime, and fluorspar. The silicide is employed for late additions of molybdenum and silicon to cast iron.

The manager of the lamp division of Westinghouse Electric reported, on Jan. 16, 1945, that molybdenum and tungsten were being used in 15,000 different types of war items. Almost every electric lamp and electric tube employ both molybdenum and tungsten in some form.

Postwar markets are expected to be well established, particularly in the iron and steel industry. Export trade will expand. Electronics research is in progress and has indicated many new applications. The constantly increasing use of this metal in the steel industry is encouraged by the availability of large domestic reserves of molybdenite ore. The United States Ordnance Department tests demonstrated that a 50 per cent reduction in tungsten requirements was possible through the substitution of molybdenum high-speed steels. This tends to eliminate the problem of limited tungsten supplies available in time of national emergency.

Domestic Sources of Supply and Production. The United States has commercial reserves of molybdenum ore estimated at a 422-year supply based on the annual rate of use in 1935–1939, as reported by Elmer W. Pehrson, U.S. Bureau of Mines. It was estimated in 1944 that more than 90 per cent of the original supply remained in the ground. Submarginal and highly speculative resources were estimated to have a life of from 100 to 500 years, although this figure is qualified by the statement that availability

is highly speculative or remote because of uncertainties in basic estimates, high costs of recovery, or technologic problems involved in utilization.

Domestic output of molybdenite in 1938 accounted for 92.4 per cent of the world total; 3 per cent was produced by Mexico. Domestic production accounted for only 13 per cent of the world total up to the First World War. The domestic strategic position is stronger in the case of this than of any other metallic mineral. Molybdenum amounting to 112,000 tons was mined between Jan. 1, 1940, and Jan. 1, 1945.

The leading source of molybdenite is the deposit at Climax, Colo., where Climax Molybdenum Company produced 21,000 of the 1942 domestic total of 28,471 tons. In 1944, production was at a reduced rate of about 10,000 tons of ore daily, representing about 60 per cent of domestic output. The ore grade averages about 0.5 per cent of MoS_2.

The Urad mine, near Empire, Colo., went into production in May, 1944. This is controlled by Molybdenum Corporation of America, whose major operation is the mine at Questa, N. M. Molybdenite concentrate, in 1944, was recovered at four properties in Arizona, two each in Colorado and New Mexico, and one each in California, Nevada, and Utah.

The U.S. Bureau of Mines explored four molybdenite properties in 1940–1944. None of the material indicated was of commercial grade. In Montana, the Big Ben deposit (about 2 million tons averaging 0.25 per cent of MoS_2) is suitable for mining by open-pit methods. In North Carolina, the Boy Scout property has about 550,000 tons averaging 0.45 per cent, with a small rhenium content.

Of ten mines producing molybdenite concentrate in January, 1945, six recovered the material as a by-product of copper mining. Total production for the month was 1,567 tons of contained molybdenum compared with 2,048 tons shipped, January being the third consecutive month when production fell below tonnage shipped. Total stocks held by producers and consumers amounted to 9,124 tons compared with 9,683 tons at the end of 1944. At the end of 1941, industry stocks were 10,600 short tons; in 1942 6,245; at the end of 1943, 8,875 tons, and molybdenum in the government stockpile was an additional 1,084 tons. Industry stocks, at the end of May, 1943, reached the lowest point of the war period, equal to a 3 weeks' supply.

In 1944, domestic output was about 98 per cent of the world total, as estimated by the U.S. Bureau of Mines; in 1940, 93 per cent. The United States shipped 25,329,000 lb. of molybdenum contained in concentrates, in 1940, for domestic consumption and for exports; in 1943, 53,955,000 lb. valued at $38,500,000. An increasing proportion of domestic output, about double the prewar rate, was being recovered from copper mines as a by-

product. Alloy steels were produced in decreased quantity in 1944, and there was smaller demand for molybdenum as a substitute metal. In 1943, the steel industry used approximately 30,000 tons of molybdenum for alloys.

At the close of 1943, the War Production Board announced curtailed output, with stocks on hand of 14,837 tons. Government stockpiles, on July 17, 1944, were reduced to 2,209 tons, as reported by *The Wall Street Journal.* The Metals Reserve Company made a first commitment in 1941 to purchase molybdenum for stockpiling. The material acquired by the MRC ranked thirtieth among stockpile items with a total value of $1,607,938. No sales were reported, but the MRC inventory, as of Oct. 31, 1944, showed a reduction in value to $1,558,523. Molybdenum remaining in the stockpile of the Office of Metals Reserve was reported at 4,746,202 lb. on Oct. 31, 1945.

The WPB General Preference Order M-110, effective on May 1, 1942, governed the distribution of all forms of molybdenum, including scrap. An amendment to the order, on Aug. 8, permitted the melting of molybdenum only after approval of melting schedules, as provided in Order M-21-a. The order was amended on Nov. 6, 1942, by Order M-110-a, in order to permit without allocation the delivery to users of up to 500 lb. of contained molybdenum in any one month. Secondary molybdenum chemicals were removed by the WPB from the M orders on molybdenum, on Jan. 9, 1943. An individual license was required for clearance of exports of molybdenum ore and concentrates, products, alloys, and scrap to all foreign countries except Canada and Newfoundland. Export to these two countries was permitted only under a general license, as announced by the Board of Economic Warfare, on July 9, 1942.

The WPB amended Supplementary Order M-110-a on Oct. 2, 1943, to authorize the acquisition of 500 lb. or less by foundries so that they could fill certain high-preference orders without securing a special allocation. General Preference Order M-21-h was amended by the WPB, in April, 1943, to require that 75 per cent of all high-speed steel orders accepted in any one quarter be of the molybdenum type and not more than 25 per cent of the tungsten type, with a leeway of 5 per cent by weight, but not exceeding 500 lb. This order was amended, on May 12, raising the permitted ratio of tungsten-type high-speed steels to 35 per cent, which decreased the molybdenum requirement. The WPB classified molybdenum in the most critical group of metals insufficient for war uses, in August, 1942.

Allocation control was lifted by General Preference Order M-110-a, on Dec. 30, 1943. A check on molybdenum and its products was maintained by the requirement that all vendors of more than one ton in any one month report their sales to the WPB. This order included ferromolybdenum, molyb-

denum sulfide, molybdenum oxide, and calcium molybdate. Allocation was continued on molybdenum ingot, wire, and sheet, under General Preference Order M-369. Consumption curbs were revoked on molybdenum wire in August, 1945. The Civilian Production Administration estimated, on Nov. 30, 1945, that supplies of molybdenum available to industry were adequate for its needs.

MOLYBDENUM DOMESTIC PRODUCTION, SHIPMENTS AND IMPORTS, IN POUNDS OF CONTAINED METALLIC MOLYBDENUM
(After U.S. Bureau of Mines)

Year	Production	Shipments	Imports
1939	30,324,000	32,415,000	26,347
1940	34,313,000	25,329,000	
1941	40,162,000	38,200,000	4,300
1942	56,918,000	66,437,000	756,000
1943	61,406,000	53,706,000	1,789,000
1944	40,000,000*	†	†

* Estimated.
† Data not available.

The Office of Price Administration on June 12, 1946, suspended price controls from all products subject to the regulation affecting molybdenum and certain other alloys and metals.

World Production, Imports and Exports. The United States holds a natural monopoly of molybdenum. However, during the war, Japan developed a deposit in Manchuria that was reported by Edwin C. Pauley's reparations mission to be possibly larger than the deposit at Climax, Colo. Limited production is secured in Mexico, Canada, Norway, and some fourteen other countries. Molybdenum is one of the metals of which there is a severe shortage in Europe, which is dependent on imports.

In the early stages of the Second World War, the "moral embargo" used by the United States in international diplomacy was placed on the export of molybdenum and other war materials. This forced the Axis nations to find substitutes to supplement the limited sources available on the Continent and in French Morocco.

World production in 1939 was made up of 13,755 metric tons from the United States; Mexico, 523; Norway, 423; Peru, 342; and minor amounts from 14 other countries. U.S.S.R. was scheduled to start substantial production in 1941. In 1940, the world total was more than 17,000 metric tons, of which 90 per cent came from the United States. World output in 1901–1913 averaged less than 100 tons a year, of which only 13 per cent came from the United States.

Canada shipped 1,064 tons of high-grade concentrate having a total value of $1,079,698 in 1944; in 1943, shipments contained 192 tons of molybdenum valued at $549,515; in 1942, 44; in 1941, 38; in 1940, 4. Canada produced molybdenite concentrates from Sept. 1, 1939, to Sept. 1, 1945, amounting to 1,700 short tons valued at $1,900,000. Output was secured from deposits in Quebec, largely from the LaCorne property of Wartime Metals Corporation. Operations were carried on from March, 1942, to July 15, 1945. The original owners, Molybdenite Corporation of Canada, repurchased the property and resumed production with the 200-ton mill that was erected by Wartime Metals. In the war period, the government operation resulted in treating about 200,000 tons of ore grading 0.7 per cent of MoS_2, from which concentrates containing 1,429,711 lb. of molybdenum were produced. Wartime Metals paid Molybdenite Corporation 10 cents for each pound of molybdenum in concentrates shipped. After taking over operation of the property, Molybdenite Corporation shipped about 50 tons of concentrate to Europe monthly.

Indian Molybdenum, Ltd., owned by Dome Mines, erected a 600-ton mill and operated a large low-grade deposit (about 0.45 per cent of MoS_2) located 20 miles northwest of the LaCorne mine. Production started in September, 1943; and by the end of April, 1944, when the mill was closed down, about 93,000 tons of ore had been treated and the concentrate shipped. Ore reserves on the property are stated to be large.

The Quyon Molybdenite Company, Ltd., was a minor producer from the deposit 35 miles northwest of Ottawa, which was closed down in May, 1944. The concentrates were converted to the oxide in a small roasting plant on the property. During the First World War, this mine was the world's largest producer of molybdenum. It contributed nearly 80 per cent of Canada's output before 1939.

Five steel companies in Canada consumed about 90 per cent of the 600 odd tons of molybdenum used in the Dominion in 1943; consumption was almost 540 tons in 1944; in 1939, 72 tons. In Canada, metallurgical practice is to add MoO_3 direct, using no molybdate, compared with the 70 per cent of this agent used in 1937.

Mexico, in 1941, produced 956 metric tons, chiefly as semirefined and concentrate. All but three tons were exported. Molybdenum was one of 17 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus from Mexico, as part of the foreign procurement program initiated late in 1940, at Washington. By-product molybdenite obtained from copper ores in Mexico is, normally, the equivalent of about 1,000 tons a year of molybdenum metal.

In Alaska, molybdenite has not yet been brought into commercial production, as reported on May 7, 1945, by the U.S. Geological Survey, but favorable possibilities have been indicated for important advances in the postwar period.

In Brazil, molybdenite deposits located in the states of Parahyba and Rio Grande do Norte have "world potentialities greater than any others newly discovered," as reported by James S. Baker, Foreign Economic Administration, in May, 1945.

In Chile, molybdenite is secured as a by-product of copper mining. Braden Copper Company, in 1939, started mill recovery of the sulfide, concentrating more than 800 tons. The MRC, in 1943, contracted for the Braden output of molybdenum concentrate. In Peru, the principal mine, Peru-Molybdenos started production in 1936 and increased its annual output from 13 to 350 tons at the end of 1939. Ore reserves were reported at more than 100,000 tons averaging 0.8 per cent of molybdenite. Several undeveloped deposits are known in Peru.

Macedonia, according to a report quoted by the U.S. Bureau of Mines, claims to be the world's fourth largest producer of molybdenum and the major source of supply in Europe. Of 14,000 miners in that country, 9,000 were stated to be employed in molybdenum mines. The mining industry was also engaged in producing lead, zinc, and chromite.

Manchuria claims to have a major molybdenum deposit that gives promise of ranking second only to the operation at Climax, Colo. Output was slightly higher in 1943 than in the preceding year, which marked the beginning of a "4-year plan" for mine expansion in molybdenum, as well as in iron, lead, and zinc. Manchuria Lead Mining Company reported the molybdenite ore discovered in 1939, 40 miles inland from the Gulf of Liaotung, to have an average grade of 0.5 per cent. Output in 1942 was stated to be "equivalent to one-tenth the world's production." Japanese estimates placed ore reserves at 8 million tons. War production averaged 400,000 metric tons a year.

Korea (Chosen) was reported in March, 1945, by the U.S. Department of Foreign Commerce, to be the most important Japanese-controlled producer of molybdenum in the Far East.

For many years, French Morocco has produced the annual equivalent of upward of 100 tons of molybdenum from contact metamorphic ores in limestone at Azegour.

In U.S.S.R., the first molybdenum smelter was completed in 1941. The material treated was a by-product of concentrating the copper ores of Kounrad, Kazakstan. Minor production is reported in Turkey, Greece, Yugoslavia, and Australia.

The FEA reported in August, 1945, that substantial quantities of molybdenite were included in almost 350,000 tons of minerals and metals available in Norway for immediate shipment, in spite of extended military occupation by the Nazis. In the last 4 months of the year, it was estimated that 1 million tons of metals, minerals, and fertilizers would move out of Norway. The Knaben mine, in prewar years, was the major producer of molybdenite outside the United States. Operated since 1901, the Knaben is reported to be the oldest molybdenite mine, the metal being used in the ceramic industry. The ore is reported to average from 0.2 to 0.4 per cent of MoS_2. Production was controlled by British capital up to the time of the German army's occupation of Norway. The 1940 production was stated to be 900 tons (fine). The RAF attack on the Knaben mines, in March, 1943, was believed to have caused destruction that eliminated about 75 per cent of molybdenum supplies available to Germany. In November, 1943, United States heavy bombers made an attack that resulted in serious damage to Norway's production of light metals and ferroalloys.

In 1944, the FEA followed the policy of withdrawing when possible from public purchase of foreign molybdenum, returning the trade to former private channels if no impairment to the war effort resulted.

The FEA reported that German supplies of molybdenum in 1943 were limited to about 650 tons secured from Finland, Greece, and Yugoslavia. The only supply source left open to the Axis in December, 1944, was Norway, where output was probably reduced below 200 tons a year. Germany was cramped for the metal, as reported in February, 1945, by Batelle Memorial Institute; Japan was believed to have substantial stockpiles.

Prices. The domestic price of molybdenum ore was 45 cents per pound of contained MoS_2 in 90 per cent concentrate, f.o.b. mines, as quoted on Sept. 30, 1946, by the *Engineering and Mining Journal*. Specifications for concentrate dried at 212°F. are as follows: MoS_2, minimum 85 per cent; copper, maximum 0.6 per cent; iron, maximum 3 per cent; combined phosphorus, antimony, and tin, maximum content 0.2 per cent. Prices for ore and concentrates have remained unchanged since 1938.

The duty on molybdenum concentrates was set at 17.5 cents per pound of molybdenum contained, by the tariff act of 1930, as corrected to Feb. 1, 1943. A trade agreement signed between Mexico and the United States, effective on Jan. 30, 1943, made a 50 per cent reduction in import duties on molybdenum from Mexico entering the United States on consignment to the MRC. The agreement was for 3 years, with automatic extension for another 6 months unless either country notified the other of intention to terminate.

The price of ferromolybdenum, 55 to 65 per cent of molybdenum, was

quoted on Sept. 30, 1946, at 95 cents per pound of contained molybdenum; this price had applied since February, 1932. Calcium molybdate was quoted at 80 cents; molybdic oxide, 80 cents per pound of contained molybdenum. Molybdenum metal, 99 per cent, was quoted at $2.60 to $3 a pound. These maximum prices were frozen by Maximum Price Regulation 489 on Nov. 8, 1943.

The London price was 42.5*s.* per long-ton unit for 85 to 90 per cent concentrate.

In Canada, the Metals Controller's contract to purchase Canadian production at the bonus price of 85 cents a pound of contained MoS_2, f.o.b. Ottawa, was terminated on Dec. 31, 1943. The normal price without bonus was 50 cents (Canadian). Imported compounds were quoted at the following prices f.o.b. Toronto (Canadian funds): calcium molybdate, in 12½-lb. bags (5 lb. of molybdenum, 42 per cent of molybdenum), 98 cents; ferromolybdenum (60 per cent of molybdenum), $1.15 a pound.

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MONAZITE SAND

Properties. A monoclinic phosphate of rare earths (containing about 32 per cent of cerium oxide and up to 18 per cent of thoria, yttrium, and silica), monazite sand is the only commercial source of thorium, cerium, and other rare-earth oxides. These are by-products from the mining of beach deposits for contained ilmenite, rutile, and zircon. No other thorium-bearing minerals are plentiful or cheap enough to compete with monazite.

Cerium, yttrium, and other rare earths (the group includes 15 elements) are quite accessible, but their separation is extremely difficult. Although forming a larger percentage of the earth's crust than copper, lead, or zinc, the rare earths are not concentrated in large deposits but are sparingly distributed as constituents of some 150 or more minerals. Uranium and thorium minerals usually contain rare earths. In the early days of chemistry, these elements were believed to be of rare occurrence. They were called earths because their oxides resemble lime and magnesia. Thorium, although related to the rare earths, is not classed as a member of that group. (Ce, atomic number, 58; atomic weight, 140.13; melting point, 640°C. Th, atomic number, 90; atomic weight, 232.12; melting point, 1845°C. Y, atomic number, 39; atomic weight, 88.92; melting point, 1490°C.)

Commercial cerium usually includes five rare-earth elements for most industrial uses, in the following percentages: cerium, 45; lanthanum, 25; neodymium and praseodymium, 15; samarium, 10. Pure cerium is seldom made, except for research, since the properties of these metals are closely similar and their salts can be individually isolated only by repeated fractional crystallizations. Cerium is one of the 16 industrial nonferrous metals used essentially as alloying constituents.

Cerium in the commercial alloy form of mix metal is prepared by electrolysis of the molten salts of the five elements listed above, with 15 to 40 per cent of iron, using molten iron as a cathode and carbon as the anode. Cerium has strong affinity for oxygen, nitrogen, and sulfur; it has no value as an alloying element for steel. Mix metal is brittle and pyrophoric; when rubbed with a file or other abrasive, it produces copious sparks. Pure cerium is nearly as soft and ductile as lead. Cerium, the most important of the rare-earth elements in commercial application, is followed in value by praseodymium, neodymium, and lanthanum. The elements included in the rare-earth group have many similar chemical properties.

The mineral monazite occurs in yellow to brown grains. Its specific gravity is 4.9 to 5.3; its hardness, 5 to 5.5. It is brittle and uneven in fracture. It is radioactive, due to the presence of mesothorium and, sometimes, radium. Monazite sand usually contains all the rare-earth elements. Thorium is present, probably as a silicate. Monazite crystals weighing up to 60 lb. are on record, but the amount of this mineral, as a primary constituent of granite, gneiss, and pegmatite, seldom is more than 0.1 per cent of the host rock.

Stream and river placer sands are reconcentrated on beaches by wave and tide action. In dune deposits, wind action has concentrated the heavy sands into rich layers consisting of ilmenite, zircon, rutile, and monazite, with quartz as the principal gangue mineral. "Crude sand" is a composite of the heavy minerals secured by rough gravity concentration.

Monazite is soluble in hot, concentrated sulfuric acid. Ground ore is digested with acid until the monazite has been decomposed. The pasty mass is poured into cold water to form a solution of thorium, rare earths, and phosphoric acid. The thorium is precipitated out, the rare earths being less soluble.

Uses. Cerium and the rare-earth oxides were essential to many war industries which, however, used only small quantities of these materials. Commercial application has expanded considerably in recent years. Cerium and the cerium group are employed chiefly, as fluorides, to stabilize the cores of arc carbons of "flaming arc" lights as stabilizers, to increase lighting intensity in searchlight cores and motion-picture projectors, as a component of flashlight powder, and for therapeutic lamps. These applications accounted for about 50 per cent of consumption in 1944.

Cerium acetate has important use as a waterproof and mildewproof compound. The cerium group is also essential in the manufacture of pyrophoric (sparking) and other alloys, chiefly ferrocerium (mix metal) for sparking flints of pocket lighters and other ignition devices. This application accounted for about 25 per cent of total consumption in 1944.

In the First World War, pyrophoric alloys containing iron or aluminum were used for tracer bullets, the friction of the air causing the alloy to ignite. Ferrocerium is reported to be useful as a scavenger for removing oxygen from cast iron, increasing strength and machineability. In prewar years, 50 per cent of cerium consumption was for arc-light electrodes, 25 per cent for pyrophoric alloys, and the balance for mildewproofing, ceramics, and miscellaneous uses. The other major use was in the manufacture of special optical glassware, for which praseodymium and neodymium are required, as coloring materials. For glass polishing, the hardness of ceria is regulated by varying the temperature of calcination. This application was reported, in

1944, to be gaining in importance in Canada. Cerium metal is used in the evacuation of radio tubes.

The use of cerium (0.15 per cent) in the composition of a complex aluminum alloy was reported in 1935. Other metals in this alloy are as follows: copper, 2.5 per cent; nickel, 1.5; magnesium, 0.8; iron, 1.2; silicon, 1.2. The cerium, having a refining effect on the microstructure, permits "beneficial mechanical effects of high iron content to be obtained by suppressing the formation of the embrittling iron-aluminum constituent." This is an age-hardening alloy suitable for high-duty service in the form of die castings, chill castings, and sand castings. Heat treatment causes no distortion, fully heat-treated chill castings showing tensile strength of approximately 50,000 lb. per sq. in.; sand castings, 40,000 lb. per sq. in. The addition of small amounts of mix metal to aluminum or magnesium acts as a purifying agent and increases the ductility.

Misch metal is formed when rare-earth oxide, after thoria has been extracted, is converted to the metallic state. The common pyrophoric alloys are Auer metal, Kunheim (containing aluminum and magnesium), and ferrocerium (cerium, 63 per cent; iron, 35; calcium, 1; copper, 0.4; magnesium, 0.2). Magnesium and its alloys are hardened by the addition of 20 per cent of cerium or 6 per cent of cerium and 20 per cent of aluminum, for use in making pistons for internal combustion engines.

Thorium now has important application in electronemissive elements. The efficiency of certain types of radio tubes is greatly increased by adding 2 per cent of thorium to the tungsten filaments. Thorium nitrate for the manufacture of gas mantles was being exported to Japan and China up to 1940.

For many purposes, the rare earths are used as a group, the separation of rare-earth metals from monazite sand being a complex procedure. Changes in the application of monazite from special wartime uses are expected to be followed in peacetime by more stabilized requirements. The following uses were proposed in 1932: in the manufacture of dyes for dyeing leather and textiles, as catalysts or oxidizing agents in various chemical processes, in photography, and in antiseptics.

Domestic Sources of Supply and Production. The mining of Florida beach sands was resumed in 1940 for monazite as a joint product with ilmenite, rutile, and zircon; but in 1943, the U.S. Bureau of Mines reported that no domestic production of monazite had been secured in recent years—since the 48 tons recovered in the First World War (1915–1917).

Former production was secured at Melbourne, Fla., and in North and South Carolina, but low prices have made production from domestic sources

uneconomic. In the Carolinas, monazite is associated with ilmenite, rutile, magnetite, garnet, hornblende, and gold. Deposits in Idaho include gold, ilmenite, and zircon. Monazite occurrences are known in many other states, usually in scattered, low-grade concentrations.

Stockpile supplies of monazite adequate for 30 months were reported by the U.S. Bureau of Mines in March, 1943. For the year 1943, domestic consumption was lower; the procurement division of the Treasury Department purchased 3,360 short tons of monazite sand for the government stockpile at the request of the Army and Navy. Imports during 1943 amounted to 1,112 short tons. Stockpiled monazite sand was reported at 3,188 tons by *The Wall Street Journal* on July 17, 1944. All monazite held by the Office of Metals Reserve had been sold, it was announced by the Civilian Production Administration, on Nov. 31, 1945.

Cerium products are supplied to the domestic market by Cerium Products Corporation, Niagara Falls, N. Y. Indian monazite sand is imported by C. Tenant Sons & Company, 9 Rockefeller Plaza, New York City. Brazilian monazite sand is imported by the following: Rare Mineral and Metals Company, 40 Exchange Place, New York City; Maywood Chemical Works, Maywood, N. J.; and Foote Mineral Company, 16th and Summer Streets, Philadelphia, Pa.

By a proclamation and an executive order on Sept. 28, 1945, President Truman placed under Federal jurisdiction the natural resources of the continental shelf contiguous to the coasts of the United States. Although no minerals have ever been discovered in the subsurface lands of the shelf, evidence indicating their presence has been found in the inland sands around Jacksonville, Fla., and along the Gulf coast of Texas and Louisiana. Monazite was one of the five minerals, in addition to petroleum, that have been indicated in offshore areas. "The rapid development of technical knowledge and equipment occasioned by the war now makes possible the determination of the resources of the submerged lands outside of the three-mile limit." The proclamation was for the purpose of carrying on orderly development of these resources. Prior to the Second World War, advanced technology had made possible the exploitation of a limited amount of minerals from submerged lands within the 3-mile limit.

World Production, Imports and Exports. Imported monazite sand was a key wartime product filling important industrial needs. In prewar years, supplies came chiefly from high-grade thoria-rich monazite beach sands in four areas of the state of Travencore, British India, the source of 75 per cent of world output. The high thoria content of these monazite sands and the availability of cheap labor have been factors in making India the leading

source of supply. Indian monazite is better cleaned and graded than the Brazilian.

In India, beach sands are mined chiefly for their ilmenite content. After concentration, the 50 per cent monazite is increased to 95 per cent. In recent years, production has shown the monazite to average only 2 to 5 per cent compared with the 46 per cent grade formerly secured in certain small areas. For the period 1906–1922, the monazite content averaged 15 to 25 per cent.

Brazil, during the war period, regained its former position as an important producer and is now prepared to supply all requirements of the United States in case of necessity. In 1941, imports from Brazil represented 21 per cent of total supplies for the United States; in 1942, 31 per cent; in 1943, Brazil and India (combined tonnage) increased their shipments 12 per cent.

Brazilian beach sands are now concentrated, although, formerly, they were rich enough to ship without treatment. At present, the rare-earth content of monazite sand is higher than for the sands imported from India, but the thorium content is lower. Considerable tonnage is produced from the beach deposits of the states of Espirito Santo, Bahia, and Rio de Janeiro. Regular deliveries were being made to consumers, as reported in May, 1945, by James S. Baker, Foreign Economic Administration.

Brazil, in 1909, reached peak output of 7,121 short tons and dominated world markets from 1895 to 1914. Since 1920, small production was secured in Brazil, mainly for the purpose of holding concessions in good standing.

In Malaya, monazite is associated with cassiterite in alluvial tin deposits. In Ceylon, heavy sands are composed of 47 to 75 per cent of ilmenite and 4 to 8 per cent of monazite, deposits being located on the west coast. These have produced since 1936. Australia, in 1943, for the first time reported commercial production of cerium alloys from monazite deposits. The Netherlands East Indies had small production of monazite sand in 1936–1941. Norway reported annual output of less than one ton during the war years. Monazite crystals are saved as a by-product of feldspar mining. In 1944, world production of monazite was estimated at 5,000 tons.

MONAZITE SAND AND OTHER THORIUM ORE IMPORTED INTO THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Country of origin	1939	1940	1941	1942	1943
Brazil	54	201	734	1,346	1,911
India and British India	1,336	2,766	2,714	3,052	3,033
Netherlands East Indies	170				
United Kingdom	.....	.....	.....	.....	36

In Canada, Shawinigan Chemicals, Ltd., Shawinigan Falls, Quebec, started the preparation of cerium products from cerium chloride in 1940. Cerium Company, Ltd., Montreal, purchases the output for use in manufacturing sparking flints. Prewar supplies for markets in Europe were manufactured in Berlin, London, and Paris.

The German monopoly on monazite, in effect prior to the First World War, was not broken until 1934. Germany and the United States have been the major consumers of monazite sand and the chief producers of rare-earth compounds and metals. The United States is entirely dependent on Brazil and British India for supplies.

Prices. The price of monazite sand, containing a minimum of 8 per cent of thoria, was $60 to $65 a ton in 1940, compared with $60 to $75 in previous years. The price was $60 per ton on Apr. 12, 1945, as reported by *E & M J Metal and Mineral Markets.*

The original basis of value of 6 to 8 per cent thoria content was superseded in 1944 by the content of ceria and other rare-earth oxides; present requirements are based on a 57 to 60 per cent minimum of rare-earth oxides. Buyers occasionally specify a 70 per cent minimum rare-earth oxide plus thoria content for Indian sands; for Brazilian, a 65 per cent minimum.

Indian sands are finer grained and higher in thoria content than Brazilian sands. Brazil and the state of Travancore, India, collect royalties on monazite exports. The tariff act of 1930 imposed a tariff of $2 a pound on cerium metal and ferrocerium; on all other cerium alloys, 25 per cent ad valorem.

Ferrocerium was quoted in 1928 at $5.75 to $8 a pound.

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NICKEL

(Matte and Refined)

Properties. More abundant than any other "common," heavy, nonferrous metal (in twenty-second place in order of abundance among the elements), nickel ranks ninth among the metals in value consumed. Nickel is one of 16 industrial nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. (Ni, atomic number, 28; atomic weight, 58.69; melting point, 1452°C.) Nickel has a density of 8.9. It is a lustrous, white, metallic element, the third in the triad with iron and cobalt.

Iron meteorites contain from 5 to 15 per cent of nickel. Nickel ore occurs in Canada as huge lenses or masses largely composed of nickeliferous pyrrhotite and small quantities of the nickel-iron sulfide pentlandite. Millerite is far less common. The arsenides, niccolite and chloanthite, occur in the Cobalt district, Ontario. In New Caledonia and Brazil, a serpentine is capped with red "clay" (genthite, a nickel-magnesium silicate) containing 1.64 to 3.14 per cent of nickel oxide. Stringers of richer silicate ore occur through the serpentine. The electrolytic refining of certain copper ores results in the recovery of small quantities of nickel.

Nickel, because of its indispensable properties in the machine age, is considered to be the best example of the recent development from obscurity to an essential place in the metallurgical and electrical industries. In electrical conductivity of metals, nickel has a value of 22.1 for volume and mass conductivities compared with 100 for copper. The metal fortifies steel, cast iron, and bronze. It imparts strength, hardness, toughness, and resistance to wear, shock, fatigue, and chemical action. Nickel in the alloy improves response to heat-treating and machining. Nickel alloys assure uniform properties in castings and forgings and improve the strength-weight ratio. Carburizing and oil-hardened steels have greater ability to withstand shock and high tooth pressure in gear teeth when fortified with nickel. Nickel steels account for about 60 per cent of the nickel consumed, the balance being employed in copper, aluminum, and other alloys. Nickel plating is used on such metals as steel, brass, copper, and zinc. Alloys contain nickel in amounts ranging all the way from 0.5 to 80 per cent. The broad diversity of nickel alloys is due to the capacity of nickel to dissolve other metals freely, particularly iron and copper.

Nickel is recovered from sulfide ore of the Sudbury district, Ontario, by roasting in a reverberatory furnace in order to eliminate part of the iron and sulfur. It is then blown in a Bessemer converter for final removal of iron sulfide, producing matte. Roasting the matte produces nickel and copper oxides, for reduction to monel metal (natural copper-nickel alloy) in a reverberatory furnace. In the Orford process, the matte is fused with sodium sulfide in which the nickel sulfide is insoluble. It can be removed for roasting to the oxide; later, it is reduced to metallic nickel.

Nickel is recovered from silicate ore by smelting in a blast furnace to form matte. In a converter, iron sulfide in the matte becomes oxidized and unites with flux to be drawn off as a slag, leaving the nickel sulfide. Roasting then reduces the latter to nickel oxide, which is reduced, with carbon, in a reverberatory furnace.

Uses. The importance of nickel to the war effort resulted in making this one of the first metals to be placed on the priority lists and one of the last to be taken off, on Aug. 24, 1945. It is one of the 23 minerals and metals most vital in war. Nickel is more widely used industrially than either chromium or manganese, having the most varied application of any alloy metal.

Steel and nonferrous mills were the principal consumers. The volume employed for alloying metals in the steel industry increased in 1943 to 125,000 tons. Following in volume of nickel used were the iron and steel and nonferrous foundries, manufacturers of alloys, and the electroplating and chemical industries. The steel industry in the United States used about 60 per cent of the total refined nickel delivered in 1945.

Low-nickel steels (0.5 to 0.7 per cent of nickel) are essential in aircraft, automobile, and railway construction for such parts as frames, connecting rods, and axles. The use of nickel is required in many types of heavy-duty machinery and in construction shapes. High-nickel steels (7 to 35 per cent of nickel) are important in shipbuilding, chemical apparatus, furnace parts, cooking utensils, and various other equipment. Precision instruments require high-nickel steel alloys, which are also essential for controls subjected to electric current and high temperature. Nickel steels are vital in the manufacturing of armor plate, gun forgings, rotating and driving bands in shells, bullet jackets, and recoil springs. The tonnage of stainless steels, which used 40 per cent of the nickel consumed by the steel industry for wrought steel in 1945, averaged the highest on record in 1943–1945.

National Emergency Steels, some containing 0.2 to 0.7 per cent of nickel, were first produced in May, 1942, for the purpose of conserving both nickel and vanadium. No primary nickel was used in these steels. In 1943, about one-third of the alloy steels produced were National Emergency specifica-

tion. By the substitution of manganese and molybdenum, 24,000 tons of nickel were saved and an additional 10,000 tons were salvaged through the recovery of residual alloys in scrap, in 1943.

Substitutes for use by industry under the war emergency included stainless steel and chrome and cadmium plating. There are no known substitutes in the manufacture of ductile steel and of structural steel for certain purposes. The German rustproof steel, roneusil, has no nickel but 12 per cent of manganese and 8 to 9 per cent of chromium. Manganese steel can be substituted for those nickel steels required chiefly for their resistance to abrasion. For those uses where parts can be replaced more frequently, standard alloys can be substituted for nickel.

Favorable long-range prospects for nickel were reported on Dec. 19, 1945, by Robert C. Stanley, chairman and president of International Nickel Company of Canada, Ltd. "World War II has utilized more technically advanced equipment than ever before and nickel was employed in most of its construction. Since much of this equipment will be produced for peacetime applications, nickel's usage will be broadened."

The nickel industry of Canada has no extensive plant alterations to make and no problems of reconversion. Unsettled conditions following VJ-Day led to a sharp decline in nickel consumption. It was expected that greater improvement in consumption would have taken place before the end of 1945 if the steel and automotive industries had not greatly curtailed operations as a result of strikes.

Many war uses of nickel were in industrial equipment converted to war services, which resumed their place as peacetime applications. Manufacturers who had made no prewar use of nickel discovered its beneficial qualities in new uses developed during the war. In wartime, additional peacetime applications were perfected that promise to compensate for losses to competitive materials. Postwar expanded uses are seen for nickel-chromium stainless steels in the chemical, transportation, and food-processing industries.

War restrictions prevented the use of nickel silver for civilian purposes, but large demand for this material was shown before the end of 1945. Many peacetime applications include hardware, slide fasteners, and silver-plated flatware. Nickel electroplating was resumed after the war, using thicker nickel coatings, particularly for automobiles and trucks. Cupro-nickel in condenser tubes, having wartime application on large ships and in piping in naval construction, has a postwar demand for construction of new commercial ships, coastal power stations, oil refineries, and other equipment.

Postwar uses are expected to be largely in alloy steels and a variety of nickel alloys, of which the best known are the stainless steels. An expanding

market for nickel-alloy steels is expected to result from the increasing use of high-temperature industrial processes. Nickel cast irons and nonferrous metals alloyed with nickel are expected to show substantial growth. Research for new uses has been making steady progress.

Monel metal (nickel, 67 per cent; copper, 28 per cent; minor amounts of ferromanganese, silicon, and carbon) is widely employed in shipbuilding, for hospital and laundry equipment, and for a wide range of materials used by industry. The nickel-plating industry requires a substantial tonnage of nickel metal.

In high-speed aircraft motors, in diesel engines, and in the moving parts of heavy-duty transportation equipment which was of vital importance in military operations, nickel steel was of first importance. Worn-down parts of machinery and equipment are built up by means of nickel plating. The radio industry employs rolled nickel in the manufacture of vacuum tubes. The alloy kovar, a product of the induction furnace, contains nickel-iron-cobalt. Its unusual property of expanding with temperature at the same rate as hard glass makes possible permanent, gastight seals of metal to glass. This property was of major consequence in high-quantity production of radio, radar, and other military electronic tubes.

In the electrical industry, nickel is employed in nonmagnetic alloys, as well as for radio and various types of transformers. Nichrome, a chromium-nickel alloy, is notable for its high melting point; it is used as the resistance element in electrical heating devices. A highly magnetic alloy having nickel as the chief constituent is used in sheathing submarine cable. Important applications of nickel are in the manufacture of Edison alkaline storage batteries and in the ceramic industry.

Postwar uses are expected to include new alloys containing nickel where high temperatures are required, as in gas turbines. In the automobile and electrical industries, heavier electroplating will be required. Nickel will also be needed in stainless steel and in coinage as a silver substitute. New applications in low-alloy steels, replacing carbon steels, will require nickel. Nickel and nickel alloys will be used in powerful transmitting tubes and in amplifying tubes for radar, loran, and microwave beam transmission, developed for war communications.

Domestic Sources of Supply and Production. Progress has been made with several methods for recovering nickel from low-grade ores, particularly by the chemical leach with ammonia and by a metallurgical process depending on partial reduction of the iron in nickel-bearing iron ores to produce a low (6 per cent) ferronickel.

Nine exploration projects in four states were conducted in 1940–1944 by

the U.S. Bureau of Mines. Of the material found, 4 million tons averaged about 1 per cent of nickel and 17 million tons averaged less than 0.5 per cent, located chiefly in the Cle Elum and Blewett Pass properties, Washington, and the Mouat project, southern Montana. Production of nickel-cobalt ore has been secured at Mine La Motte, Fredericktown, Mo., where the ore occurs in sedimentary rocks and is associated with copper-zinc-lead sulfides. Nickel-bearing ore also occurs at the Gap mine, Lancaster County, Pennsylvania, owned by the International Nickel Company.

Ferro Enamel Supply Company, Cleveland, Ohio, completed construction of a plant in September, 1943, where speiss imported from Burma was treated. The speiss contained about 30 per cent of nickel, 7 per cent of cobalt, 40 per cent of arsenic, and 10 per cent of copper. This metallurgical plant, having annual capacity of 700 tons, was built by the Defense Plant Corporation at a cost reported to be $1,084,000.

Submarginal domestic resources of nickel are available for a period of 5 to 25 years, in terms of prewar consumption, as reported by Elmer W. Pehrson, U.S. Bureau of Mines. There is less than one year's supply of commercial ore in known reserves. These supplies, however, are available only under emergency conditions and at a high price. In the postwar period, continued dependence on foreign sources is indicated.

CONSUMPTION OF NICKEL SCRAP IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Metal	1942	1943	1944
Pure nickel	332	268	867
Monel metal	3,684	4,184	2,997
Nickel silver	3,154	1,144	1,853
Nickel alloys	479	10	2
Nickel residues	259	3,109	350

In 1940, domestic output of primary nickel amounted to 554 short tons; in 1941, 660; in 1944, 988; in 1945, 1,155. Domestic production, in 1944, consisted largely of reclaimed scrap metal. The total recoverable nickel content of purchased nonferrous scrap, in 1944, was 4,321 short tons valued at $3,024,700; this was 37 per cent lower than the 6,917 tons recovered in 1943, as reported by the U.S. Bureau of Mines. The decline was due to the lower amount of monel scrap treated compared with the volume made available in 1943 by an intensive salvage campaign. The domestic recovery of nickel, in the form of nickel salts recovered as a by-product of copper refining, amounted to 392 tons in 1944; in 1943, 796. Secondary monel-metal pig, shot, and

castings produced in 1944 (1,100 tons) were down from the 3,336 tons of 1943; copper-nickel pig and shot, 776 tons in 1944; in 1943, 875. The use of monel scrap dropped from 5,680 tons in 1943 to 2,997 in 1944.

Imports included matte (containing about 55 per cent of nickel and 25 per cent of copper), nickel alloys, and nickel oxide. Imports in 1945 amounted to 137,932 tons, largely from Canada; this total was adequate for war needs and was about 9 per cent less than in 1944. Nickel production increased 105 per cent in the period 1929–1939, according to the American Bureau of Metal Statistics. Domestic consumption increased from 50,000 tons in 1937 to 112,500 tons in 1944; in 1945, 96,237 short tons.

Primary nickel was placed under complete allocation on May 15, 1941. The use of nickel in many items was prohibited on Apr. 1, 1942; later in the same month, regulations were issued to conserve nickel in waste materials by means of segregating nickel-bearing scrap, both ferrous and nonferrous, as to grades and degrees of nickel content.

Special authorization restricted nickel to war materials on Oct. 3, 1942. Nickel was withdrawn from use in coinage in Sept. 1942, the 5 cent piece being made of new alloy (silver, 35 per cent; copper, 56; manganese, 9). Distribution of primary and secondary nickel (except nickel contained in iron and steel scrap) was placed under complete allocation in the United States in General Preference Order M-6-a, as amended. The War Production Board, through Order M-21-a, controlled the proportions of alloying elements, including nickel, for use in iron and steel alloys.

The WPB on Mar. 1, 1944, designated nickel as a ferroalloy insufficient for war uses plus essential demands for industry. Owing to heavy military requirements, there was no hope in the near future of relaxing restrictions on the metal, as reported by the WPB on Nov. 1, 1944. After VE-Day, the automobile industry was prohibited by the WPB from using nickel in chrome plating and for certain other purposes, but consumption curbs were revoked on nickel and nickel products for all other applications. Nickel requirements of the United States increased 1,000 tons a month for jet-aircraft production, as reported in the July, 1945, issue of *Fortune Magazine*.

The Metals Reserve Company made a first commitment for the purchase of nickel for stockpiling in 1941. Ranking twelfth among the stockpile items, nickel purchased by the MRC had a total cost of $20,403,289. Inventory value had been reduced to $2,388,800 on Oct. 31, 1944; on Oct. 31, 1945, the Office of Metals Reserve reported the nickel stockpile at 18,310 tons. Some of the metal was stored in Canada. Stocks were accumulated in the war period as a safety factor against interruption of supply and sudden changes in war requirements. On June 1, 1946, stockpiled nickel amounting

to 16,350 tons was held by the OMR for the Reconstruction Finance Corporation.

Harold L. Ickes, Secretary of the Interior, in December, 1945, published the following comments on the shortage of domestic mineral supplies:

> We have less than a 35-year peacetime commercial supply of nickel and twenty other minerals . . . which we shall have to import in larger and larger quantities. . . . We cannot afford another prolonged war in 20 or 30 years. The prodigal harvest that we have reaped to win this war has bankrupted some of our most vital mineral resources. We no longer deserve to be listed with the British Empire and Russia as one of the "have" nations. We should be listed with the "have nots," such as Germany and Japan. Even more alarming than the fact that we are coming to the end of some of our known resources is the fact that we are uncovering few, if any, unknown deposits of minerals.

World Production, Imports and Exports. Canada, holding first place in world nickel output, achieved maximum production in 1943 with 144,009 short tons valued at $71,675,322, or about four-fifths of the world supply. Production in 1945 was reported by the Dominion Bureau of Statistics at 123,098 short tons, compared with 137,299 tons in 1944. Exports of all forms of nickel in June, 1945, amounted to 8,002 tons; in June, 1944, 10,843. Deliveries of Canadian nickel to all markets in 1945 were 25 per cent below the requirements of the war period but were higher than in any peacetime year except 1937. In 6 years, September, 1939, to September, 1945, International Nickel delivered about 750,000 short tons of nickel in all forms. International Nickel Company of Canada mined a greater tonnage of ore in the war years than was produced by the company and its predecessors in the preceding 54 years of their existence. Total Canadian nickel production, Sept. 1, 1939, to Sept. 1, 1945, was 816,350 short tons valued at $401,752,000. Normal production of refined nickel was expanded about 50 per cent in the war period to almost 160,000 short tons a year, compared with the maximum prewar consumption, in 1937, of 120,000 tons.

PRODUCTION OF NICKEL IN CANADA, IN SHORT TONS
(After Dominion Bureau of Statistics)

1939*	1940	1941	1942	1943	1944	1945†
113,052	122,779	141,129	142,606	144,009	137,607	115,460

* World output was 133,400 short tons.
† First 11 months.

The nickel-copper ores of the Sudbury district, Ontario, are the world's major source of nickel. Minor amounts are secured as a by-product in the

treatment of cobalt-silver ores of Cobalt and other areas in northern Ontario. All Canadian nickel ore is treated at the Copper Cliff smelter of International Nickel Company and the Falconbridge smelter of Falconbridge Nickel Mines. International Nickel Company operates the only Canadian nickel refinery, at Port Colborne, Ontario, and ships some matte to its plants at Huntington, W. Va., and Clydoch, Wales. During the war, Port Colborne treated matte from the Falconbridge smelter, which had formerly been shipped to the refinery in Norway.

Several properties in Ontario were in various stages of exploration and development in the war period, including Nickel Offsets, Ltd.; North Range Nickel Mines, Ltd.; Dominion Nickel Mining Corporation; Denison Nickel Mines, Ltd.; Shewan Copper Mining Corporation; and Harlan Nickel Mines, Ltd. In Manitoba, low-grade copper-nickel deposits have been reported in the Cat Lake and Bird River areas. In British Columbia, prewar shipments to Japan were made by Pacific Nickel Mines, Ltd., Yale mining district; the property remained inactive during the Second World War.

In 1944, Canadian exports of fine nickel, nickel in matte, and nickel in oxide amounted to $68,400,634; in 1943, $68,346,346; imported nickel and its products in the same period amounted to $918,931 and $1,167,458. The United States, in 1940, imported 8,986,834 lb. of oxide from Canada and 17,442 tons of ore and matte and 70,248 tons of metallic nickel and alloys. The matte is refined at Huntington, W. Va. In 1940, International Nickel Company of Canada installed additional refinery capacity for treating accumulated stock as well as the current recoveries at mines operated by both International and Falconbridge Nickel Mines.

All restrictions on the use and distribution of nickel mill products were reported removed on Aug. 24, 1945, by Munitions Minister Howe at Ottawa. Sudden cutbacks on military requirements led to curtailed output at Copper Cliff and Port Colborne. The MRC purchased nickel at a total cost of $20,403,289. Inventory value had been reduced to $2,388,800 on Oct. 31, 1944, when stocks of refined nickel were at an all-time high. The unsettled conditions in the reconversion period were credited with the sharply lower demand for nickel. Canadian production was reduced, in August, 1945, to a rate about half of the wartime peak. In November, 1945, operations were further reduced by the closing of a reverberatory furnace at the Copper Cliff smelter and a blast furnace at Conniston. Nickel that had been held in reserve for war materials was being liquidated, in competition with new metal.

American capital controls less than 50 per cent of the Canadian nickel industry, the balance being held in Canada and England. Although Canada

approaches a monopoly position in nickel, the metal is mined in some sixteen other countries. Canadian supplies have held first place in world markets since 1905, when Canada first exceeded the output from New Caledonia. Distribution of Canadian matte and metal was controlled throughout the war period by the Canadian government in accordance with recommendations of the Combined Raw Materials Board.

In Norway, the nickel refinery of Falconbridge Nickel Mines, at Kristiansand, was lost in April, 1940, under the Nazi invasion. Falconbridge matte was treated in 1940–1945 on a customs basis by International Nickel. Possession of the refinery was regained by Falconbridge in June, 1945.

Norwegian nickel mines have been closed down for many years. Prewar production was secured mainly from small mines located at Evje and Nakkarud, with output amounting to about 1,500 metric tons a year; in 1938, 1,245 tons.

The Foreign Economic Administration reported in August, 1945, that substantial quantities of nickel were included in almost 350,000 tons of minerals and metals available in Norway for immediate shipment, in spite of the German occupation of the country. In the last 4 months of the year, it was estimated that 1 million tons of metals, minerals, and fertilizers would move out of Norway.

In Alaska, nickel has not yet been brought into commercial production, as reported on May 7, 1945, by the U.S. Geological Survey, but favorable possibilities have been indicated for important advances in the postwar period. The Yakobi Island deposit, explored by the U.S. Bureau of Mines, is reported to have large-tonnage possibilities, of which 500,000 tons have been indicated, averaging 0.346 per cent of nickel and 0.217 per cent of copper. Low-cost open-pit methods have been recommended. Nickel-bearing ore is reported to occur on Admiralty Island and elsewhere in Alaska.

At the end of 1943, Nicaro Nickel Company (controlled by Freeport Sulphur Company) opened its metallurgical plant at Levisa Bay, Cuba. Rated production was 4,000 short tons daily, which was expected to be reached in August, 1943. The Nicaro lateritic ore averages about 1.35 per cent of nickel, the deposits being located about 8 miles inland. Nickel oxide recovered in Cuba from calcined nickel carbonate is shipped to Wilmington, Del., for briquetting and reduction to metal in a 12-ton electric furnace.

The Defence Plant Corporation and the MRC provided the $33,500,000 required by this major installation. The estimated capacity of Nicaro was 16,000 tons of metal a year, which was smaller than the metal recovered by Falconbridge Nickel Mines in Canada, where the capital outlay had been about one-third that at Nicaro. Nickel oxide, containing 75 per cent of nickel,

amounting to 6,902 tons (5,157 tons nickel content) was recovered in 1944; in 1945, 15,425 short tons (12,015 tons nickel content).

The Nicaro process has been described as one of the major metallurgical advances of the war period. The nickel is sold to steel companies which introduce the material into steel furnaces without its first being reduced to metallic nickel. Output from this plant in 1945 was expected to account for 10 per cent of the world nickel supply. Nicaro will collect a royalty up to 2.57 cents a pound at such times as the production cost is reduced below the market price. Costs in April, 1945, were reported at 25.7 cents a pound. The prospect of postwar higher prices in Europe for nickel, lower wage rates in Cuba, and various plant improvements are considered to favor the commercial success of this installation.

The Petsamo mine in Finland, which follows New Caledonia in third place as a source of nickel, was developed by American capital. In 1942, while the mine was under German control, it was reported that production was started. Petsamo was later captured by the Russian army. International Nickel Company, which had developed the Petsamo under lease, relinquished claims to the mine, plant, and lease under an agreement whereby U.S.S.R. would make payment of $15,000,000 in full settlement of plant investment and property rights. The installation was designed for annual output at the rate of 10,000 tons of nickel and 3,000 tons of copper.

U.S.S.R. has nickel deposits in the Ural Mountains and in Siberia. A refinery completed in 1933, at Ufaley, had an annual capacity of 3,000 tons of ferronickel. Construction of another plant at Orsk was started in 1935, with an annual capacity scheduled at 500 tons of metallic nickel. In 1938, Russia, produced about 2,500 metric tons of metal and, as an importer of ore, matte, and fine nickel, followed Germany, the United States, and Britain. Europe is dependent on imported nickel and seven other metals.

New Caledonia, displaced in 1945 by Cuba as second largest producer, supplies about 10 per cent of world consumption. In 1940, about 459,000 metric tons of ore were mined averaging 3.8 per cent of nickel; shipments were reported, by the U.S. Bureau of Mines, at 8,570 metric tons averaging about 77 per cent of nickel. In 1934, the ore grade averaged 4.5 to 6 per cent; in 1942, 3.5 per cent. Ores are found in small, scattered, surface deposits which are not suitable for large-scale methods of production. International Nickel Company of Canada owns certain deposits in New Caledonia. In the Second World War, matte was shipped for refining in the United States, increased output being reported in 1944. Formerly, the matte had been treated in France and Belgium for marketing in France, Germany, and Japan.

Prewar production was largely controlled by French and Belgian capital, and shipments were made also by several Japanese concessionaires.

The Philippine Islands had no reported production of nickel ore in 1939, but about 5,000 lb. of ore and matte were shipped to the United States in 1940. In that year, England shipped 454,551 lb. of metallic nickel and alloys, and Norway, 107,666 lb.

New sources of supply, in 1943, included French North Africa and Cuba, the latter supplying nickel oxide for export by aircraft in larger quantity in 1944, as reported by the FEA, in April, 1945. In the Union of South Africa, nickel ores of the Sudbury type occur in the Rustenburg district, Transvaal. Other occurrences are in Tasmania, Celebes Islands, and Greece, the last producing 1,207 metric tons in 1938. Twelve other countries reported production amounting to 3,300 tons in 1938.

In Venezuela, International Nickel Company of Canada reported in November, 1945, that potential nickel deposits were being developed in the serpentine belt south of Caracas. Exploratory work was to continue for about six months, after inconclusive results were obtained from the early stages of diamond drilling.

In Brazil, the Livramento mine, state of Minas Geraes, produces garnierite ore containing a 2 per cent nickel for reduction to a 20 per cent ferronickel in a 20-ton electric furnace. The ore is reported to be of the New Caledonia type. American Smelting & Refining Company, with Brazilian associates, spent upward of $6,000,000 in developing a property controlled by Companhia Miguel Tocantins, located 1,200 miles from the coast near San Jose do Tocantins, state of Goias. Many millions of tons averaging about 5 per cent of nickel were reported. However, unsatisfactory results of metallurgical studies and inadequate transportation led to the withdrawal of American Smelting & Refining Company in March, 1945. This property was formerly developed with capital from Japan, Germany, and Brazil.

Ferronickel was one of 10 minerals included in the agreement negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus from Brazil as part of the foreign procurement program initiated late in 1940.

About half of Germany's nickel was secured from the mine and smelter at Petsamo, Finland, until its capture by U.S.S.R. in 1944. German supplies amounted to 10,000 tons in 1943, including metal secured from Petsamo and Greece, as reported by the FEA in December, 1944. An additional 1,000 tons were believed to be available from domestic sources. Germany was reported by Batelle Memorial Institute, in February, 1945, to be seriously short of the

metal, whereas Japan had supplies estimated to be substantial. Germany and Italy both secured large prewar shipments from Canada.

The Directorate of Nonferrous Metals, London, in December, 1945, reported that 12,520 tons of nickel were consumed in Britain in 1944; in the first 9 months of 1945, 6,611 tons.

With Petsamo capable of supplying about half of Europe's postwar nickel requirements and the United States expecting to secure a certain tonnage from Cuba, Canada's share in the world market may drop below the present 90 per cent. It is also regarded as a possibility that production may have been developed in the Celebes by Japan, which would make additional sources available for world consumption. The monopoly position previously secured by International Nickel Company is now strongly established, however, through research and the development of special alloys for a wide range of industrial applications. National security will make it imperative that nickel resources at Sudbury remain available to the United States and Britain with expanded facilities as at present installed.

WORLD PRODUCTION OF NICKEL (CONTENT OF ORE), IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Brazil	25	*	*	*	*
Burma	921	*	*	*	*
Canada	102,559	111,383	128,029	129,369	130,527
Greece	1,336	*	*	*	*
Netherlands Indies	753	2,222	*	*	*
New Caledonia	10,625	10,535	10,395	9,415	5,408
Norway	1,106	*	*	*	*
Southern Australia	490	*	*	*	*
South Africa	398	416	*	*	*
United States	357	503	599	555	582
U.S.S.R.	*	8,650	*	*	*

* Production not reported.

Prices. No change has taken place since 1928 in the price of nickel, at 35 cents a pound for electrolytic cathodes and 36 cents for single lots of spot metal, shot, and pig made from remelted electro. These prices remained in effect on Aug. 1, 1946, as reported by *E & M J Metal and Mineral Markets.*

Monel metal, hot-rolled standard sheet, was quoted at 38 cents a pound, f.o.b. mill. Full cold-rolled, in tempers to quarter-hard and softer, was 5 cents a pound over standard sheet; strip, cold-rolled, 38 cents; rods, hot-rolled, 35 cents. Nickel sheets, cold-rolled, were 49 cents a pound. Nickel silver sheets, 10 per cent, were 28.37 cents a pound; 18 per cent, 30.75 cents. Wire

and rods, 10 per cent, were 31 cents; 15 per cent, 34.12 cents; 18 per cent, 37.12 cents.

Nickel ore, matte, and oxide are admitted duty free into the United States. Nickel metal and shapes, according to the tariff act of 1930 and the revenue bill effective on June 21, 1932, as recorded to Feb. 1, 1943, carried rates as follows: nickel and alloys in pigs or ingots, shot, cubes, grains, cathodes, etc., 2½ cents a pound; bars, rods, plates, sheets, strands, castings, strips, wire, and electrodes, 25 per cent (5 per cent additional if cold-rolled, drawn, or worked).

Pure nickel scrap and monel-metal scrap were suspended from price control by the Office of Price Administration on Nov. 15, to be effective Nov. 20, 1945. This affected Revised Price Schedule 8, which included stainless-steel scrap. These rulings followed policies approved by the Office of Economic Stabilization to permit decontrol of goods and services when supplies balance demand "or when items are judged to have little effect on the cost of living, the cost of business, or production of other commodities."

The Metals Control, London, maintained the price of nickel at £190 to £195 per ton, as reported on Sept. 1, 1945.

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NITROGEN COMPOUNDS

(Natural and Synthetic)

Properties. Chemical nitrogen is the term referring to a large number of nitrogen-bearing substances. They are derived from the few nitrogenous compounds secured from the basic materials: chemical sediments or evaporites, atmospheric nitrogen, and coal (disregarding the comparatively small sources from bird guano, slaughterhouse wastes, and leather and hoof scraps). The greater part of the chemical-nitrogen industry of the United States now depends on ammonia as raw material. (N, atomic number, 7; atomic weight, 14.08; melting point, 209.6°C.)

Nitrogen is one of six nonmetallic or semimetallic elements used for alloying purposes. The only elements having a lower boiling point than nitrogen are fluorine, oxygen, hydrogen, and helium. Nitrogen forms four-fifths of the atmosphere by volume. The air above each square mile of the earth's surface is stated to have about 20 million tons of nitrogen. It is estimated that lightning results in the fixation of 100 million tons of atmospheric nitrogen each year.

In nature, sodium nitrates generally occur mixed with sodium chloride and sodium sulfate, combined with sand, gravel, and rock fragments. Sodium nitrate (Chile saltpeter) in natural form has the same crystalline structure and cleavage as calcite. Potassium nitrate (niter) is secured in limited supply from excreta of birds and mammals in caves and on rock ledges by means of small-scale, primitive methods. For more than half a century, prior to the First World War and before synthetic nitrogen was recovered from the atmosphere, Chile held a natural monopoly in the production of nitrate as sodium nitrate (saltpeter).

The process for recovering free nitrogen from the air, as a source of ammonia, was developed in 1913 by the German Haber. Ammonium sulfate was recovered from ammonia neutralized with sulfuric acid. Supplementing Haber's major contribution, the Ostwald process came into general use. By the Ostwald process, ammonia gas and air are blown through a hot tube packed with platinum wire gauze as a catalyst; the nitrogen oxide produced reacts with water to form nitric acid.

Fixed nitrogen is recovered from the atmosphere and combined with

other elements by the electric-arc, cyanamide, and direct synthetic-ammonia processes. The first method uses the natural air mixture, after removal of carbon dioxide and water vapor, to produce nitric acid directly. The method is now uneconomic, owing to excessive electric-power requirements, and is used only in Norway.

The second and third methods require the isolation of nitrogen from oxygen, water vapor, and carbon dioxide in the atmosphere to produce nitrogen. Nitrogen is combined with hydrogen to produce ammonia, either by the cyanamide method or by passing the hydrogen-nitrogen mixture under pressure through a catalyst. In the cyanamide process, nitrogen is fixed by bringing it in contact with finely powdered calcium carbide heated to 1000°C., forming calcium cyanamide. Coal is a source of ammonia liquor and ammonium sulfate, recovered in coke-oven operations.

Uses. Nitrogen is the basis of every type of military explosive and was also essential to the war program as fertilizer for the production of food. The largest single use in industry, for explosives, amounted to about 9 per cent of total consumption in 1924–1935. About 18 per cent of industrial consumption was in ammonium salts, nitric acid and nitrates, cyanamide, and cyanogen. The principal uses of ammonia and its compounds were military and agricultural, with only minor quantities made available for industry in the war period. Since 1924, about 75 per cent of domestic consumption was in fertilizers, for which about 87 per cent of the nitrogen imported as sodium nitrate was used in the period 1924–1935. Of imported Chilean nitrate, in the year ending June 30, 1943, about 8 per cent went to war industries and the balance to agriculture, for which even the impurities in the saltpeter are beneficial.

All synthetic chemical nitrogen from domestic sources is produced in the primary form of ammonium sulfate (NH_3). Ammonia and ammonium compounds, in time of war, were either the direct or the indirect source of most commercial nitrogen compounds. Ammonia is the source of sodium nitrate, which is consumed in the manufacture of explosives, as well as for various industrial applications, due to the greater purity of the synthetic product as compared with Chilean nitrate.

Basic nitrogen components of military and industrial explosives are derived from ammonia after it is converted by oxidation to nitric acid. TNT and DNT are produced when toluene is nitrated with nitric acid (nitric sulfuric). Prior to VE-Day these explosives were employed as demolition bombs in the large-scale air raids. Toluene is produced from certain petroleum fractions and from distillation of bituminous coal in the coke oven. Phenol (carbolic acid) is also derived from coke; when nitrated, it produces

picric acid and picrates (Explosive D). TNA and tetryl explosives are derived from benzene, which also is the source of aniline dyes.

Torpex, derived from TNT, RDX, and aluminum powder, was a naval explosive described as "the most effective underwater explosive used during the war." It helped win the battle of the Atlantic, replacing TNT in submarine munitions, intensifying the effect of mines and torpedoes, and extending the effective range of antisubmarine depth charges. In operation "Castor," Flying Fortress robots carried torpex in 11-ton loads for the destruction of U-boat pens in Heligoland, where the 40-ft. concrete roofs had proved resistant to the heaviest bombs when dropped vertically. The Fortresses were guided by radar and television after being taken into the air by a pilot and copilot, who bailed out over England. The robot plane was controlled by radio from the mother ship at distances up to 20 miles; if separated by overcast, the plane was found by radar. Television was used to aim the plane at the target. Operation "Castor" required 26 aircraft, of which two were loaded with torpex. The bombs were sent in at 200- to 300-ft. altitudes. Torpex will produce 50 to 100 per cent more underwater damage than TNT.

Torpex, together with tritonal and RDX, was removed from the secret list of wartime scientific achievements on Nov. 19, 1945. The ingredient RDX (research department formula X), previously known as cyclonite, was developed at Woolwich Arsenal, England. It was used in preparing "plastic explosives" for molding to fit any complex-shaped structure in demolition work. The manufacturing process of RDX was developed by Canadian scientists and improved in the United States. The manufacturing process, which was adopted in Britain, Canada, and the United States, made possible continuous rather than batch production, as formerly. The striking power of the United Nations was substantially increased by the development of RDX, which is too sensitive to be used alone and forms a component of several explosives. Torpex was supplanted in the last 6 months of the war in all types of Navy munitions by HBX, a mixture of RDX, TNT, aluminum powder, and a desensitizing agent.

Other explosives that wiped out U-boat packs and destroyed the Japanese fleet included materials known as compositions A, B, and C. The first is made of RDX and wax. It increased by 60 per cent the power of antiaircraft projectiles used by the U.S. Navy. Composition B is made of RDX and TNT and was used chiefly as a component of torpex and HBX as well as in fragmentation bombs. Composition C is a plastic explosive which was used chiefly for demolition purposes.

Tritonal, also derived from TNT and aluminum powder, was another explosive used with great success in the final stages of the war in Europe.

Two-ton block-buster bombs were loaded with tritonal to give greater explosive effect than was possible with TNT, for use by the RAF and the United States Army Air Force.

Glycerin, a by-product of both petroleum refining and soap manufacture, is nitrated from nitroglycerin. Common dynamite is a mixture of nitroglycerin, wood meal, and sodium nitrate or ammonium nitrate. Gelatin dynamite is a mixture of nitroglycerin plus nitro cotton. Essential war applications of dynamite included demolition work, such as blasting bridges, destroying tanks and pillboxes, and cleaning debris after bombing. Nitroglycerin is also used in diluted form in medicine.

Cellulose nitrated with mixed acid is employed in the production of gun cotton and smokeless powder. Nitrocellulose, highly nitrated, is dissolved in alcohol. A plasticizing agent, such as vaseline, is added. Evaporation of the alcohol produces smokeless powder, which is shaped into perforated grains in the final stage of manufacture.

Under war conditions, the extensive use of fertilizer was of primary importance to increase the yield per acre. As the growth element of commercial fertilizers, domestic consumption of nitrogen reached an all-time record in 1945 of about 12,500,000 tons in the United States. In various fertilizer salts, ammonia is generally the nitrogen carrier. Nitrogen, fixed in the form of ammonia, is commonly marketed for fertilizer purposes as ammonium sulfate. Ammonium nitrate had no market in prewar years as a fertilizer ingredient; but recently, owing to a surplus of ammonium nitrate, experiments have been carried on using the nitrate as an additional means of introducing nitrogen into fertilizers. Reduced imports of Chilean nitrates together with a shortage of soda ash required for the manufacture of "Arcadian" nitrate of soda led to inadequate supplies of nitrate of soda for argiculture. Nitrogen was used in other forms (anhydrous ammonia, ammonia liquor, and nitrogen fertilizer solutions) in an effort to balance the shortage in 1945.

Ammonia had strategic uses as a reagent employed in making high-octane gasoline, synthetic rubber, leather, industrial alcohol, acids, alkalies, and glass. Some thousands of uses, both in war and peace, are supplied by such compounds as cuprammonium, ammonium chloride, cyanide, sodamide, anhydrous ammonia, ammonium sulfate, ammonium bicarbonate, ammonium nitrate, ammonium picrate, and urea. Various forms of nitrogen are used by the chemical industry, for metallurgy, and for ceramics, in addition to the major use as fertilizer. Nitrate of soda, a processing agent in ceramics, is employed in the manufacture of frit for use in enameling.

In mining, ammonia serves as a solvent for the recovery of copper, nickel,

and molybdenum from their ores. Ammonia as a processing agent is employed in the recovery of tin from scrap. In magnesium production, an ammonium salt is used as a flux. In the production of alumina from clay, ammonia is employed as a processing agent. In metallurgy, the nitriding process is used for case-hardening special alloy steels, which are subjected to the action of ammonia gas at elevated temperatures. Ammonia as a nitriding agent imparts a hard wearing surface to alloy steels for motor cylinders, bearings, crankshafts, and other parts for automobiles, trucks, and other machinery. In continuous welding and in sealing radio tubes, nitrogen and hydrogen obtained by cracking ammonia in the form of anhydrous ammonia are employed. Ammonium chloride has an important part in galvanizing, tinning, and soldering. Because of the many advantages, postwar uses of dissociated ammonia are expected to continue at the expanded rate employed in the war years.

In sintering operations in powder metallurgy and in annealing operations, large quantities of ammonia are dissociated into a mixture of nitrogen and hydrogen gases to form protective atmospheres to surface-harden and anneal vital parts in aircraft, tanks, and ships. For annealing metals, nitrate salts are used as ingredients for molten salt baths. Cyanides derived from ammonia are employed for case-hardening of metal and for electroplating.

Small-scale production of nitrogen is now being secured in the form of ammonium compounds as an important constituent of special yeasts, a new product that is stated to be a palatable substitute for meat. This has been proposed as an outlet for part of the postwar surplus nitrogen production. Ammonia and its salts are used as nutrients for yeasts in producing industrial alcohol, acetone, and penicillin. Ammonia is also required for the production of sulfa drugs, antimalarials, and vitamins. An ammonia base substituted for calcium in the bisulfite pulping of wood is reported to produce a superior pulp and to overcome the stream polution that results from pulping methods using calcium. Municipal and industrial water supplies are purified by means of ammonia and chlorine.

Waterproofing, flameproofing, and mildewproofing of paper, cotton, and wood employ ammonia and its compounds. These are also needed in the preparation of certain plastics, adhesives for plywood and paper, molded articles, dry-cell batteries, dyes, lacquers, and cleaning materials. Cuprammonium rayon and nylon require ammonia in their processing. The curing and hardening of lumber demands urea. Urea and formaldehyde, mixed together at a low temperature, which is raised to harden the material, are used for molded plastics and for water-repellent adhesive resins. The latter are employed in the manufacture of laminated wood, which had essential

war uses in aircraft and gliders and in other applications as a substitute for metals.

Anhydrous ammonia is the principal refrigerant used in the quick-freezing process for food and is also essential in the production of ice and maintenance of cold-storage plants and food lockers. Anhydrous ammonia is required in producing butadiene for the manufacture of synthetic rubber and in the production of lubricating oils. The petroleum industry employs ammonia to neutralize acid constituents of the oils and to protect equipment from the corrosive products of the oil. The heart of the catalytic cracking process for the production of high-octane motor fuels is a synthetic catalyst prepared from ammonia and ammonium salts. In fluid catalytic cracking operations, ammonia is used in the recovery of the catalyst.

Adequate supplies of nitrogen were in prospect for agriculture and industry in 1946 as the result of resuming production at three of the wartime ammonia plants in addition to the commercial synthetic ammonia plants that were active in prewar years.

Domestic Sources of Supply and Production. Under the urgency of war demand for nitrogen, the domestic industry operated at capacity in 1941–1945. Requirements for munitions, agriculture, and other essential uses were far greater than stocks available from either domestic sources or imports. The United States, never self-sufficient in nitrogen, took drastic steps to expand production facilities.

Synthetic and by-product nitrogen plants having a minimum capacity of 1,725,000 tons of nitrogen were reported to be completed or in the course of construction on Jan. 1, 1943. This quantity was almost three times the maximum prewar rate of consumption of nitrogen for all purposes. When completed, these vast facilities would make the United States as independent of foreign sources as Germany had been at the outbreak of the Second World War. Productive capacity would be far in excess of peacetime requirements.

In the postwar period, it was proposed to discontinue commercial operation of government-owned synthetic plants in order to prevent competition with Chilean nitrates. At the Mexico City Conference in March, 1945, Secretary of State Stettinius stated that government-owned plants were to be maintained in operating condition, but for use only for scientific research and technologic experiment.

Synthetic-ammonia plants are believed to have prospects for peacetime application, although productive capacity in the war period increased from the 1939 daily rate of 1,450 tons of anhydrous ammonia to 2,440 tons. Ammonia plants are capable of producing three or more ammonia compounds of value to agriculture. At some plants, there are facilities for con-

verting ammonia to nitric acid; at others, it is possible to extend conversion to ammonium nitrate. Wartime ammonia capacity was about 732,000 tons a year of nitrogen, but prewar fertilizer uses did not exceed 15,000 tons yearly. It is proposed to close the gap between production and consumption by exporting fixed nitrogen compounds, converting certain plants to the manufacture of organic chemicals other than ammonia, increasing the use of fixed nitrogen fertilizers, and withdrawing plants from production, to be held in stand-by condition for future use by the War Department.

After shortages had developed in 1941–1942, the following year saw anhydrous ammonia becoming available in greater volume, only to fall short again in 1944. Critical needs were felt by agriculture, and various organic nitrogenous materials were introduced for fertilizer use. Larger supplies of ammonia and ammonium nitrate were available from munitions plants in 1943, as a result of reduced ordnance requirements. Imports of Chilean sodium nitrate were used only for direct application to the soil, for which certain physical properties made the ammonium nitrate desirable. Experimental treatments were being studied in order to increase the usefulness of ammonium nitrate in agriculture.

Production from nitrate plants was again stepped up to capacity in 1944, in an effort to fill increased demands from agriculture and from explosive plants. Supplies of nitrogen were again too short, as they had been in 1941–1942, to meet record demands for the production of explosives and for agriculture.

Nitrogen demands in the Second World War brought about a rapid increase in domestic productive facilities. From the recovery of 270 short tons in 1920, the capacity of domestic plants increased in 1932 to about 300,000 tons of synthetic nitrogen. Expansion also developed in the recovery of by-product ammonia, from the rate of 90,000 short tons in 1919 to 200,000 tons of nitrogen in 1930. Total productive capacity, in the period 1927–1931, increased from 197,500 to 517,000 short tons. "In the case of nitrates . . . , there appears to be no necessity for their retention upon either the 'strategic' or 'critical' lists of raw materials," Brooks Emeny stated in 1934.

Greatly expanded uses in agriculture followed the increased domestic-plant capacity for producing synthetic nitrogen, from 375,795 short tons in 1930 to 456,162 in 1941. About 70 per cent of normal peacetime requirements were supplied by domestic facilities in 1941. Synthetic-ammonia production amounted to about 310,000 metric tons of nitrogen a year, of which about 88 per cent came from two plants located in West Virginia.

At the time of Pearl Harbor, synthetic sodium nitrate was produced by

only one domestic plant, that of Allied Chemical & Dye Corporation, at Hopewell, Va. By the end of 1942, the capacity of domestic sodium nitrate plants had expanded to an estimated 1 million tons a year, with production allotted chiefly to munitions plants. General Preference Order M-62 allocated both sodium nitrate and Chilean nitrates; this took effect on Feb. 1, 1942. The Office of Price Administration urged distributors on Nov. 16, 1945, to place orders at once in order to forestall the plant shutdowns that were being threatened because of the lack of storage space for surplus production. Domestic production and imports, as reported by the Department of Agriculture in 1943, were expected to amount to 805,000 short tons in the year ending June 30, 1944, including about 300,000 tons of domestic synthetic sodium nitrate.

Ammonium nitrate began to be produced in 1942 by the Muscle Shoals Nitrate Plant No. 2 of the Tennessee Valley Authority in Alabama. This plant had been modernized and rehabilitated following its construction in the First World War as a plant for the production of cyanamide. Domestic production of ammonium nitrate, used largely in the manufacture of explosives, was applied as a nitrogenous fertilizer in 1942. A privately owned plant in California made shipments of ammonium nitrate, in 1943, for use as fertilizer. By the end of that year, there were a number of government-owned plants, in the United States and Canada, supplying this material for fertilizer use. The distribution of ammonium nitrate from ordnance plants of the U.S. Army was placed under the TVA for the 3 months beginning Nov. 1, 1943. All commercial ammonium nitrate mixtures produced in the United States after Dec. 1, 1943, had a nitrogen content guaranteed at 32.5 per cent.

Production of synthetic ammonia was estimated at 1,322,000 tons (see *Fortune*, February, 1944) in 1943. No official report has been made available. Used in producing military explosives and, to a smaller extent, in the manufacture of nitrogenous fertilizers, consumption in agriculture was estimated at 65,200 short tons in 1941 and at a lower figure in 1942. Demands for war materials were greatly increased and expanded facilities were reported in 1942–1943. The War Production Board was given complete allocation control over by-product ammonia in June, 1942 (General Preference Order M-163). Order M-164, effective on the same date, gave the WPB allocation control of synthetic ammonia, both of these orders continuing in effect through 1943, as did Order M-163 (effective on June 1, 1942), placing by-product ammonium sulfate under allocation. The latter product, one of the most important of the agricultural fertilizers, reached sales in 1943 totaling 774,834 tons compared with production (almost entirely by-product)

of only 762,645 tons. Of total nitrogen used for agriculture in the United States, 30.6 per cent was supplied by ammonium sulfate in 1941. Synthetic ammonia would be produced by plants located in ten or more states, it was reported by the U.S. Bureau of Mines, in 1942.

DISTRIBUTION OF DOMESTIC CHEMICAL NITROGEN, 1937, IN PERCENTAGES
(After U.S. Bureau of Mines)

Material	Domestic Consumption	Fertilizer	Industry	Explosives
Sodium nitrate	27.2	80.9	5.4	13.7
Ammonium sulfate	24.8	*	†	
Ammonia	14.7	55.0	45.0	
Imported fertilizer	10.2	*	†	
Ammonium nitrate	7.1	51.8	1.9	46.3
Nitric acid	6.5	1.5	59.2	39.3
Ammonium phosphates	2.4	100.0	†	
Urea	2.2	*	†	
Cyanides	1.5	.....	100.0	
Nitric oxide	1.4	.....	100.0	
Ammonium chloride	1.0	.....	100.0	
Sodium nitrite	0.5	.....	100.0	
Potassium nitrate	0.4	*	†	†
Ammonium carbonates	0.03	...	100.0	
Miscellaneous	0.07	†	*	

* Largely used.
† Little used.

Three government-owned ordnance ammonia plants were reported to have resumed operations in December, 1945. The Buckeye plant at South Point, Ohio, was being operated under lease by Solvay Process Company, producing anhydrous ammonia and nitrogen fertilizer solutions. These products were being marketed by the Barrett division, Allied Chemical & Dye Corporation, pioneer nitrogen producer in the United States. Nitrogen in the form of coated ammonium nitrate for agricultural use was being produced under government directives at Eldorado, Ark., and Military, Kan. The South Point plant was reported on Sept. 7, 1946, to have been purchased for $12,500,000 from the government by the Solvay Process Company, subsidiary of the Allied Chemical & Dye Corporation.

World Production, Imports and Exports. Chile, prior to 1941, held a monopoly on natural nitrates. Insistence on national self-sufficiency for war materials led world powers to establish nitrogen fixation plants and to stimulate the production of by-product ammonia from gas and coke plants. Since the First World War, competition between natural and synthetic supplies led to depressed prices, with plant capacity far in excess of peace-

time requirements. Various countries operated a total of 83 synthetic nitrate plants in 1932.

In order to meet this competition, the government of Chile abolished the export tax on nitrates and in its place took a share in the profits of operation. The government cooperated in forming a cartel which now allocates markets between natural and synthetic nitrates. In losing control of the industry, Chile gave up a primary source of government revenue. In the Second World War, the domestic economy of Chile was dominated by copper, with minerals accounting for about 75 per cent of the total value of exports. The lack of industrial development, which might supply finished products for export, formerly made it necessary for the government to rely on an export tax on nitrates as a revenue measure.

The annual output of Chilean natural nitrates was reported in February, 1945, to average 1,500,000 metric tons valued at $52,000,000. In 1941, a stockpile was started in Chile by the United States government. Effective on Feb. 1, 1942, General Preference Order M-62, of the WPB, placed allocation of Chilean nitrates under control. Under the war emergency, imports were placed under government subsidy, absorbing some of the increased costs and prices. For the fertilizer year ending June 30, 1944, supplies of Chilean nitrate, supplemented by synthetic sodium nitrate, amounted to only 90 per cent of the supply available in the previous year, with imports limited to about 500,000 tons. Chilean nitrate imported after July 1, 1942, was reported to be for the account of the Defense Supplies Corporation, a Reconstruction Finance Corporation subsidiary. About 80 per cent of imported and synthetic sodium nitrate was allocated to agriculture, and the balance to industry.

Chilean Nitrate Sales Corporation announced in September, 1944, that agricultural uses in the United States for the season ending on June 30, 1945, required a minimum of 850,000 tons of Chilean nitrates. World requirements for nitrogen exceeded world supplies by nearly 1 million tons, or about 25 per cent, it was reported on Aug. 4, 1946, by the Department of Agriculture.

In Chile, surface nitrate deposits are scattered along inner valleys of the coast range from Iquique, at the north, to Taltal, at the south. This distance of about 400 miles is entirely in desert country. In spite of severe climatic conditions, the best of living standards for employees are reported at both of the large nitrate plants, one of which is located at Pedro Valdivia and the other at Maria Elena, the latter about 60 miles from the Chuquicamata mine of Chile Copper Company.

Owing to the need for independence of the remote source of supply in Chile, 75 per cent of prewar nitrogen world output was recovered from the

atmosphere. In the period 1932–1935, while the output of Chilean nitrate dropped to only 6.6 per cent of the world consumption, synthetic plants were built in many countries and production from this source increased to 64.3 per cent. Of world requirements of nitrogen, 18.5 per cent was recovered from coal and coke by-product plants and 10.6 per cent from cyanamide. World requirements increased from 300,000 tons in 1900 to 1,052,000 tons a year in the First World War; in 1937, 2,788,000.

In British India, several provinces treat nitrate earths on a small scale, using technologic processes similar to those employed in Chile.

In Canada, production of synthetic nitrogen was more than 850,000 tons in 1943, of which 80 per cent (including a new nitrogen product) was exported, as announced on Dec. 6, 1944, by the Department of Munitions and Supply. Commercial fertilizer amounting to 560,000 tons were used in 1943 by Canadian farmers.

On the Canadian side of Niagara Falls, American Cyanamid Company, New York City, has produced calcium cyanamide, a synthetic fertilizer, since about 1910. Under war conditions, this supply was of critical value to the United States, as were other sources of nitrogen in Canada. Imports from Canada included a mixture of ammonium nitrate and limestone, produced in Ontario. This material was released by the WPB early in 1943 for direct application to the soil. Calcium cyanamide and other chemical nitrogen fertilizers were placed under allocation by Conservation Order M-231. Large supplies were available from Canada in the critical period when submarine action and the shipping shortage cut off imports from other sources. Yearly output of fixed nitrogen was rated at about 71,000 tons from cyanamide recovered in Canada.

The Foreign Economic Administration reported in August, 1945, that nitrate fertilizers were included in almost 350,000 tons of minerals and metals available in Norway for immediate shipment, in spite of the extended military occupation by the Nazis. In the last 4 months of the year, it was estimated that 1 million tons of metals, minerals, and fertilizers would move out of Norway.

In an effort to avoid a ruinous price war, an agreement was reached in 1929 with Chilean producers of natural nitrates by the syndicate representing German producers and Imperial Chemical Industries of Great Britain. German and British producers, controlling about 70 per cent of world output of synthetic nitrogen, allocated production and marketing of nitrogen compounds in world markets, not including the United States. A new cartel was formed in Europe in August, 1930, representing not only Great Britain and Germany but also six other countries. On behalf of all these, the German

Synthetic Nitrate Syndicate signed an agreement with Chilean producers to maintain price levels, outside the United States. These agreements sustained the Chilean nitrate industry in competition with synthetic materials.

The prewar capacity of synthetic plants, including nitrogen supplies from by-product sources, was in excess of requirements. Synthetic plants, in 1935, were producing about 60 per cent of the 4-million-ton capacity. In Europe, synthetic nitrogen was one of five nonmetallic minerals (plus mercury) available for export. Japan was reported to be the only world power that controlled sources of natural nitrate as a source of domestic supply; however, these deposits were inadequate to meet Japanese requirements.

At the outbreak of the Second World War, Germany, Great Britain, and other countries in Europe were self-sufficient in the production of synthetic nitrogen. A number of nitrogen fixation plants were located in German Silesia when that area was lost to Russia in January, 1945. Information concerning increased facilities that were installed during the war years is not available for countries outside the United States.

After months of research in Germany, the Office of Military Government of the United States reported on Dec. 7, 1945, that 80 per cent of all Germany's production of military explosives, from plants valued at more than $700,000,000, was controlled by Verwert-Chemie (Verwertung Chemischer Erzeugnisse), a company established on Feb. 7, 1934, under Dynamit A.G., a subsidiary of I.G. Farbenindustrie. This marked the beginning of the munitions-manufacturing program that produced a reported 12,870 tons of explosives monthly at the climax of the Second World War. Two great plants alone produced 42 per cent of the German monthly consumption of 21,000 tons of TNT. Construction started in 1936 of five major plants, which required 1 to 3 years for completion.

After the removal of usable machinery and equipment for reparations, 24 explosives-manufacturing plants are to be destroyed. Two plants in Bavaria were demolished in November, 1945. Facilities will be left in Germany adequate only for mining and construction explosives, with no provision made for the manufacture of TNT or sports ammunition.

Prices. Nitrogen sold for agricultural uses was quoted by *Commercial Fertilizer Yearbook* as follows: ammonium sulfate, per unit of 20 lb., f.o.b. Atlantic ports, in 1939, $1.35; in 1940, $1.36; in 1941–1942, $1.41; in 1943, $1.46. Sodium nitrate, in 1939–1941, was $1.69; in 1942, $1.74; in 1943, $1.75. The OPA on Aug. 2, 1946, announced a new ceiling of $30 a ton, bulk, on sulfate of ammonia sold by producers for industrial uses in all but eleven states.

Ammonium nitrate, f.o.b. Port Robinson, Ontario, was $56.65 per short

ton, the price reduced to $47.65 in May, 1943. Domestic nitrate was quoted by the TVA at $49 a ton, f.o.b. point of production. The OPA announced that effective Nov. 26, 1945, a price formula was established for manufacturer's mixed fertilizers for export; control ended on specialty fertilizers for small gardeners. On Sept. 12, 1946, the OPA ordered a 5 per cent increase in producers' ceilings for soda ash, caustic soda, and chlorine.

John D. Small, Surplus Property Administrator, proposed on Oct. 14, 1946, that the soda-ash industry meet requirements of the aluminum program by voluntary cooperation in a move to increase aluminum production. Voluntary allocation of soda ash to the industry, rather than any form of government channeling, was recommended by the soda-ash industry advisory committee.

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OSMIUM AND OSMIRIDIUM

Properties. One of six metals forming the platinum group, osmium, together with iridium, is the heaviest of all metals. The atomic weight of osmium is lower than either platinum or iridium. The platinum-group metals arrange themselves in a triad of pairs, osmium being paired with ruthenium. Chemical and physical similarities that the platinum-group metals have in common include whiteness, high melting point, high luster on polished surfaces, and resistance to attack by destructive chemical compounds. Osmium is the most refractory of the platinum group. It is one of the 16 industrial nonferrous metals used essentially as alloying constituents. (Os, atomic number, 76; atomic weight, 191.5; melting point, 2700°C.)

Osmium, when fully divided and heated, oxidizes quite readily; when strongly heated in air, the compact metal oxidizes and gives off poisonous tetroxide fumes which are irritating to the eyes. Crystalline osmium is insoluble except in the finely divided, amorphous state when it dissolves in fuming nitric acid. Osmium and iridium have the same density (22.5). Only four other elements (carbon, tungsten, rhodium, and tantalum) have melting points in excess of osmium. Its hardness is 7 (second in hardness, after iridium, of metals in the platinum group).

So named because of the peculiar odor of its oxide, osmium was discovered by Tenant, in 1803. Native osmium is of uncertain occurrence in the crude iridosmium (iridosmine) found in Brazil, the Ural Mountains, and Borneo. The term "osmite" has been applied to iridosmium containing 40.83 per cent of osmium. Iridosmium (osmiridium is the term applied where osmium is in excess) occurs as a native element having prefect basal cleavage but is usually in irregular, flattened grains. It is brittle and tin-white in color. Its hardness is 6 to 7; its specific gravity, 19 to 21 or higher, depending on the composition. Rhodium and ruthenium are both almost invariably constituents. Iridosmine minerals are nevyanskite (over 40 per cent of iridium) and siserskite (30 per cent of iridium or less).

Always associated with one or more of the platinum metals, osmium occurs in placers, in disseminations or local concentrations in dunite and other basic igneous rocks, where it is commonly associated with chromite. Only minor amounts are reported in the main occurrence at Sudbury, Ontario, in magnetic nickel-copper sulfide deposits associated with norite.

In dunite, osmiridium or native platinum are the principal metals; erosion of such deposits is the source of the great platinum-bearing and osmium-bearing placers. In streams in the Urals, osmium is believed to have been leached from native platinum. In all the important known osmiridium placers, it is probable that basic igneous rocks were the source of the precious metals. Osmiridium in "black sand" is generally associated with platinum, magnetite, and ilmenite.

Uses. Osmium alloys were developed for strategic war requirements, which have indicated larger postwar markets. Strategic uses include bearings for small instruments, replacing jewels. In the mariner's compass, bearings of osmium alloy are essential owing to the nonmagnetic and nonoxidizing properties. Because of its resistance to wear and to corrosion by ink, the natural alloy, osmiridium, has been widely employed for tipping nibs of gold pens. This was reported to be the principal prewar use of both osmium and ruthenium. Somewhat similar alloys are now used for special electrical contacts and for long-life needles for phonographs.

Osmium oxide is used in fingerprint work. Osmium tetroxide is an effective hydroxylation catalyst. The salts are used, to a limited extent, as a biological stain for fatty tissue in microscopic work and in silk dyeing. Osmium was formerly employed as a filament-alloy in incandescent lamps, owing to its refractory properties. Uses have not been reported for osmium in the form of pure metal. The high melting point of osmium has led to its use, in small percentages, for hardening platinum and palladium alloys. Osmium-iridium-ruthenium alloys have been developed for communication and other relays, magnetos, thermostats, voltage regulators, and control devices. As pivot points, ruthenium-osmium alloy, with other materials, is employed.

Domestic Sources of Supply and Production. The Metals Reserve Company made a first commitment in 1942 for the purchase of osmium for stockpiling. The government stockpile was reported by *The Wall Street Journal* on July 17, 1944, to contain 85 troy ounces of this metal. The Civilian Production Administration announced on Nov. 30, 1945, that the Office of Metals Reserve held 185 troy ounces of osmium on Oct. 31, 1945. This stock had been accumulated in the war period as a safety factor against interruption of supply and sudden changes in war requirements.

The War Production Board, on Aug. 20, 1945, revoked Order M-302 to free osmium of all controls on uses. This conservation order was issued on Apr. 16, 1943, and provided that osmium and osmium alloy were permissible for use only for implements of war.

Domestic consumption in 1940 amounted to 14,593 oz. combining

osmium, iridium, rhodium, and ruthenium (in 1942, 25,176; in 1943, 26,804) compared with 122,978 oz. of platinum (in 1942, 260,176; in 1943, 344,719) and 69,319 oz. of palladium (in 1942, 81,460; in 1943, 137,709).

Platinum metals from domestic sources occur chiefly as a by-product of gold and copper refining and from placer deposits in the Goodnews Bay district, Alaska. Crude platinum, when refined, is reported to average 1.3 per cent of osmium. Osmiridium recovered by refineries in the United States in 1930–1932 totaled 138 oz. In 1932, refineries in the United States recovered 328 troy ounces of osmiridium from all sources, chiefly from foreign crude platinum. New osmium recovered by refiners from domestic crude platinum in 1942 amounted to 786 oz.; in 1943, 508; from gold and copper refining, 5 oz.; in 1943, 5; from foreign crude platinum, 98; in 1943, 680; making a total of 889 oz. recovered in 1942; in 1943, 1,193.

STOCKS OF OSMIUM, RHODIUM, AND RUTHENIUM HELD BY REFINERS IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

1939	1940*	1941	1942	1943
9,884	32,368	33,942	35,280	42,081

* In 1940 and later years, figures include iridium.

OSMIUM AND OSMIRIDIUM IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

Material	1942	1943
Osmiridium	276	75
Refined osmium	475	1,161

World Production, Imports and Exports. From 1929 to 1938, the production of platinum metals increased from about 231,000 to 540,000 oz. a year, recovery being chiefly as a by-product in the refining of nickel and gold ores. Imports of platinum metals in 1935–1939 averaged 4,354 oz. supplied as follows: United Kingdom, 45.6 per cent; U.S.S.R., 43 per cent; Norway, 10.9 per cent; other sources, 0.5 per cent. Osmiridium imports in 1940 were 1,857 oz. compared with 1,617 oz. of osmium, up from 623 oz. in 1939. Domestic buyers reported purchases of 53,661 oz. of foreign crude platinum or osmiridium in 1942; in 1943, 39,409. This material was from Colombia and 15 oz. from Australia.

UNMANUFACTURED OSMIUM IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

Country	1942	1943
Canada	...	11
United Kingdom	475	1,150

OSMIRIDIUM, OSMIUM, AND FOUR OTHER METALS OF THE PLATINUM GROUP (NOT INCLUDING PLATINUM) EXPORTED FROM THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

Country	1942	1943
Argentina	462	
Australia	...	84
Brazil	93	12
Canada	98,377	166
Chile	57	
Cuba	.....	116
Palestine and Trans Jordan	.....	80
Other countries	118	63

U.S.S.R. has not issued an official report on production since 1927. Metals of the platinum group secured from placer deposits were estimated by the U.S. Bureau of Mines in 1936 at 100,000 troy ounces. Many areas are still productive after reworking the gravels several times. The tenacious clays result in losses, although it is reported that dredges now recover upward of 80 per cent of the platinum content.

Recovery of osmium from Canadian nickel ores is not reported, minor amounts being included with figures for rhodium. The Department of Munitions and Supply, Ottawa, announced in June, 1945, the removal of all restrictions on the distribution of osmium.

The product of South African mines, in 1939, had an average content of 0.22 per cent of osmium and osmiridium and 66.27 per cent of platinum. Large quantities of osmium have been made available through advances in the refining of copper-nickel ores from the Union of South Africa. In 1934 production of osmiridium in South Africa was reported to amount to 5,088 oz.; in 1933, 6,712; in 1939, 7,031.

Norite deposits of the Bushveld igneous complex had an average content of 0.59 per cent of osmium. Mining operations, started in 1924, were discontinued, owing to the low grade on the Merensky reef and in another zone. The Waterberg and Potgietersrust districts have platinum deposits stated to contain enormous ore reserves. Production is reported only for the period

1924–1926. Large metal stocks led to shutting down the last of the producing mines, Rustenburg Platinum Mines, Ltd., in 1932. Operations were resumed in 1933.

In 1923, mines on the Witwatersrand started the large-scale recovery of osmiridium, containing several distinct metals of the platinum group. Total output for 1927 was reported at 1,725 oz. of osmium and lesser amounts of iridium and three other metals of the platinum group.

In the Transvaal, principal production of osmium is secured from the Main Reef Leader conglomerate on the far east Rand. Notable amounts are also recovered from the Battery Reef on the west Rand. The platinum metals are also known in other conglomerates. Secured as a by-product of gold recovery, osmiridium forms 50 to 75 per cent of the concentrate which contains three other metals of the platinum group and gold.

In Ethiopia, production from alluvial deposits in 1930 amounted to 8,038 troy ounces of platinum, of which osmiridium represented 1.41 per cent; in 1932, total output was only 4,832 oz. Primitive mining methods and theft are stated to account for large metal losses. Prewar shipments of concentrates were reported by a native firm and by an Italian using French capital, operating along the Birbir River, Wallega province.

In Belgium, prewar recovery of platinum metals was made at Antwerp as a by-product of the refining of copper ore mined at Katanga, Belgian Congo.

In Colombia, platinum metals occur in conglomerate of Tertiary age. The chief source, however, is reported to be gold- and platinum-bearing gravels derived from a belt of ultrabasic rocks, including dunite and pyroxenite, in Cerro Irro. This is the origin of placer deposits of the Choco district, where iridosmium and osmiridium occur in crude platinum that contains about 85 per cent of platinum. Iridosmium of two varieties is reported, one containing 20 to 50 per cent of osmium and the other 70 to 75 per cent. South American Gold and Platinum Company is the only operator carrying on dredging operations in the Choco district. Limited output is secured on the Pacific coast and from gravels of the Cauca River, Antioquia Department. Production of crude platinum metals amounted to 30,548 oz. in 1941; in 1942, 51,974 oz.; in 1943, 23,945.

In New South Wales, Australia, osmiridium, gold, and platinum occur in river gravels. Analysis of the platinum has shown a 9.3 per cent osmiridium content. These deposits had been worked continuously since 1893, it was reported in 1935.

In Tasmania, iridosmium is concentrated in weathered dunite, as eluvium or partly decomposed rubble. Prior to the First World War, Tasmania was

reported to be the main source of osmiridium, or iridosmium. Production was secured from placer deposits, where it was sometimes associated with gold but very rarely with platinum. In the period 1930–1932, the total recovery of osmiridium in Tasmania amounted to 3,018 oz.; in 1934, 488 oz.; in 1939, 283 oz.

In Borneo, the occurrence of osmiridium with platinum has long been known in gold- and diamond-bearing gravels. The prewar production of minor amounts of platinum metals was reported in Papua (4 oz. per year of osmiridium produced in 1934 and in 1939) and Sierra Leone.

In Japan, gravels of several rivers contain osmiridium, which forms up to 65 per cent of the precious-metal content.

Prices. In 1939 the price of osmium was $36 per troy ounce; in 1940, $35; in 1942, $45 to $48. The price was quoted at $50 per ounce on Aug. 10, 1944, continuing in effect through May 10, 1945, as reported by *E & M J Metal and Mineral Markets.*

Osmium prices fluctuated from a high of $115 in 1925 to a low of $55 in 1927–1929; in 1930, $60 to $75; in 1931, $60 to $70; in 1932, $60 to $65, the London quotation being £11 10*s.* to £12. In 1934, the price of osmium represented the highest unit value of the six platinum metals.

Maximum Price Regulation 309, established by the Office of Price Administration, set osmium at $50 per troy ounce on Feb. 1, 1943.

Foreign crude platinum or osmiridium was quoted at $24.05 to $97.55 per ounce in 1942; in 1943, $26.69 to $90.10, as reported by the U.S. Bureau of Mines.

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PALLADIUM

Properties. Of primary importance among the five metals associated with platinum, palladium is about half as common and is available at a lower price than both platinum and gold. A rare, silver-white element, palladium has the power of absorbing gases such as hydrogen, of which it will take up several hundred times its own volume without losing metallic properties. (Pd, atomic number, 46; atomic weight, 106.7; melting point, 1555°C.) It has the lowest melting point of the platinum group. One of the three light platinum metals, palladium has a specific gravity of 12.16 and a hardness of 4.8.

Palladium is one of the 16 industrial nonferrous metals used in substantial quantities in the pure state or serving as the base for alloys.

Platinum and palladium are the most generally applicable of the platinum group. They are ductile and only moderately hard but can be alloyed with other platinum metals to increase hardness. Commercial palladium has an ultimate strength of 48,000 lb. per sq. in.; its strength is increased to 71,500 by the addition of 3 per cent of rhodium and 2 per cent of ruthenium, with a 5-min. anneal at 1000 to 1100°C.; strength is about 59,000 for the alloy containing 1 per cent of rhodium and 4 per cent of ruthenium, at 1000 to 1100°C., after a 5-min. anneal. Palladium is hardened by readily absorbing hydrogen at moderate temperatures. For this reason, it is important to avoid cooling palladium in hydrogen if a soft product is required. Alloys rich in palladium will withstand drastic working and forming operations.

The platinum-group metals arrange themselves in a triad of pairs, palladium being paired with platinum. Palladium has certain chemical and physical similarities in common with other metals, including whiteness, high melting point, high luster on polished surfaces, and resistance to attack by destructive chemical compounds. Platinum and palladium, the most abundant of this group, are about one hundred times as rare as gold. These two metals occur in nearly equal proportions in the copper-nickel ores of the Sudbury district, Ontario; elsewhere, the palladium content of the ore is usually much lower than the platinum. Palladium occurs in the native state and as allopalladium and palladium gold.

Palladium-clad stock is made by welding the alloy to a backing of silver or nickel, then rolling or drawing the composite bar to the desired thickness. Stock of this type is widely applied in chemical equipment. Palladium-

platinum-silver alloy is fabricated into optical frames similar to those formerly used of gold-clad or gold-filled stock.

Important properties of palladium as a basis for broad industrial application include the following: catalytic activity, low vapor pressure, high strength at elevated temperatures, high ductility, low coefficient of thermal expansion (about the same as glass), high coefficient of electrical resistivity, stable thermoelectric behavior, and high resistance to spark erosion. Palladium differs considerably from platinum in producing greater whiteness and in raising the solidus temperature, though inducing less rapid aging on heat treatment. Discovered in 1803 by Wollaston, palladium was named after the planet Pallas.

Uses. Palladium is the most extensively used of the five metals associated with platinum. Strategic uses were in electrical equipment for small contacts as a very effective addition to platinum and as a catalyst in a growing number of hydrogenation processes. Spongy palladium is more active than platinum as a catalytic agent, absorbing over eight hundred times its own volume of gas. The gas is retained until the palladium is heated in a vacuum. Palladium is being applied to large-scale production of vitamin adjuncts and other organic materials.

Palladium alloy is used for fuses employed to detonate explosives. The manufacture of pens and pencils has become an important consumer of palladium, the metal being reported in sufficient supply in 1944 for industry as well as for the jewelry trades. Baker and Company, Inc., reported that expanded uses and advantages of palladium and other platinum metals for war applications are expected to be applied in postwar processes and products.

Prewar domestic consumption amounted to about one-fifth that of platinum. Lower price was given as one reason for the use of palladium in dentistry and for the medium-duty electrical contacts, replacing platinum. Prior to the First World War, there were no uses for palladium, which was introduced as a substitute for platinum. Minimum munitions requirements were estimated by Brooks Emeny, in 1934, at 20,000 oz. of palladium yearly, based on industrial uses in 1929. The following distribution to various industrial requirements was estimated for a 2-year period: electrical, 18,856 troy ounces; dental, 12,156; jewelry, 4,451; chemical, 1,345; miscellaneous, 1,048. Emeny placed palladium in the category of a "relatively unimportant" metal for strategic uses. In the First World War, palladium-silver alloys were replaced by nickel-chromium in ignition apparatus to resist spark erosion.

In 1944, war demands increased for palladium in dental, industrial, and jewelry applications. Uses also increased for this metal in the electrical industry which, in 1940, consumed 47 per cent of the palladium sold.

Essential applications are in electrical contact points in instruments, regulators, standard resistors, primary battery electrodes, relays, and similar devices for telephone and other equipment, because of its long life and dependable service. An important application is in supplying extremely pure hydrogen for furnace atmospheres.

Essential applications of palladium, reported in 1941 by International Nickel Company, include the following: palladium-copper alloy used in electrical contacts, control devices, and resistors; platinum-palladium-gold alloy for temperature-limiting fuses; platinum-palladium-gold alloy in spinnerets for rayon; palladium chloride in color-responsive carbon monoxide detectors; a platinum-palladium-gold-silver alloy in platinum solders for jewelry and the decorative arts; the two alloys, palladium-platinum-silver and palladium-ruthenium-rhodium, for watchcases and spectacle frames. In dentistry, palladium is essential in tooth pins, anchorages, and wrought alloys, including a range of six alloys which include gold, silver, copper, platinum, rhodium, and ruthenium.

Expanded application for plant equipment and for other industrial purposes was made possible early in the war period by the stabilized price. Palladium is employed by the jewelry trades as an alloy with gold and other precious metals. In the palladium alloys, rhodium is desirable in securing a brilliant polish; ruthenium is primarily useful as a hardener. Palladium is used as an electroplate on silver and other metals to prevent tarnish. Superior tarnish resistance, strength, and response to age-hardening treatment are properties making palladium an important element in dental metallurgy for gold dental alloys.

In artificial teeth, palladium-gold alloys are employed for producing the porcelain-to-metal junction. Palladium is beaten into foil in the same manner as gold for jewelry applications and in the decorative arts. Sales of palladium to the jewelry industry increased 130 per cent in 1943, when the dental industry took 30 per cent of palladium.

Domestic Sources of Supply and Production. Domestic consumers bought 69,319 oz. in 1940, when consumption in the United States amounted to 60,204 oz. compared with 96,829 oz. in 1939. Palladium amounting to 14,773 oz. was recovered in 1940 from the treatment of scrap metal, sweeps, and other waste products of manufacture.

During the period 1925–1934, annual recovery from palladium-bearing copper ore averaged 600 oz. of platinum metals: In Alaska, the Goodnews placer platinum deposits have produced 62.10 to 73.48 per cent of the values in platinum, 5.90 to 20.34 per cent in iridium, and 0.23 to 0.56 per cent in palladium.

Refiners reported 1940 recovery of 21 oz. of palladium from crude platinum, 3,183 oz. from gold and copper refining of domestic ores, and 1,360 oz. from foreign ores. The 1940 total of 4,564 oz. compares with 3,491 oz. in 1939.

Domestic consumption of palladium expanded from 12,000 oz. in 1920 to 25,725 in 1932; in 1943, 137,709. Sales of palladium to the chemical industry in 1943 gained 158 per cent and to the jewelry industry, 130 per cent. Distribution to domestic consuming industries over a 2-year period is shown as follows:

PALLADIUM CONSUMPTION IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

Industry	1942	1943
Electrical	28,452	25,907
Dental	27,480	41,522
Jewelry	19,658	45,218
Chemical	5,480	14,162
Miscellaneous	390	10,900
Total	81,460	137,709

SECONDARY PALLADIUM RECOVERED IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

1939	1940	1941	1942	1943
13,039	14,773	12,630	16,416	23,616

NEW PALLADIUM RECOVERED BY REFINERS IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

1939	1940	1941	1942	1943
3,491	4,564	49,812	140,262	82,441

The Metals Reserve Company made a first commitment for the purchase of palladium for stockpiling, in 1942. The platinum metals as a group held rank as twenty-second in the government stockpile, with a combined value of $3,764,526. Market value reduced to $1,216,754 was shown by the MRC inventory of Oct. 31, 1944. Government stockpiles were reported by *The Wall Street Journal*, July 17, 1944, to hold 174 troy ounces of palladium.

The War Production Board issued Order L-45, effective on Apr. 15, 1943, restricting the use of palladium and gold by large manufacturers in their production of jewelry (Apr. 15 through June 30) to 75 per cent of the use

of these two metals in the same period of 1941. Uses were reduced to 50 per cent on July 1, 1943, in order to release plant facilities and workers for war production. This action was not taken as a result of any shortage in palladium supplies.

World Production, Imports and Exports. Consumption in 1940 represented the following imports: United Kingdom, 49,588 oz.; Canada, 10,168; Norway, 443; Argentina, 5. World production of platinum and the platinum-group metals in 1944 was estimated at 570,000 oz. Figures for world output in the war years are not available.

Canada, the leading palladium producer, supplied 42,229 fine ounces valued at $1,960,085, in 1944; in 1943, 126,004 oz. valued at $5,233,068 (including palladium, rhodium, iridium, etc.). The Department of Munitions and Supply, Ottawa, announced in June, 1945, the removal of all restrictions on the distribution of palladium. The recovery of palladium and other platinoids from the refining of copper-nickel ores in the Sudbury district, Ontario, has made Canada the world's largest producer, replacing the U.S.S.R.

The prewar substitution of palladium for platinum, an example of inter-commodity competition, was stressed by International Nickel Company as a move to increase outlets for the platinum-group metals. Under the cartel Consolidated Platinums, Ltd., International Nickel Company was limited to marketing 52 per cent of Russia's output of platinum. This cartel, however, applied only to platinum, while production of palladium and three other metals of the platinum group by International Nickel exceeds that company's output of platinum metal. International Nickel is by far the world's foremost producer of palladium and minor platinum metals (except osmium), which must be produced as by-products in mining copper-nickel ore. The cartel, formed on Oct. 21, 1931, for the purpose of stabilizing prices and securing international agreements controlling production, has not functioned since 1932.

The Belgian Congo produced 2,025 troy ounces of palladium in 1932; in 1934, 3,569. Platinum and palladium occur in the Ruive gold deposit, Katanga, in banded sandstone associated with lead and copper vanadates. The bullion is reported to contain 36.11 per cent of platinum and 6.06 per cent of palladium.

In South Africa, production of palladium and other platinum metals has not been reported since October, 1942, when the U.S. Bureau of Mines stated that mine output was being maintained at capacity. The platinum-ore concentrates were being shipped for refining in England.

Colombia, the only world source of platinum-group metals until 1823,

remained in second place until the early 1930's. Production comes chiefly from the Choco district. Palladium represents only 0.54 per cent of the output of crude platinum, Consolidated Platinums, Ltd.; the cartel was allotted only 9 per cent of world sales of concentrates produced in Colombia, this action accounting for the substantial drop in United States imports from 43,155 oz. in 1931 to 7,824 oz. in 1932.

In Brazil, certain river gravels contain palladium amounting to 21.77 per cent of the total platinum-group content. Both gold and palladium (as the natural alloy porpezite) occur in alluvial deposits in jacutinga reefs of the state of Minas Geraes.

Prices. The price of palladium was in effect at $24 a troy ounce from 1940 through Sept. 30, 1946, as reported by *E & M J Metal and Mineral Markets*. This maximum price was established by the Office of Price Administration in Maximum Price Regulation 309, effective on Feb. 1, 1943, for the refined metal of commercial purity of 99.5 per cent minimum. For metal of less purity and for palladium content of scrap, sweeps, and other waste products, the maximum price was set at the maximum secured in the first quarter of 1942.

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PLATINUM ORE

Properties. A malleable, steel-gray to white metal, platinum is often magnetic. It is not attacked by oxygen and most acids. The melting point is 1773.5°C. compared with 1063°C. for gold. (Pt, atomic number, 78; atomic weight, 195.23.) Its specific gravity is 21.4.. It is a bad conductor of heat and electricity. Platinum is one of 16 industrial nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. The platinum metals arrange themselves in a triad of pairs. Of the platinum-palladium pair, platinum possesses almost twice the atomic weight and density of palladium and a higher melting point. It is about one hundred times as rare as gold.

Platinum occurs in association with iron, gold, copper, and nickel. In primary ore deposits, platinum is associated with ultrabasic rocks, such as dunite and norite, but never with granite. In alluvial and eluvial placer deposits, platinum consists of nuggets, scales, and irregular grains, sometimes associated with chromite, ilmenite, and magnetite. It is treated with dilute aqua regia to dissolve out impurities. In most platiniferous ores, the palladium content is much lower than that of platinum; in the Sudbury copper-nickel ores, platinum and palladium occur in nearly equal proportions.

Platinum is alloyed with other metals, chiefly of the platinum group, which act as hardening and strengthening agents and raise the annealing temperature. Prized for jewelry manufacture, owing to high value, beauty, and properties of malleability and resistance to corrosion, the latter qualities are of strategic importance in chemical and electrical applications. Platinum is free from attack by most chemical reagents. It is nonoxidizable at any temperature, very ductile, and only moderately hard and has an extremely high fusing point. Other uses of platinum are based on catalytic activity (in the form of platinum black), low vapor pressure, high strength at elevated temperatures, low coefficient of thermal expansion (about the same as glass), high temperature coefficient of electrical resistivity, high resistance to spark erosion, and high and maintained reflectivity.

Platinum and platinum alloys withstand drastic working and forming operations. For very fine wires, down to 0.00004 in., platinum wire surrounded by a heavy silver jacket is drawn to a small over-all diameter. The silver is then dissolved, leaving the minute platinum-wire core.

Uses. In the First World War, platinum was one of eight critical metals presenting a strategic problem. In the Second World War, it was of even greater strategic importance to science and industry. Platinum metal was utilized in many military and industrial applications, particularly in the construction of aircraft, ships, guns, and tanks and in the manufacture of various types of instruments, including numerous electrical and electronic devices and radio equipment required by warfare on land, on sea, and in the air. Very fine wires are used for telescope and microscope cross hairs and for small electric fuses.

Platinum crucibles, electrodes, and other pieces of laboratory apparatus had vital use in the scientific research that contributed directly to the successful conclusion of the Second World War. In the chemical laboratory, no effective substitute for platinum has been found. Many new pieces of platinum equipment have been applied in microchemical technique. Platinum and platinum alloys are vital to plants and apparatus specially constructed for the production of such strategic materials as explosives and electrochemicals.

The chemical industry, largely as a consequence of catalytic activity, has used about 13 per cent of the platinum consumed since 1918. Ranking first in wartime importance in catalytic use was the production of nitric acid by the oxidation of a mixture of synthetic ammonia and air by passing it through red-hot rhodium-platinum alloy gauze (platinum black). In addition to its use for explosives, nitric acid is required for various chemical and metallurgical processes, photographic materials, fertilizers, dyestuffs, plastics, and lacquer. In the manufacture of sulfuric acid by the oxidation of sulfur dioxide to sulfur trioxide, platinum is also employed as a catalyst. In hydrogenation and dehydrogenation, platinum and palladium are both important as catalysts. In the laboratory, platinum has an important function for large-scale production of vitamin adjuncts and various special organic products.

Persulfuric acid and hydrogen peroxide are manufactured by means of platinum anodes, which are the most satisfactory for producing highly oxidized materials, such as "per salts," halogens, organic oxidations, electroplating, and electroanalysis. Insoluble anodes of platinum and iridium-platinum alloy are used in various electroplating processes, including the recovery of metals from waste solutions. The safe handling of corrosive liquids and gases is made possible by the use of platinum rupture disks. In plant-scale equipment, platinum-clad sheet, pipe, rod, and lined reaction vessels are required in a wide range of sizes.

In special glass products, platinum has been responsible for spectacular achievements. The commercial production of fiber glass provides a new and vastly superior insulation for copper wire. Resistance to attack by molten

glass made platinum an essential material in the manufacturing process. Glass fiber is produced by permitting molten glass to pass through a bank of platinum nozzles. The fine strands of glass are stretched to provide the fibers of required minute diameter. Fiber glass is employed in manufacturing fabrics that are chemically inert and also in producing air-filter and heat-insulation mediums and a storage-battery separator. Platinum alloys (platinum-gold and rhodium-platinum) are employed by the rayon industry as nozzles or spinnerets through which the viscose is forced.

Because of its long life and complete resistance to oxidation and tarnishing, platinum is indispensable in aircraft high-tension magnetos, spark coils, and spark plugs. It holds a strategic and critical position as a contact material in telephone relays, in radio and radio-location equipment, and in many types of automatic-control gear. The electrical industries, since 1918, accounted for about 13 per cent of the annual consumption of platinum, dropping to 8 per cent after 1929 as a result of substituting cheaper materials. Largest demand for platinum was in the manufacture of contact points of ignition apparatus and for fuse wires and electrical-furnace windings. Thermoelectric properties have made the platinum metals essential for certain special applications. In telephone relays, platinum metals will break larger voltages without sparking than other metals.

In overload electric fuses that will blow at a few thousandths of an ampere, platinum wire of extremely small diameter is indispensable. Immunity to oxidation is an essential quality, both for electric fuses and for detonating fuses employed with explosives. In temperature-compensating networks of electrical instruments, platinum has proved to be an efficient metal. Resistance thermometers, electrical gas analyzers, and high-temperature precision thermocouples use platinum and rhodium-platinum alloy as effective materials. "Liquid" platinum is used in metal-to-glass seals.

Various substitutes, developed since the First World War, were regarded as adequate for many uses of platinum, in response to greatly stimulated demand for the strategic and critical uses for munitions and special research projects. Vanadium sponge was reported as a satisfactory substitute for platinum as a catalyzer. Platinum, in connecting wires in incandescent lamps, has been largely replaced by platenite, an iron-nickel alloy coated with copper. Adequate substitutes have been found in certain alloys for resistance windings in electric furnaces and for thermocouples. Various substitutes are available for crucibles in laboratory equipment and plant apparatus. Materials used as substitutes include artificial corundum, porcelain, fused quartz, rustless iron alloys, chromium, nickel, tungsten-nickel, and tantalum.

In the case of platinum, Brooks Emeny states that available substitutes

make it unnecessary to retain this metal on either the "strategic" or "critical" lists. "Not only is our situation in [this] commodity relatively secure, but adequate plans for the procurement of necessary supplies or substitutes . . . have been thoroughly devised, and need only to be put into proper execution in time of a war emergency."

Since 1918, the jewelry industry has taken 60 per cent of the platinum used in the United States, particularly for setting gems. Platinum is also beaten into foil for use in the decorative arts. Dentistry has used about 9 per cent, and miscellaneous uses accounted for about 5 per cent. In dental alloys, platinum and palladium are widely employed because of their strength, resistance to tarnish, and response to age-hardening treatment. Platinum-base alloys are used in the finest type of dental restorations, and platinum-foil matrices for producing porcelain crowns and inlays. Uses of the metal, in the form of a chemical compound, are limited, including fluorescent screens for X-ray work, photographic paper, and platinum salts for use in electroplating platinum.

War demands for essential equipment involving platinum and platinum alloys included a wide range of applications. War industries employed platinum and platinum alloys for producing fiber glass and rayon and in a variety of corrosion-resisting equipment operating at moderate temperatures. In large plating and electrochemical equipment, use was found for insoluble anodes of platinum-clad copper; additional applications were under consideration in 1944. Platinum and rhodium-platinum gauzes are employed in a wide range of chemical and industrial uses.

Absolute war requirements were estimated by Brooks Emeny in 1934 at 50,000 oz. of platinum. A sufficient supply of the metal was maintained in the form of catalysts and stocks to assure maximum output of installed sulfuric acid and nitric acid plants, which were estimated to require less than 12,000 oz. a year.

A new platinum thermocouple was reported in September, 1945, by Brown Instrument Company. This was developed by Rustless Iron and Steel Corporation as a revolutionary device in speeding up and providing more accurate and economic production of stainless steel. Few new uses were developed for the platinum metals in the Second World War, as reported by the U.S. Bureau of Mines. A substantial decline in consumption for the postwar period was forecast, although price stabilization and more diversified markets were expected to lead to demand greater than in prewar years. Chemical and allied manufacturing were believed to offer favorable long-term possibilities in postwar products and processes.

Domestic Sources of Supply and Production. Platinum, a deficient material, was placed on the industrial strategic list in 1942, as a result of dependence on foreign sources for more than 95 per cent of the supply. It is secured mainly from placer mining and has very limited domestic production as a by-product in smelting copper ore. Domestic demand was greater in 1940 than formerly; new record demand was established in 1942–1943. Recovery of new and secondary metal increased 14 and 5 per cent, respectively, in 1940. In 1943, consumption mounted 36 per cent above the maximum volume reported for 1942, owing mainly to requirements in the manufacture of electronic tubes, contact points, and spinnerets for glass fiber and in jewelry

PLATINUM PRODUCED IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

Production	1941	1942	1943
Crude platinum from placers	26,221	21,063	21,510
From ore and gold-copper refining	.....	4,340	5,205
New platinum, domestic	17,027	25,403	26,715
New platinum, foreign	81,349	218,823	207,605
Secondary platinum	37,522	56,150	68,613

NEW AND SECONDARY PLATINUM RECOVERED IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

	1939	1940	1941	1942	1943
New platinum	36,033	38,951	98,376	244,226	234,320
Secondary platinum	45,432	47,657	37,522	56,150	68,613

The Metals Reserve Company made a first commitment in 1941 for the purchase of platinum for stockpiling. Ranking twenty-second among stockpile items, platinum metals purchased by the MRC had a total cost of $3,764,526. Inventory on Oct. 31, 1944, showed a market value of $1,216,754; as of Oct. 31, 1945, government stocks held by the Reconstruction Finance Corporation through the Office of Metals Reserve amounted to 55,166 troy ounces; 31,148 oz. on Sept. 30.

The metal was withdrawn from nonstrategic uses, chiefly in the manufacture of jewelry, in 1943. Restrictions were placed by the War Production Board on the sale and delivery of platinum scrap, under Order M-162, as amended on Nov. 22, 1943. This order prohibited the delivery of platinum to processors having more than a specified amount of scrap and limited

inventories of platinum in the hands of processors and consumers. Order M-162, effective on Oct. 21, 1942, prohibited the use of platinum and platinum alloys in jewelry manufacture. The WPB designated platinum as insufficient for war uses, plus essential industrial demands, on Mar. 1, 1944; in August, the metal was reported to be urgently needed in war production.

Platinum and some of the platinum metals were included by the WPB in June, 1945, with a list of materials and products that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and it was anticipated that further changes in controls would be announced. The WPB revoked Order M-162, freeing platinum of all restrictions on Aug. 20, 1945. No new scrap metal could be promised in the near future to the jewelry trade for manufacture and repair work.

The government stockpile contained 58,753 troy ounces of platinum, as reported on July 17, 1944, by *The Wall Street Journal.* Domestic commercial reserves of platinum were estimated by Elmer W. Pehrson, U.S. Bureau of Mines, at a 4-year supply based on the annual rate of use in 1935–1939, Submarginal domestic resources estimated at a 4-year supply were stated to be available in terms of prewar consumption, under emergency conditions and at a high price. For the postwar period, continued dependence on foreign sources was indicated.

Platinum and 20 other minerals were listed by Harold L. Ickes, Secretary of the Interior, in December, 1945, as inadequate for a peacetime commercial supply to last more than 35 years. Imports of these minerals would be required in increasing quantities.

World Production, Imports and Exports. In 1938, world output was 537,000 troy ounces; in 1939, 531,000 including an estimated 100,000 oz. from placer operations in U.S.S.R. World output in 1944 was estimated at 570,000 oz. The principal producing countries were Canada, U.S.S.R., South Africa, and Colombia.

World consumption was believed to be making use of all available supplies. Canada was credited with 54.4 per cent of prewar output; U.S.S.R., 18.6 per cent. National self-sufficiency in platinum is held by only the British Empire and Russia, all other world powers being dependent on foreign sources. Japan controls limited sources which are inadequate to supply all domestic requirements, and imports are required to make up the deficiency.

Canada, ranking as the foremost producer of platinum and metals of the platinum group, reported 1944 output of 157,523 fine ounces of platinum valued at $6,064,635; in 1943, 219,713 oz. valued at $8,458,951. Output in 1945 was 162,000 oz.; in 1942, 285,228 oz. In 1944, exports of platinum-

group metals in all forms were valued at $6,776,508; in 1943, $7,738,998. In 1944, imports of platinum products were valued at $99,381; in 1943, $454,946.

The purchase of platinum remained on a permit basis in Canada in June, 1945, when the Department of Munitions and Supply announced the removal of restrictions on the distribution of other metals of the platinum group. Canadian output of platinum is mainly as a by-product of nickel-copper mining in the Sudbury district, Ontario. In British Columbia, limited recovery is secured annually from black sands and from impure residue in the refining of gold at Trail.

Shipment of precious-metals residue is made to the refinery of International Nickel Company, at Acton, England (operated by the subsidiary, Mond Nickel Company). Annual capacity of the Acton refinery, the world's most important, is 300,000 oz. of platinum-group metals. Before the Nazi invasion of Norway, the Kristiansand copper-nickel refinery treated matte shipped by Falconbridge Nickel Mines, Ltd., and recovered refined platinum, palladium, gold, and silver. International Nickel facilities were made available for Falconbridge matte in the war period. International Nickel's costs for the recovery of platinum are far lower than production costs of any other operator.

World supply is now secured largely from British territory: Canada, South Africa, Australia, and Sierra Leone. U.S.S.R. is credited with an annual output of about 100,000 oz. of platinum. Alluvial deposits in river beds and river terraces are the main source of the metal in Russia. A main occurrence is in dunite in the Nizhni Tagil district, in the Ural Mountains. Dredges have replaced the primitive methods formerly used and are reported to recover 80 to 90 per cent of the platinum.

Colombia ranks third as a source of platinum. Major deposits occur in the Choco, Guapi, and Barbacoas districts and in the bed of the Cauca River, Antioquia department. South American Gold and Platinum Company, the only operator equipped with dredges, mines platinum by either primitive or hand methods, as reported in 1937. The Colombian government announced on Dec. 28, 1945, the repeal of all regulations and restrictions on the mining and marketing of platinum. The order was expected to increase exploratory work in the Choco and other districts.

In South Africa, platinum recovery from gold ore on the Rand started in 1923. In the following year, gravel deposits were discovered in the Lydenburg district, and a platinum-bearing horizon was found on the Merensky reef in the Bushveld igneous complex. On the Merensky reef, commercial-grade platinum ore is confined to the Rustenburg area. Rustenburg Platinum

Mines, Ltd., has been in production since 1933. In the Waterburg district, production was secured from vein deposits in 1924–1926.

IMPORTS AND EXPORTS OF PLATINUM INGOTS, SHEETS, WIRE, ALLOYS, AND SCRAP BY THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

	1939	1940	1941	1942	1943
Exports	46,329	55,027	15,405	103,707	3,183
Imports*	190,226	126,696	254,714	315,002	362,251

* Refined and unrefined.

EXPORTS OF PLATINUM AND PLATINUM ALLOYS FROM GREAT BRITAIN,* IN TROY OUNCES
(After American Metal Market)

1939	1940	1941	1942	1943
14,042	38,011	20,185	43	6,175

* Includes shipments to the United States under reciprocal aid.

WORLD PRODUCTION OF PLATINUM, IN TROY OUNCES
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Belgian Congo (from refineries)	868	*	*	*	*
Canada:					
Placer	25	24	60	30	*
Refined†	148,877	108,464	124,257	298,400	*
Colombia, placer	39,070	35,859	37,349	49,163	39,961
Netherlands Indies‡	28	34	*	*	*
New Zealand, placer	13	. . .	35	21	*
Sierra Leone, placer	83	135	*	*	*
South Africa§	59,311	71,975	85,730	73,210	49,361
U.S.S.R.‖	100,000	100,000	100,000	100,000	100,000
United States:					
Placer	32,460	33,800	26,221	23,213	27,162
Refined and ore	5,336	4,470	1,820	4,359	5,205

* Data not available.
† From nickel-copper matte.
‡ Probably placer platinum.
§ From metal and concentrates.
‖ Estimated.

In Ethiopia, concentrates are exported for refining, production being secured by primitive methods from gravel deposits on the Birbir River, Wallega province.

Copper ores of Katanga, Belgian Congo, are the source of by-product platinum recovered at Antwerp, Belgium.

In Alaska, total mineral production to the end of 1944 included gold (70 per cent), copper (25 per cent), and eight other minerals including the platinum group (5 per cent). Expansion in the output of platinum can be secured through systematic development, as reported on May 7, 1945, by the U.S. Geological Survey. Production at the rate of about 20,000 oz. a month is secured from the Goodnews Bay placer deposits in the short dredging season.

Chief consumers up to 1941 were the United States, Germany, Great Britain, and France. Imports of refined platinum by the United States in 1940 were 195,645 oz. compared with 306,627 oz. in 1939. Canada was the main source of imports.

Prices. The official quotation of $35 per fine troy ounce for commercial quantities and qualities was in effect for platinum through the war period, as reported by *E & M J Metal and Mineral Markets.* Price and other restrictions were removed by the Office of Price Administration, the price rising to $56 an ounce on May 6, 1946. In June the price averaged $54.68 for platinum packed in cases, in lots of 5 tons or more but less than a carload; in August, $78.556. On July 1, the price advanced to $67 an ounce for large lots and $70 an ounce for small lots. The following prices were quoted by *American Metal Market:* in 1939, $36.61; in 1942, $35.15; in 1943, $35.02; in 1940–1941 and 1944–1945, the price was unchanged at $35; on Sept. 30, 1946, $90.

The maximum price was established by the OPA in Maximum Price Regulation 309, effective on Feb. 1, 1943. The OPA announced that ceiling prices were revised in order to make them more uniform for the six platinum-group metals, effective on Feb. 25, 1946.

The Metals Control, London, maintained the price of platinum at £8 12*s.* 6*d.* per ounce, as reported on Sept. 1, 1945. The official British price was revised to £17 ($75.65 U.S.) from £13 10*s.* a fine ounce on July 1, 1946.

A new cartel, Consolidated Platinums, Ltd., was formed in 1931. This allotted U.S.S.R. 50 per cent of world sales; Canada was allotted 26 per cent; South Africa, 15 per cent; Colombia, 9 per cent. International Nickel, as a partner under this agreement, was given a quota for world sales substantially lower than its potential output, owing to the limited demand for nickel in 1931–1932. The cartel, which has not functioned for some years, applied only to platinum and excluded other metals of the platinum group.

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POTASH

(Muriate)

Properties. Potassium carbonate, a white, alkaline salt, is commonly called potash; when purified, it is known as pearl ash and salts of tartar. impure potash is obtained by leaching wood ashes. Muriate is a salt of muriatic, or hydrochloric, acid. The term "potash" includes all potassium compounds. In chemistry, potash refers only to oxide of potassium. Industry restricts the term potash to potassium carbonate and potassium hydroxide. Potassium is one of the eight elements that together account for about 98.5 per cent of the composition of the outer 10 miles of the earth's crust, of which potassium represents 2.6 per cent. (K, atomic number, 19; atomic weight, 39.096; melting point, 62.3°C.)

Sylvite (potassium chloride) and langbeinite (anhydrous double sulfate of potassium and magnesium) have a theoretical content of 22.7 per cent of K_2O. Sylvite is processed to yield 60 per cent or higher of K_2O muriate. Langbeinite, harder than common salt, is a greenish- or reddish-white glassy mineral. It usually occurs in massive granular aggregates. The discovery of this mineral was announced in Germany in 1891. Its specific gravity is 2.81 to 2.86; its hardness, 3 to 4.

Deposits of langbeinite of economic importance are limited to the United States and Poland, production being secured only since 1940. Other known occurrences are in salt deposits of central Germany; the Salt Range, Punjab, India; and the salt beds of Salzburg and the Tyrol, Austria. Deposits of Austria and India are not known to have commercial value. Langbeinite and sylvite are saline residues of the evaporation of sea water. They are found associated with the following water-soluble minerals forming potash: kainite, kieserite, halite (common salt), polyhalite, carnallite, and schoenite.

Nearly all potash deposits have been formed by the evaporation of sea water. Potash-bearing beds of New Mexico and Texas occur in the Salado formation, of late Permian age. Beds of potassium salts lie at depths from 300 to more than 3,000 ft. below the surface. Polyhalite is the most abundant and widespread potassium-bearing mineral, followed by sylvite. In German deposits, carnallite, kainite, and sylvite are the most important minerals.

Crude carnallite salts contain a potassium equivalent of 9 to 12 per cent of potash; kainite, 12 to 15 per cent; alunite, 11.4 per cent. Potash salts are

marketed as kainite (without previous treatment), manure salts, sulfate, and muriate. Potash sulfate is produced by refining the crude material and by treating potassium chloride with sulfuric acid. Muriate and manure salts are dissolved in hot water and allowed to cool, the potassium separating as potassium chloride in two grades: (1) manure salts, containing 30 to 50 per cent of potassium chloride, and (2) muriate, containing more than 50 per cent of potassium chloride, partly refined and recrystallized.

Uses. Largely used in the production of fertilizer (90 per cent) and chemicals, potash salts include muriate of potash, sulfate of potash, sulfate of potash-magnesia, and run-of-mine potash. These are prime necessities of war, along with such chemical raw materials and fertilizers as sulfur and pyrite, salt, chemical and industrial lime, fluorspar, barite, boron minerals, phosphate rock, and nitrogen. These substances are employed in great quantities either as components of finished products or as active reagents in chemical processes that are essential to various strategic industries. Potash is one of 23 minerals and metals most vital in war.

Langbeinite is used as a raw material for the production of sulfate of potash-magnesia and sulfate of potash for fertilizers to be used on soils having magnesium deficiency. Sulfate of potash and sulfate of potash-magnesia are valuable plant foods in water-soluble form.

Permanent agriculture requires addition of adequate amounts of potassium salts (potash) to the soil. As a plant food, potash has no substitute. For industrial uses, caustic potash is essential. High-grade and optical glass, electric-light bulbs, and soap manufacture require potash, which is also of strategic value in making explosives. Potassium chlorate is an important material in the manufacture of matches, and minor quantities are required in metallurgy and in the tanning and dyeing industries. Potash salts are required for photographic, medicinal, and miscellaneous chemical uses.

Domestic Sources of Supply and Production. The abundance and availability of potash in the United States have contributed to the very large expansion of domestic chemical industries and have provided one of the principal mineral-fertilizer raw materials. "Potash . . . is the subject of one of the most dramatic chapters in the history of American mining."

"The prodigal harvest of minerals that we have reaped to win this war," referred to by Secretary of the Interior Harold L. Ickes, includes 3,155,000 tons of potassium produced between Jan. 1, 1940, and Jan. 1, 1945. From the national standpoint, America has larger potash reserves than any other country.

In 1941, domestic output of potash and other production was 531,346 tons; potassium salts increased from 284,497 tons in 1937 to over 800,000

tons in 1944. Output expanded 22 per cent in 1939–1940. There was urgent demand for all material mined. In 1942, production was 1,267,455 short tons containing 680,831 tons of equivalent K_2O; in 1943, 732,151 tons valued at $26,183,073.

Agriculture and chemical grades of potassium chloride, potassium sulfate, and potassium bromide are recovered in small quantities from the highly complex brines of Searles Lake, California, by American Potash & Chemical Corporation, formerly controlled in Germany. The German potash trust, until February, 1943, controlled the Pioneer Potash Company, importing and selling in the United States potash of German origin until title was taken over by the Alien Property Custodian. Products similar to those now made from langbeinite were formerly imported from Germany. Recovery from Searles Lake is as a by-product of borax and magnesium chloride manufacture.

In the Carlsbad, N. M., potash district, three companies, in 1942, produced 3,035,549 tons of sylvite and langbeinite having an average equivalent K_2O content of 21.52 per cent. Production of metallic magnesium from magnesium chloride recovered at Carlsbad was terminated in 1944. Treatment had been carried on by International Minerals and Chemical Corporation at Austin, Tex., where by-product magnesium chloride recovered from potash operations is converted to metal.

Large deposits of soluble potash salts were discovered at Carlsbad, and first production was obtained in 1931. Sylvite is being mined east of Carlsbad, N M., by three companies. Of these, one company, International Minerals & Chemical Corporation, also mines a bed of langbeinite located about 100 ft. above the productive sylvite bed.

Potash salts have gradually become sufficient to supply all domestic requirements, supplemented by salts obtained from saline lakes in California and Utah. Potassium-bearing brines are being produced commercially in Utah, where alunite and bedded chlorite deposits are under development. In Salt Lake City, a plant produces alumina and potassium sulfate from alunite.

Domestic production expanded greatly after 1934, supplying potash demands both for food and for chemicals. Output was nearly five times as great in 1941 as in 1934. Domestic sales exceeded 732,000 tons in 1943.

The United States has been self-sufficient in potash since 1941; plants have been enlarged, and the refining process improved. Domestic supplies of this important commodity will be adequate for many years. Commercial reserves are estimated at a 117-year supply, and submarginal resources for over 500 years, as reported by Elmer W. Pehrson, U.S. Bureau of Mines. This is one of eight minerals that may be expected to be available for more than 100 years, on the basis of known usable domestic reserves.

Owing to shortages of potash for national defense and for export, the War Production Board placed domestic production under allocation control on Feb. 27, 1943. Allocation was in effect through May, 1944. Late in 1942, it was disclosed that domestic output was largely under government control.

On Apr. 12, 1946, it was recommended that potash salt be returned to allocation control. The OPA reported on Aug. 26, 1946, that potash supplies would meet only 60 per cent of the total quantity requested by domestic fertilizer companies, although postwar production had shown a slight increase. In the period ending June 30, 1947, established fertilizer firms were to have about the same allocation of potash as in the previous year.

A public hearing was held on Sept. 26, 1946, by the Department of the Interior in Albuquerque, N. M., to consider liberalizing the regulations governing potash exploration and development on public lands.

World Production, Imports and Exports. Imports from Germany and France continued until the Second World War interfered. Potash was one of six materials exported by Europe in the prewar period. Foreign sources supplied 62,255 short tons valued at $5,726,898 in 1941; in 1942, 21,328 tons valued at $2,203,461. Muriate (chloride) of potash amounting to 1,557 tons was imported from U.S.S.R. in 1942, compared with 1941 receipts from Spain and Palestine amounting to 14,671 tons.

Imports in 1942 were chiefly from four countries: Chile, 14,514 short tons of crude potassium-sodium nitrate mixtures; Algeria, 1,403 tons of argols or wine lees bitartrate; French Morocco, 626 tons of bitartrate; Argentina, 1,402; Portugal, 249; Brazil, 247.

Exports amounted to 140,329 tons in 1939, with Japan the principal buyer. For the first time in the history of the industry, in 1941, exports exceeded imports. Canada, in 1942, received 81 per cent of total exports from the United States, amounting to 76,162 short tons of fertilizers and 3,321 tons of chemicals.

In 1938, the world potash industry was dominated by four countries: Germany, France, United States, and U.S.S.R. Minor output was obtained by Poland. The K_2O content of production from these countries amounted to 3,105,000 metric tons, and 54,000 tons were produced by other countries. Germany accounted for 58.9 per cent of the world total, and France, 18.4 per cent. The United States, Germany, France, and Spain have national self-sufficiency in potash, whereas other countries, except U.S.S.R., are almost entirely dependent on imports.

In central Germany, beds of potash salts and common salt occupy a great basin. The potash mines of Hanover and Saxony and magnesite

deposits in Bavaria are the source of magnesium production in Germany, principally as a by-product of the potash industry.

Large Russian reserves are located in the Solikamsk region, 150 miles west of the Ural Mountains. Potash beds lie in a basin similar to that of central Germany. Extensive deposits were discovered, in the 1930's, in Russia and Spain. The production of Spanish potash reached important volume in 1932, from the Ebro basin, province of Barcelona. Poland produces potash in Galicia. Palestine produces potash by the evaporation of water of the Dead Sea. In France, potash salts occur in upper Alsace and in the Pyrenees region. A potential source of fertilizer is reported to be the potash-bearing dust from the recent eruption of Vesuvius, in Italy.

German reparations to U.S.S.R. and Poland, as reported on Oct. 11, 1945, by Edwin C. Pauley, were to be taken out of the eastern zone of occupation. U.S.S.R. and Poland were also to receive 25 per cent of the industrial equipment of the western zone, which was under control of the United States, Britain, and France. In exchange for this equipment, U.S.S.R. and Poland were to deliver various commodities, including potash, clay products, and zinc, equal in value to three-fifths of the amount received from the western zone. The United States made limited reparations claims to patents, samples of specialized machinery, "know-how," and German foreign-exchange assets.

Germany controlled world potash production from 1861 to 1914. A cartel dominated by the German government controlled price and distribution. Wasteful methods in the industry were encouraged by the monopoly; high prices maintained on foreign sales aroused resentment among consumers in the United States.

Opposition to the price policy of the German Syndicate helped speed the discovery of new deposits in various parts of the world. With the German monopoly broken, and all producers joined in a cartel, production proved to be so widely distributed that control could not be exercised by any one group.

The development of domestic production in the United States had advanced to the point where German sources would have held only minor importance in the Second World War, even though shipping facilities had not been disturbed.

Prices. Base prices reported by *E & M J Metal and Mineral Markets*, on Apr. 12, 1945, were as follows: muriate of potash, per unit of K_2O, 58 cents (in 1942–1943, 53½ to 56 cents for 48 to 63 per cent K_2O). Purchases could be made f.o.b. Carlsbad, N. M., at 11.2 cents per unit below ex-vessel price, and f.o.b. Trona, Calif., for 8 cents per unit of K_2O below net ex-vessel price at Pacific coast ports.

Manure salts, per unit of K_2O, 60 cents (in 1942–1943, 20 to 21 cents for 22 to 26 per cent grades), based on Carlsbad, N. M.

Kainite, 20 per cent of K_2O, 63¾ cents per unit.

Sulfate of potash, 90 to 95 per cent of K_2SO_4 (basis 90 per cent of K_2SO_4), $36.25 per short ton.

Sulfate of potash-magnesia, minimum 40 per cent of K_2SO_4, 18.50 per cent of MgO, $26 per short ton, ex-vessel price at Atlantic and Gulf ports within the United States, minimum carlots of 40 tons.

The general Maximum Price Regulation, effective May 11, 1942, under authority of the Price Administrator in accord with the Emergency Price Control Act of 1942, fixed potash prices at the maximum as of March, 1942. The prices of muriate of potash and other substances containing K_2O when marketed were fixed at the price prevailing on Feb. 16–20, under Maximum Price Regulation 135. Maximum Price Regulation 404, effective June 18, 1943, was issued by the Office of Price Administration, setting ceiling prices for sales by domestic producers to fertilizer manufacturers, for muriate of potash, sulfate of potash, sulfate of potash-magnesia, and manure salts. Second Revised Maximum Price Regulation 135, effective not later than Jan. 1, 1944, established prices for potash and every grade of mixed fertilizer whose manufacture and sale were permitted by the War Food Administration.

Allocation controls on primary potash salts were reimposed on May 31, 1946, by the OPA to "protect the nation's food supply."

Maurice H. Lockwood, president of the National Fertilizer Association, on Sept. 17, 1946, reported that the majority of the 480 members of the industry favored a revival of the German potash industry and the importation of that product to conserve supplies in the United States for any national emergency. Germany, with more than 80 per cent of the world's known reserves, was believed to be producing at one-third capacity. Domestic reserves could be extended for 50 to 100 years if reduced production can be maintained, compared with peak output of 13,200,000 tons in 1946. Government-owned potash plants had annual capacity of less than 200,000 tons.

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QUARTZ CRYSTAL AND PLASTIC OPTICS

Properties. Next to the feldspar group, quartz is the most abundant mineral in the earth's crust. Quartz has physical and chemical properties that lead to a variety of uses in industry. Its hardness is 7; it is moderately tough, resistant to acids, refractory, and often transparent. Quartz crystal, or rock crystal, ranks as a mineral of great strategic importance.

Quartz is transformed into cristobalite or tridymite at about 800°C. and has no true melting point of its own. Silica has an appreciable tension at about 1200°C. and vaporizes in air at about 1750°C. (Si, atomic number, 14; atomic weight, 28.06; melting point, 1420°C.)

In March, 1943, methods of inspection for quartz crystals were established and specifications for inspecting and grading piezoelectric quartz were revised by the National Bureau of Standards to include fragments ranging from 100 to 200 g. in weight, 45 per cent usable, and quartz containing blue needles. The specification for usable quartz in pieces weighing 200 g. or more was revised, in January, 1944, to include quartz containing moderate quantities of hard and soft blue needles, some color, fine bubbles, and inclusions. Radio grade included 100- to 200-g. material only if 80 per cent appeared usable when inspected without instruments.

The marketing system depends on the usability of a crystal for piezoelectric purposes. A Brazilian-American agreement, in effect from May, 1943, through June 15, 1944, governed exports of mica and quartz crystal. The quality of quartz crystal is designated by Grades A, B, C, and D, the last grade referring to crystal that is 50 per cent or better by volume "eye clean." The material is sorted by weight into 12 classes, 100–200 to 7,000–10,000 and above 10,000 g. Faced and unfaced crystals depend on the presence or absence of one or more natural crystal faces. In grading quartz, 84 possible classes must be considered.

As a natural silica abrasive, quartz is grouped with diatomite, tripoli, ground sand and sandstone.

In the manufacture of plastic optics, fluid plastics of molasseslike consistency are poured into precisely surfaced glass molds. The plastic is hardened in a baking oven in order to reproduce the surface precision of the molds to a very exact degree. When removed from the molds, the optics are ready for use and grinding, and polishing of each optic is eliminated. Of the

two organic plastics standardized, one corresponds in optical characteristics to crown glass and the other is used for elements ordinarily made from flint glass. One problem of the plastic material is the greater softness, making it more easily scratched than glass.

Uses. The phenomenal increase in demand for quartz crystal is regarded as one of the outstanding effects of war on the application of minerals in industry. Originally produced principally for use in jewelry, quartz crystal became a strategic material in the early 1920's for use by the radio industry. Quartz crystal is a key product filling essential industrial needs for which no satisfactory substitute has been found, particularly for oscillator plates employed in radio transmitting and receiving sets, for radio-frequency control, and in detection devices.

The most important war development in radio and telephonic transmission was reported to be a method of X-ray irradiation in which frequencies of the plates may be adjusted downward from their original values, permitting salvage of those quartz plates which had been damaged in manufacture or in cleaning or as a result of aging. Weekly output by the X-ray method, in 1944, amounted to about 1,000 overfrequency quartz plates.

In detection devices, ocean cables, and local and long-distance telephone-transmission equipment, quartz crystal makes possible the simultaneous transmission of hundreds of independent messages over the same wire at the same time. Demand increased greatly after 1937, following development of the use of quartz crystal in equipment for ocean cables and for telephone communication. Other uses include range finders and precision instruments for measuring pressures or detonation in gun barrels or aircraft engines.

As a result of technical advances, it is now permissible to use smaller and more impure quartz crystal than formerly in radio work, for cutting into piezoelectric plates to be used in telephone resonators and filters, or oscillators. Quartz used for these purposes is limited to crystals weighing 3 to 8 lb. and having at least two crystal faces. Domestic production of piezoelectric devices in 1943 amounted to 14,011,677 small oscillators, 8,474,523 large oscillators, 65,595 telephone resonators, and 24,355 units of detection equipment.

In radar and in acoustic antisubmarine devices employed by the U.S. Navy, quartz crystal is a vital element. It amplifies a mechanically produced sound wave, transforming it into electric energy and projecting it to detect objects. The electric wave bounces back and is transformed into sound by the quartz. The sound is projected upon a screen that indicates the approximate position of the submarine.

Postwar uses of quartz crystal are expected to include radios, radar, and

television. Nonstandard equipment, such as quartz crystal, has been found of use in unrelated industrial products. Advances during the war in communication technique are expected to increase postwar consumption of quartz crystal.

Laborious grinding and polishing operations for glass optical materials were eliminated by a new method developed by Polaroid Corporation, announced on Nov. 14, 1945. A manufacturing process made possible the mass production of molded plastic optical elements for use in lenses, prisms, and mirrors for telescopes and other high-precision optical instruments.

In the Second World War, plastic optics were developed from synthetic materials for use in telescopes, experimental aerial cameras, binocular attachments, and a Schmidt-type lens system ten times more efficient than an F.2 camera lens. A joint announcement of the Office of Scientific Research and Development and the War and Navy Departments stated that research into plastic optics was conducted by the Polaroid Corporation under contract awarded by the National Defense Council in 1940. The supply of optical glass was supplemented by plastic optics, resulting in a saving of time and labor by producing elements that could be readily machined at the edges without danger of fracture. Costs were reduced by mass output which used semiskilled and unskilled labor.

Full-scale mass production of plastic optics was reached before the invasion of North Africa in 1943. Antitank gunners had been injured by telescopic sights during the recoil of their guns. The new Polaroid sight permitted gunners to keep their eyes on the target 6.5 in. back from the eyepiece without sacrificing accuracy and with complete safety, which was lacking when the eye was held an inch or less from the eyepiece. The 3-in. M5-type gun was equipped with a three-power, fixed-focus, telescopic sight with a fixed recticle, for direct antitank fire. Plastic optics are suited for large, nonspherical optical parts employed in optical systems where the amount of light lost in transmission must be held to an absolute minimum. Plastic optics may be used in combination with glass, being placed at the eye end of the instrument.

Uses of the natural silica abrasives include the following: diatomaceous earth, used chiefly in filtration, in various types of insulation, and also as fillers or admixtures and as abrasives; tripoli, used chiefly as fillers and abrasives and other applications such as for concrete, in oil-well drilling, and foundry facing; flint (sugar quartz or vein quartz), used in sandpaper and abrasives; ground sand and sandstone, used by foundries in the production of pottery, porcelain, tile, and abrasives and also for fillers and in the glass and enamel trades. Quartz was of high strategic value in the manufacture

of optical glass used in high-quality lenses for various applications for the armed forces.

Domestic Sources of Supply and Production. Small quantities of satisfactory quartz crystals were produced in Arkansas and California in 1943, for the first time since the First World War. Domestic production of 2.9 tons was valued at $25,598. In 1940, the production of piezoelectric quartz expanded from $1,500,000 to more than $150,000,000 a year for oscillator plates supplied to the Army and Navy.

The War Production Board designated quartz crystal, on Mar. 1, 1944, as insufficient for war uses plus essential industrial demands. Piezoelectric-grade quartz was near the top of the list of strategic and critical minerals. The WPB retained control of imports, stocks, sales, and transfers of piezoelectric quartz, through Conservation Order M-146.

The Metals Reserve Company made a first commitment for the purchase of quartz crystal for stockpiling in 1941. Ranking fourteenth among minerals and metals in the government stockpile, quartz crystal was used under war conditions at the rate of about 2 million pounds a year compared with pre-war consumption of less than 100,000 lb. annually. The cost of deliveries for stockpiling was $14,883,130 with a market value of $10,787,801 shown in the MRC inventory, on Oct. 31, 1944. Quartz crystal in government stocks held by the Reconstruction Finance Corporation through the Office of Metals Reserve, as of Oct. 31, 1945, amounted to 993,019 lb.; on Sept. 30, 1,341,350 lb.

The average number of oscillator plates recovered from quartz crystals increased as a result of improved cutting efficiency and changed design of oscillators permitting the use of smaller plates. Oscillator plates averaged 9.5 per pound of usable quartz, in 1942; in 1943, 16.3. Usable quartz amounting to 650,000 lb. was recovered from discarded material on hand in 1943.

Domestic production of the natural silica abrasives is as follows: Diatomite comes from California and Oregon; tripoli, chiefly from Arkansas, Illinois, Missouri, Oklahoma, and Pennsylvania; crude, crushed, and ground quartz, from some 15 states, particularly Virginia, Maryland, Tennessee, North Carolina, and Massachusetts; ground sand and sandstone, from 10 states of which Illinois, New Jersey, Ohio, and Pennsylvania are the most important.

World Production, Imports and Exports. National self-sufficiency in quartz crystal is not held by any world power. Brazil is credited as the only source of piezoelectric quartz for use in radio and telephone equipment. Accessible deposits are located in four districts of Minas Geraes and in the states of Goyaz and Bahia. The known quartz area had been greatly extended

in the war period, stimulated by higher prices, and new deposits of commercial value were reported to have been opened in 1944.

Brazilian deposits of quartz crystal are generally discontinuous and require selective mining, only a small part of the material produced being usable. Crystals are mined by primitive methods, usually from residual deposits of decomposed granite or from veins of quartz or pegmatite. Inspection to provide material for export was established by the Foreign Economic Administration in connection with the extensive procurement campaign.

Brazilian quartz crystal exported in 1910 amounted to 24 metric tons compared with 1,103 tons in 1940; in 1941, 1,979 tons. Brazil, in 1944, exported quartz crystal having a value that exceeded the combined value of crude feldspar, gypsum, and fluorspar produced in the United States in 1941. Machinery purchases on a large scale were made by the RFC, on the direction of Board of Economic Warfare, for the purpose of producing quartz crystal in Brazil. After the equipment had been shipped, it was learned that mining the product could not be mechanized, with the result that all mechanical supplies were left to rust in storage.

Quartz crystal was one of 25 minerals included in agreements negotiated by the Federal Loan Agency, through the MRC, for the purchase of the entire exportable surplus from Brazil as part of the foreign procurement program initiated late in 1940.

The United States imported more than 2,000 tons in 1944, almost entirely from Brazil. Imports of quartz for piezoelectric use amounted to 1,678 short tons valued at $11,370,803 in 1943; in 1942, 1,306 tons valued at $8,987,108. This material was received from Brazil except for 680 lb. from Guatemala and 585 lb. from Colombia.

The procurement division of the Treasury Department, in 1940, built up a substantial stockpile so that the United States purchases in Brazil, early in the war, amounted to only about 5 per cent of the normal exports from that country. Brazilian pebble, in 1939, was imported to the extent of 750 tons.

Prices. The price varied from $2 to $15 a pound, delivered at New York, 1936 to 1940. All sizes for fusing were being sold at $100 to $150 a ton, it was reported by *E & M J Metal and Mineral Markets*, on Apr. 12, 1945. Prisms for piezoelectrical and optical uses were reported to command a substantial premium.

The MRC purchased piezoelectric quartz on the basis of inspection at the Bureau of Standards.

List 1, faced material, Grade 1, 30 to 45 per cent usable, 0.44 to 22 lb., $3.95 to $18.50 per pound; 45 to 60 per cent usable, $5.95 to $27.70; 60 to

100 per cent usable, $7.85 to $36.95 per pound. Grade 2, $3.30 to $30.80 per pound. Grade 3, $1.95 to $9.20 per pound.

List 2, unfaced material, 30 to 45 per cent usable, 0.44 to 22 lb., $3.16 to $16.65 per pound; 45 to 60 per cent usable, $4.76 to $24.93; 60 to 100 per cent usable, $6.28 to $33.25. Grade 2, $2.64 to $27.72 per pound. Grade 3, $1.56 to $8.28 per pound.

List 3, small material (must be faced) weighing 0.22 to 0.44 lb., $1.60 to $2.40 per pound.

Tripoli, as reported by *E & M J Metal and Mineral Markets*, remained from 1942 through Aug. 1, 1946, at $14.50 per ton, f.o.b. Missouri, once-ground through 40-mesh, rose or cream colored; double-ground through 110-mesh, $16; air-floated through 200-mesh, $26.

Crude dried diatomite, f.o.b. Nevada mines, was quoted at $7 a ton in bulk; in bags, $12; 40-mesh, $18; 98- to 100-mesh, $20; 200-mesh, $22.50; low-temperature insulation, $19; high-temperature insulation, $30 to $40. Fine abrasives were 2 cents a pound (bags extra). Silica in bags, 325-mesh, was $20 to $40 a ton.

Brazilian quartz crystals were one of ten imported items which the OPA on Aug. 21, 1946, removed from dollar-and-cent ceilings. Quartz crystals were made subject to the general import pricing formula which allowed total landed costs plus customary markup.

Quartz crystal and optical glass are strategic and critical materials to be acquired and guarded in accordance with the stockpile bill passed by Congress in July, 1946; the Procurement Division of the Treasury Department was designated to buy reserve supplies of these strategic materials, aided by the Office of Metals Reserve and other agencies.

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RHODIUM

Properties. One of the platinum-group metals, rhodium is a white, lustrous metallic element. Its specific gravity is 12.44. (Rh, atomic number, 45; atomic weight, 102.91; boiling point, 4800°C.; melting point, 1955°C.) It is more efficient than chromium as a reflecting surface. Rhodium is ductile and malleable at a red heat. The pure metal is almost insoluble in all acids but is more easily attacked by chlorine and sulfur than other platinum-group metals. Rhodium is one of the 16 industrial nonferrous metals used essentially as alloying constituents.

The platinum-group metals arrange themselves in a triad of pairs, rhodium being paired with iridium, the latter possessing almost twice the atomic weight and density of rhodium and having the higher melting point. Rhodium is less workable and higher melting than either platinum or palladium, which are hardened by alloying with small percentages of rhodium.

Uses. Rhodium, subject to conservation regulations as an essential metal for war applications, was used mainly for alloying purposes. As a hardener for either platinum or palladium, rhodium is used as high-melting-point wire for thermocouples, for furnace windings, and for laboratory ware in special applications. For the measurement of high temperatures, rhodium-platinum thermocouples have been used in war industry to maintain temperatures as high as 1600°C. under oxidizing conditions. Such instruments have given increased control and economy in steelmaking. Rhodium is used as a catalyst in the production of nitric acid, nitric oxide, and sulfuric acid. One troy ounce of 10 per cent rhodium-platinum catalyst will produce approximately 1 million pounds of nitric acid. Of major wartime value was rhodium-platinum alloy gauze used as a catalytic agent in the production of nitric acid by the oxidation of a mixture of synthetic ammonia and air.

A rhodium-plating process is used in the protection of components of electrical and radio apparatus. It gives a hard, corrosion-resistant coating that withstands attack by salt spray and atmospheric corrosion. Platinum-rhodium alloys have been applied as spark-plug electrodes and furnace-heating resistors; for crucibles for oxide fusions, including glass; and in synthetic crystals for optical parts, for gas meters and orifices, and for feeder dies for glass lamp bases. In dentistry, palladium-rhodium-ruthenium alloy is used for wrought alloys.

Rhodium is highly desirable as an auxiliary element in platinum used for ammonia oxidation catalysts, for high-temperature furnace windings,

and for electrical contacts. Rhodium is a very desirable component of palladium alloys in securing a brilliant polish. Higher rhodium, lower ruthenium alloys are best suited to deep draws, particularly in sections that are perforated before drawing.

Rhodium metal is used in the optical field for surfacing searchlight reflectors and projectors in order to provide a permanent, nontarnishing reflecting surface for the all-metal reflectors of searchlights employed by the Army and Navy. Rhodium has an important peacetime application as a plating for a finish on glassware and silverware. Silver-encrusted glassware has been revolutionized by rhodium plating, making the product practical and popular because of greater durability. Palladium-rhodium-ruthenium alloy is employed by the jewelry industry for ring blanks, diamond and other gem mountings, watchcases, and decorations in conjunction with gold. The jewelry industry uses rhodium for electroplates. In the production of rayon and glass fiber, the spinnerets of platinum-gold, formerly used, are now replaced by platinum-rhodium alloy owing to the higher resistance to corrosive agents.

Much that was learned in the war years concerning the uses and advantages of rhodium and other platinum-group metals will be applicable to postwar products and processes, as reported in 1944 by Charles Engelhard, president of Baker & Company, Inc.

Domestic Sources of Supply and Production. The Metals Reserve Company made a first commitment for the purchase of rhodium for stockpiling in 1942. Rhodium amounting to 105 troy ounces in government stockpiles was reported on July 17, 1944, by *The Wall Street Journal.* Rhodium amounting to 161 troy ounces was held in government stocks by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration on Nov. 30, 1945.

All restrictions on the use of rhodium were removed by the War Production Board on Aug. 20, 1945, when Order M-95 was revoked. The WPB prohibited the use of rhodium in the manufacture of jewelry under Conservation Order M-95, effective Mar. 11, 1942. This order was amended to prohibit the use of rhodium alloys and rhodium plating in jewelry manufacture, on Apr. 1, 1942.

Refiners and importers of platinum-group metals in the United States, in 1939, held 9,884 troy ounces of rhodium, osmium, and ruthenium. This was an increase of 253 oz. over the stocks held in 1938. Total recovery of rhodium by refineries in the United States amounted to 7,131 troy ounces in 1943; in 1942, 6,031. This was from refining Canadian nickel-copper matte, except for 265 oz. from crude platinum and 20 oz. from gold and copper

refining, both from domestic sources, in 1943; in 1942, 28 oz. from crude platinum. Imports of rhodium in 1943 were only one-tenth the 4,609 oz. in 1942; in 1941, 2,780.

World Production, Imports and Exports. Imports of the platinum metals in 1939 were at the all-time high level of 306,627 oz., dropping to 195,645 oz. containing 3,586 troy ounces of rhodium in 1940. This quantity was exceeded only by platinum and palladium. Unmanufactured rhodium and ruthenium imported in 1940 included 2,759 oz. from the United Kingdom, 2,266 oz. from Canada, and 9 oz. from Japan.

Recovery of rhodium is secured at the precious-metals refinery of the International Nickel Company of Canada, located at Acton, England. This refinery was reported in 1930 to have a yearly capacity of 300,000 oz. of platinum-group metals, with recovery of rhodium in that year amounting to 3,300 oz. having an average analysis of 99.76 per cent purity. Unlike other platinum refineries, Acton deals with concentrates that are a by-product of ores worked primarily for the recovery of other metals. Mining and treatment costs, up to the refining stage, are absorbed in the cost of producing nickel and copper. The process developed at Acton is efficient and operates at the low cost of about 10*s.* an ounce. The Clydach plant deals with washed sulfide to produce a concentrate having a high content of platinum metals.

The average rhodium content of platinum metals from South Africa was 0.64 per cent in 1930, when the average content of rhodium in the osmiridium sold was 0.40 per cent. Deposits of platinum metals of the Bushveld complex accounted for 1930 recovery of 300 fine ounces of rhodium.

The Department of Munitions and Supply, Ottawa, announced the removal of all restrictions on the distribution of rhodium, in June, 1945. The Canadian Wartime Prices and Trade Board removed all restrictions on the use of rhodium and its alloys in the manufacture of jewelry, effective on Feb. 21, 1944.

Prices. Rhodium sold at $125 per troy ounce from 1940 through May 10, 1945, as reported by *E & M J Metal and Mineral Markets.* The average market price was $85 to $105 per troy ounce in 1924; $40 to $55, in 1929–1931; $48 to $50, in 1932.

The maximum price for rhodium was established by the Office of Price Administration in Maximum Price Regulation 309, effective on Feb. 1, 1943. The price was not to exceed the highest net price that the seller had in effect during the first quarter of 1942 for metal of less than 99.5 per cent purity and for the rhodium content of scrap, sweeps, and other waste products.

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See "Platinum."

RUBY

Properties. The red transparent variety of corundum (crystalline aluminum oxide), the ruby is characterized by parallel fibrous structures, red color, and low dispersion. Both the ruby and the sapphire are of the same chemical composition. The ruby is dichroic in crystalline structure, unlike both spinel and garnet, which belong to the cubic system. When examined by the dichroiscope, the typical ruby exhibits one image of an aurora-red color while the other image is carmine. The refractive index of the ruby (1.77) is higher than that of glass. The ruby can be scratched only by the diamond, for which property it has been given the mineralogical name "adamantine spar."

The most valuable stones of the jewelry trade are those of pigeon's blood red found in Burma. Ruby of gem quality rarely occurs of any appreciable size. Single crystals can be given a surface that is perfectly smooth. The true ruby is described as "oriental ruby" to distinguish it from spinel and other red or reddish corundum minerals. Early writers confused the ruby with both spinel and garnet. In ancient Greek literature, the ruby was referred to as anthrax and carbunculus, owing to its fiery appearance suggestive of a live coal.

Uses. Wide application was made of rubies in the war years as bearing jewels for various instruments having vital industrial application. Jewel bearings are essential for delicate precision instruments of strategic importance in the manufacture of naval, military, and aircraft equipment. Ruby bearings were important in combating wear in the manufacture of a wide range of industrial equipment.

Production of instrument jewels increased 370 per cent in 1943. The manufacture of synthetic rubies and sapphires and the fabrication of instrument jewels were two domestic industries established as a result of urgent war demands. Postwar prospects are favorable for maintaining production of synthetics, although the substitution of small ball bearings for jewels in watches is not expected to continue.

Domestic Sources of Supply and Production. The ruby was specified in February, 1945, as one of the 35 stockpile items for essential war production. The War Production Board eased controls and restrictions on instrument and jewel bearings in Order 4717, issued on Dec. 23, 1943.

Imported natural ruby and the synthetic stone formerly made in Switzerland have been replaced largely by stones produced in Montana and by

domestic synthetic stones. The latter have been manufactured since 1941 by Linde Air Products Company, Bulova Watch Company, and several smaller companies in quantity sufficient to make the United States independent of foreign sources. Linde ruby is produced in the form of boules (a cylinder-shaped crystal) and in the form of rods of varying sizes for more efficient and economical fabrication.

Natural ruby is recovered from stream gravels near Helena, Mont., in Granite and Powell counties. In Yogo Gulch, Fergus County, rubies were mined from a monchiquite-comptonite dike until 1929, when production terminated. About one-fourth of the output was of gem grade, the balance having industrial use. The principal producer, in 1942, was American Gem Mines, Philipsburg, Mont., which sold its entire output to the government in the war period.

World Production, Imports and Exports. Although some rubies are produced in Cambodia, Afghanistan, and the Anakie field of Queensland, Australia, rubies of commerce have been secured mainly from Burma, southern Siam, and Ceylon.

Upper Burma, source of the finest and largest supply of rubies of gem quality, has been a producer since the fifteenth century or earlier. Prior to its conquest by Great Britain in 1886, the location of ruby mines was a closely guarded secret. The Mogok district is the most important "ruby tract" or "stone tract," covering an area of about 45 square miles located east of the Irrawaddy River.

Commercial deposits of ruby and spinel occur in caves and in talus gravel derived from metamorphosed limestone associated with gneiss and schist. Work is restricted to the dry season, when local natives carry on mining operations by primitive methods. Production on a small scale has been carried on by natives since 1931, when Burma Ruby Mines Company stopped operations. In its 40-year life, Burma Ruby Mines reported gross recovery averaging $300,000 a year. America and western Europe, principal markets for Burma rubies, were shut off in the war period.

Ceylon has produced rubies and sapphires since about 600 B.C. The rubies, generally pale in color, occur in stream gravels derived from limestone, gneiss, and schist. The gravel occurs locally to a thickness of 120 ft., the lower portion and depressions in the bedrock being important for concentrations of the stones.

Prices. No prices are available for synthetic and natural rubies for industrial uses.

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RUTHENIUM

Properties. One of the minor rare metals of the platinum group, ruthenium can be accurately determined by the gravimetric method. The pure fused metal is white, hard, and brittle. Ruthenium has a lower atomic number and higher melting point than other platinum metals. (Ru, atomic number, 44; atomic weight, 101.7; melting point, 2450°C.; boiling point, 5300°C.; specific gravity, 12.10.) Its hardness is 6.5. It is very refractory. Next to osmium, ruthenium is the most infusible metal of the group. Ruthenium combines with chlorine at red heat; it combines more readily with oxygen than other platinum-group metals except osmium.

These metals arrange themselves in a triad of pairs, ruthenium being paired with osmium, the latter possessing almost twice the atomic weight and density of ruthenium and having the higher melting point. Both platinum and palladium can readily be hardened by alloying with them small percentages of the rare and very high-melting ruthenium. The oxide of ruthenium is volatile. Ruthenium resembles platinum in its resistance of attack by acids but is of limited use in industry except in alloys with other metals of the platinum group.

Residues containing ruthenium and other platinum-group metals are treated at Acton, England, and Newark, N. J.

Uses. In the war years, ruthenium continued to be used mainly for alloying purposes. It was primarily employed in the palladium alloys and for hardening platinum and palladium jewelry. Certain ruthenium salts are used in the dye industry, and one of its salts serves as a biological stain. Ruthenium has been employed for certain special reactions in connection with the synthesis of long-chain hydrocarbons. Palladium and platinum alloys containing up to 10 per cent of ruthenium are widely adapted for contacts that must operate reliably at low temperatures, as in instruments or small relays, thermostats, voltage regulators, and control devices. The alloy is used for contacts in high-tension magnetos for aircraft.

The principal prewar use of ruthenium was with osmium in the form of hard, extremely corrosion-resistant alloys for tipping the nibs of precious-metal pens, such as those used in fountain pens. Ruthenium had replaced iridium as a hardener for either platinum or palladium in jewelry. The palladium-ruthenium-rhodium alloy is used for diamond and other gem

mountings, ring blanks, watchcases, spectacle frames, and decorations in conjunction with gold. Ruthenium or osmium compounds are employed in fingerprint detection. Palladium-rhodium-ruthenium is used in dentistry for wrought alloys.

The advantages of platinum metals are expected to have postwar application in industry, indicating favorable long-term possibilities for ruthenium and other metals of the platinum group.

Domestic Sources of Supply and Production. The main sources in Alaska were the placer workings of the Goodnews district, where analyses of platinum metals in four separate localities show the ruthenium content ranging from 0.13 to 0.33 per cent.

In 1940, 7.1 per cent of consumption of the platinum metals was represented by ruthenium, iridium, rhodium, and osmium. There was a considerable increase in 1940 of imports of unrefined platinum, chiefly due to the receipt of larger amounts of concentrates from Canada, the main producing country. Imports of ruthenium for consumption in the United States declined from 5,030 oz in 1939 to 1,448 troy ounces in 1940.

The Metals Reserve Company made a first commitment for the purchase of ruthenium for stockpiling, in 1942. Government stockpiles were reported on July 17, 1944, to have 21 troy ounces of ruthenium. The Office of Metals Reserve held 39 troy ounces on Sept. 30, 1945, as reported by *The Wall Street Journal.*

Total recovery of ruthenium by refineries in the United States amounted to 4,885 troy ounces in 1943; in 1942, 3,817 oz. This was from refining Canadian nickel-copper matte, except for 161 oz. from domestic crude platinum and 8 oz. from domestic gold and copper refining in 1943; in 1942, 55 oz. from crude platinum. Sales of ruthenium in 1943 were 44 per cent higher than in the previous year, this metal being in greater demand than others of the group, after platinum and palladium. Imports of ruthenium in 1943 were three times those of 1942, amounting to 10,515 and 2,930 oz., respectively; in 1941, 3,155.

World Production, Imports and Exports. In 1940, imports of unmanufactured platinum metals are shown for rhodium and ruthenium combined, as follows: United Kingdom, 2,759 oz.; Canada, 2,266 oz.; Japan, 9 oz. The Union of South Africa, in 1939, sold platinum metals containing 2.2 per cent of ruthenium; osmiridium from the same source included 13.52 per cent of ruthenium.

Recovery of ruthenium at the precious-metals refinery of the International Nickel Company of Canada, located at Acton, England, amounted to 700 oz. in 1930; in 1929, 1,376. The average analysis of ruthenium recov-

ered at Acton was reported at 99.72 per cent purity in 1930. Of world consumption of about 400,000 oz. of platinum metals in 1931, the Acton refinery accounted for about 300,000. The cost of refining amounted to about 10*s.* an ounce on the 1931 scale of operations. The Sudbury district, Canada, is the major source of ruthenium and other platinum-group metals.

The removal of all restrictions on the distribution of ruthenium was announced in June, 1945, at Ottawa by the Department of Munitions and Supply.

In South Africa, platinum deposits of the Bushveld complex had an average ruthenium content of 0.47 per cent. Production amounted to 222 fine ounces in 1930.

REFINED RUTHENIUM AND RHODIUM IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN TROY OUNCES
(After U.S. Bureau of Mines)

	1942	1943
Canada	2,914	5,895
United Kingdom	4,830	5,025
Other countries	9	

Prices. The price of ruthenium was steady at $35 to $40 an ounce in 1940 and continued to be quoted at $35 by *E & M J Metal and Mineral Markets*, through May 10, 1945.

In 1926, the price of ruthenium was reported at $69 per troy ounce; in 1928, $45 to $75; in 1931, $38 to $65; in 1932, $40 to $45.

The maximum price for ruthenium was established by the Office of Price Administration in Maximum Price Regulation 309, effective Feb. 1, 1943. The price was not to exceed the highest net price that the seller had in effect during the first quarter of 1942 for metal of less than 99.5 per cent purity and for the ruthenium content of scrap, sweeps, and other waste products.

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See "Platinum."

SAPPHIRE

(Natural Montana)

Properties. Pure translucent or transparent blue corundum is known as sapphire, a crystalline aluminum oxide. All other colors except red (the ruby) are grouped as sapphire. The dispersion of corundum stones is low; both the ruby and the sapphire are characterized by parallel fibrous structures. Single crystals can be given a surface that is perfectly smooth.

In fabricating synthetic sapphires, the stone is built up from the same molecules that constitute the natural stone. Sapphires and rubies are the only gems that have been produced in quality and quantity to make them commercially valuable. Finely powdered pure aluminum oxide is dusted at intervals into an oxy-hydrogen flame at a furnace temperature of 2000°C. The fused mass settles along a thin pillar set within the furnace and builds up as matte to form a long, colorless crystal described as a "boule" because of its bulletlike shape. Within a 5-hour period, the boule builds up to a convenient size weighing about 300 carats. An aluminous compound is introduced to give the stone a natural sapphire color. Natural and synthetic stones have the same hardness, specific gravity, and refractive indices. X-ray examination of synthetic stones discloses level strata compared with kinks in some of the lines in natural stones, a difference in the pattern of coloration. In machining, the angle of the drilled recess in which the instrument pivot will rest must be controlled within fine limits.

Uses. Natural and synthetic sapphires, under war conditions, have been used largely as jewels for instruments having strategic applications. Few sapphires have been cut for gems. A battleship requires some 4,000 jewel bearings; delicate precision instruments of aircraft require large numbers of jewel bearings. Every bomber was equipped with almost 100 sapphires in various instruments. These bearings are required in a wide range of military instruments, particularly range finders. Industry employs sapphire bearings to combat wear in precision gauges, diesel injector nozzles, cutting tools, dies for drawing wire from soft metal, machining tools for soft metals, thread guides for textile mills, barometers, compasses, and watches. Sapphire gauges offer closer tolerances and are of longer life than those of steel. Synthetic sapphire is also used for phonograph needles.

Small ball bearings have replaced jewels in watches and certain instru-

ments, but this substitution is not expected to continue into the postwar period. In 1943, synthetic corundum was reported to be giving strong competition to natural Montana sapphire, the synthetic "rod" sapphire reducing fabricating time and costs. Sapphires and rubies are next in hardness to the diamond, for which its high cost and difficulty of machining make substitutions desirable where practical. Wider postwar applications of synthetic corundum sapphire have been indicated.

Domestic Sources of Supply and Production. Imported natural sapphire and the synthetic stone formerly made in Switzerland have been replaced largely by stones produced in Montana and by borosilicate glass. Synthetic sapphires have been manufactured since 1941 by Linde Air Products Company in sufficient quantity to make the United States independent of foreign sources. Linde sapphire is produced in the forms of boules (cylinder-shaped crystal) and of rods of varying sizes for more efficient and economical fabrication.

A pale sapphire with a steely luster is recovered from stream gravels in Granite and Powell counties and from a comptonite dike in Yogo Gulch, Fergus County, Montana. Several hundred thousand carats a year were produced before operations were stopped in 1929. About one-fourth was reported to be of gem grade, the balance being sold for industrial use.

American Gem Mines, Philipsburg, Mont., was the principal producer in 1942, selling the entire output to the government. Industrial stones and pink sapphire gem stones were produced, in 1941, in Macon County, South Carolina. Perry-Schroeder Mining Company, operating near Helena, Mont., continued gold-dredging operations for the recovery of by-product sapphire. Montana sapphires valued at $47,000 were produced in 1942; in. 1943, $20,000. About 50,000 oz. were produced in 1942; in 1943, 20,000. Although a few were cut for gems, the stones were chiefly stockpiled for use as instrument jewels. Production in 1943 was also secured by Charles H. Carpp of Philipsburg.

Of the total value ($150,000) of domestic uncut stones produced in 1942, 31 per cent represented sapphires. After they were cut, the value increased to $400,000 (in 1941, $770,000). Production of synthetic sapphires and other synthetics for instrument jewels increased 370 per cent in 1943, as reported by the U.S. Bureau of Mines.

The War Production Board issued Order 4717 on Dec. 23, 1943, easing controls and restrictions on instrument and jewel bearings. The manufacture of synthetics and the fabrication of instrument jewels were newly established industries in America for supplying critical war needs. Postwar continuation of these industries is indicated.

Ruby and sapphire are strategic and critical materials to be acquired and guarded in accordance with the stockpile bill passed by Congress in July, 1946; the Procurement Division of the Treasury Department was designated to buy reserve supplies of these minerals, together with manganese ore, mercury, mica, monazite sand, nickel, and the platinum-group metals, aided by the Office of Metals Reserve and other agencies.

World Production, Imports and Exports. World statistics were not available under war conditions. It is reported that an all-time peak was reached in producing sapphire gem stones from the Anakie field, central Queensland, in 1941. In Burma, the Mogok district recovered 10,532 carats from sapphire and ruby deposits in metamorphosed limestone associated with gneiss and schist, in 1939. Spinel, tourmaline, and other gem stones were recovered as by-products. Sapphire localities are also worked in Afghanistan.

Ceylon has produced gem sapphires since about 600 B.C. Ceylon sapphire is frequently fine, although paler than stones of some other fields. Production is secured from stream gravels derived from crystalline limestone, gneiss, and schist. The government of India, in 1943, attempted to secure from Ceylon 8,000 sapphires and garnets for instrument jewels.

In prewar years, production was also secured from southern Siam, Cambodia, Kashmir, and New South Wales, Australia. The Cambodia supply was reported to be approaching exhaustion in 1937.

In Europe, the chief production centers for synthetic sapphire were in and near Switzerland and its watchmaking factories. In order to acquire stones in England to replace sapphire stocks for war production, British authorities secured the services of Salford Electrical Instruments, Ltd. (General Electric subsidiary), in making synthetic sapphires and cutting and machining gem stones into jewelled bearings.

Prices. Second-grade stones produced in central Queensland in 1941 realized 15 to 30*s.* an ounce; blue stones, £45 an ounce; high-quality gems, £85 an ounce.

Prices are not available for natural Montana sapphire.

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SELENIUM

Properties. A nonmetallic element, selenium resembles sulfur chemically. It occurs in association with sulfur; in the form of selenides, it accompanies the sulfides of most of the important copper-silver-gold and copper-nickel ore bodies. Selenium is recovered in association with tellurium from the tank slimes or residues deposited in the electrolytic refining of copper; some tellurium is a by-product of lead. (Se, atomic number, 34; atomic weight, 78.96; melting point, 175°C.)

Selenium and tellurium are classed among the rarer elements. They occupy adjacent positions in the odd division of Group VI of the periodic table immediately below sulfur. The abundance of selenium is estimated as about equal to silver; tellurium is about equal to gold in relative quantity. The electrical resistance of selenium changes under the action of light, a property known as photoelectric conductivity. Selenium is one of the 16 industrial nonferrous metals used essentially as alloying constituents.

Selenium, although not sufficiently abundant in nature to be mined for itself alone, is widely distributed. The element is prepared for marketing in the form of metallic cakes, sticks, and black to steel-gray amorphous powder. Other products include ferroselenium (as an alloying agent) and selenium dioxide, the latter dissolving in water to form selenious acid from which are derived sodium selenite and other selenite salts. Selenium forms a series of compounds with the halogens.

Blister copper produced in the United States contains 0.03 to 0.14 per cent of selenium and about one-fifth that amount of tellurium. Canadian coppers contain as much as 0.26 per cent of total selenium and tellurium. Selenides and tellurides, being insoluble in the electrolyte when refining blister copper, are precipitated with the slimes from the anodes. The process of separation and final purification of selenium is long and involved; so only such quantity of the element is recovered as is required to meet market demands. Research to expand the application of both selenium and tellurium has been stimulated by ready availability of supplies.

Uses. Major war uses for selenium were in electrical rectifiers in connection with radar and with generators for aircraft and for Army equipment. Purified selenium, properly annealed, is used to obtain the necessary light-sensitivity for photoelectric cells and various types of photometers. The variable electrical resistance of selenium when exposed to light is essential

in the application of selenium in both photocells and rectifiers, although consumption of the element for these purposes has been relatively small.

The extensive development of selenium rectifiers has been applied in direct-current motor operation, magnet coils, arc lamps, and the direct operation of direct-current apparatus from an alternating supply. In battery charging, the selenium rectifier automatically reduces the charging current as the battery voltage increases, preventing battery discharge through the rectifier when the alternating current fails. The selenium rectifier developed in the United States on a phenomenal scale in the war years.

The selenide, or photovoltaic, cell has found wide application as a door opener, counter, exposure meter in photographic work, smoke detector, burglar alarm, and turbidity detector. This cell is also used as a valve to rectify or change alternating current into direct current, as in the copper oxide cell. Copper selenide rectifiers have found application for electroplating.

Widely used for war materials in stainless steels, copper alloys, and the low-expansion alloy invar, selenium has the property of developing free-machining qualities without impairing the noncorrosion properties. In copper and copper-rich alloys, small additions of selenium, tellurium, or sulfur improve the machinability without producing the low ductility at high temperatures (hot shortness) that is associated with additions of lead. Bars of selenium-bearing stainless metal are used as an ingredient of austenitic chromium steels. Cable connectors of tellurium-copper replaced silver-plated brass for use in aircraft, torpedo boats, tanks, and trucks.

A main application is in glass and pottery making, the largest consumers in 1942. Glass batches are cleared by the addition of a few ounces of selenium, which neutralizes the greenish cast imparted by traces of iron in the sand. Selenium is reported to be the most widely used colorant for pink and ruby glass, replacing red lead and gold chloride. In ceramics, selenium is used to produce red colors.

Coatings of red selenium pigment on magnesium alloys, to resist attack by sea water, have found application in Europe, replacing the cadmium sulfoselenide red, maroon, and orange pigments when the cadmium shortage made these no longer available for signal lenses under war conditions. Selenium red is reported to be superior to all other inorganic red compounds. In antifouling paint for ship bottoms and in lubricating oil, selenium has proved to be an important ingredient.

Selenium replaces sulfur in producing certain "super-rubbers." It is added for rubber cable coverings to promote resistance to heat, oxidation, and abrasion, increasing resilience, tensile strength, and aging qualities. Selenium is used in quantity in vulcanizing synthetic rubber.

Tellurium is used chiefly in the manufacture of rubber products (cable coverings) to increase tensile strength and resistance to heat and abrasion; in lead and lead alloys, from 0.1 to 0.5 per cent of tellurium gives resistance to acids and serves as a hardening and strengthening agent. Tellurium was employed as a substitute for chromium in the development of wear-resistant surfaces on cast-iron products, particularly gears and wheels. As a substitute for tin, tellurium is used in small quantities in the lead sheathing of electric wire cables to improve resistance to heat and corrosion. It has been used for improving the machining qualities of certain steels. Ferrotellurium is applied as a carbon stabilizer in cast iron. Only 15 years ago, selenium and tellurium were referred to as "the useless elements." The small percentages required and the high cost have limited the range of industrial applications, but the important uses recently developed indicate a higher postwar level of consumption.

Domestic Sources of Supply and Production. Production and use studies were carried on during the war by Dr. W. J. Kroll at the Electrodevelopment Laboratory of the U.S. Bureau of Mines, Albany, Oreg. Production has increased rapidly since the First World War. Sales in 1933 were about 350,000 lb. of selenium and 10,000 lb. of tellurium; in 1943, 521,779 and 62,260, respectively.

Producers' stocks at the end of 1943 amounted to 455,677 lb. of selenium and 139,403 lb. of tellurium. Although producers' shipments increased 65 per cent over 1942, the record level of 1941 was not equaled and stocks remained high. Domestic plant capacity for producing selenium is about 750,000 lb. a year; tellurium, 300,000 lb.

ELEMENTAL SELENIUM PRODUCTION IN THE UNITED STATES, IN POUNDS
(After U.S. Bureau of Mines)

1939	1940	1941	1942	1943
227,131	328,731	620,493	506,426	635,581

World Production, Imports and Exports. Exports amounted to 5,550 lb. in 1942; in 1941, 23,169 lb. In 1941, imports of selenium and selenium salts (all from Canada) amounted to 197,873 lb.; in 1942, 83,666; in 1943, 81,720.

Canada, the chief source outside the United States, produced 374,013 lb. valued at $654,523 in 1943; in 1944, 298,592 lb. valued at $537,466, of which International Nickel Company of Canada produced 85,519 lb. Maximum output of 495,365 lb. was secured in 1942, Quebec accounting for about 58 per cent of the total; Manitoba, 24 per cent; Ontario, 18 per cent.

Selenium was first produced in Canada in 1931, at the Copper Cliff refinery, from copper-nickel ore of the Sudbury district. Canadian Copper Refiners, Ltd., Montreal East, started production in 1934, from the treatment of gold-copper ore of the Noranda mine, Quebec, and the gold-copper-zinc ore of the Flin Flon mine, Manitoba. A plant was erected by Canadian Copper Refiners in 1944 for the manufacture of selenium compounds. Canada exported 250,404 lb. of selenium and selenium salts in 1944; in 1943, 211,530 lb. valued at $380,493.

CANADIAN PRODUCTION OF SELENIUM, IN POUNDS
(After Dominion Bureau of Statistics)

1940	1941	1942	1943	1944
179,860	406,930	495,369	374,013	345,000*

* Preliminary figure.

Russia, Rhodesia, Mexico, and Sweden produce minor quantities, and Australia is reported as a potential source. Boliden Mining Company expanded its selenium-recovery facilities in Sweden in 1943. The world output of selenium amounts to 600 to 700 tons a year; tellurium, about 150 tons.

Prices. The price of selenium, black powdered, 99.5 per cent pure, at New York, was $1.75 a pound, on Sept. 30, 1946. This price had been in effect since 1938, as reported by *E & M J Metal and Mineral Markets*, for both selenium and tellurium. *Glass Industry* quoted barium selenite at $1.40 to $1.60 a pound; sodium selenite, at $1.50 to $1.65 a pound, 1941–1943.

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SILLIMANITE

(Andalusite and Dumortierite)

Properties. A trimorph of kyanite, sillimanite can be treated for long periods of any temperature below 1545°C. without changing. Occurring in long, slender, prismatic crystals nearly square in cross section or in radiating fibrous or columnar masses, sillimanite is gray, brown, yellow, or green in color. Its hardness is 6 to 7; its specific gravity, 3.23. It has an uneven fracture and a glassy or silky luster. Decomposition to mullite takes place at 1545°C. and is accompanied by a drop in specific gravity to 3.1, while the volume expands. Pure sillimanite is composed of 63 per cent of Al_2O_3 and 37 per cent of SiO_2. Andalusite, kyanite, and dumortierite are also aluminum silicates, comprising the "sillimanite group." Dumortierite contains some boron oxide and water.

Heating to high temperatures reduces all four minerals of the sillimanite group to mullite and a liquid (silicious glass). Andalusite occurs in fibrous, granular, and coarsely granular masses. Its hardness is 7.5; its specific gravity, 3.16 to 3.23. It is infusible and insoluble in acids. Its color is gray, green, red, brown, yellow, or blue. Its luster is glassy to dull. Andalusite occurs in metamorphic rocks made up largely of quartz, commercial deposits forming more than 75 per cent of the rock. Impurities are not objectionable in the material used for spark plugs but must be removed for use in refractories.

Andalusite products have high electrical resistivity at high temperatures; the tensile strength is reported to be three to five times that of products made of ordinary electrical porcelain.

Dumortierite, although classed as a rare mineral, has world-wide distribution. It occurs as inclusions in other minerals, in fan-shaped, radiating masses, or as prismatic crystals. Its color is intense blue to deep pinkish lilac; its luster glassy to dull. Its specific gravity is 3.26 to 3.36; its hardness, 7. The mineral is resistant to weathering, containing 55.01 per cent of Al_2O_3, 37.05 per cent of SiO_2, and 4.65 per cent of B_2O_3. Decomposition to mullite begins at about 1250°C., the volume expanding slightly and specific gravity being reduced to 3.1.

Less common than kyanite, andalusite, and dumortierite, sillimanite is found in commercial concentrations only in remote districts in India.

Uses. Sillimanite, having ceramic uses similar to kyanite, toughens the product to which it is added and is favored, along with kyanite, in the manufacture of porcelain for spark-plug cores, refractory brick, electrical and chemical porcelain and chinaware, enamelware, and hotelware. Refractories with sillimanite and kyanite as component parts are used in glasshouse refractories; in crucible, boiler brass-melting, electric and forging furnaces; in high-temperature cements; in oil and gas fireboxes; and in combustion tunnels and cement-kiln linings.

Products of sillimanite, andalusite, and dumortierite are reported to have good insulating power, even at high temperatures. They have low thermal expansion, resistance to heat, and resistance to corrosive action of fluxing agencies and furnace gases.

Andalusite is employed in the manufacture of laboratory porcelain and protecting tubes for thermocouples, the chief application being as insulators for spark plugs and other high-tension electrical equipment. Pyrometer tubes made of andalusite retain their shapes at high temperatures and give longer life to the rare-metal thermocouple by resisting carbon monoxide and other injurious gases.

Dumortierite forms a good basis for refractory material because of its high alumina content. Essential uses are as spouts employed in pouring molten glass in the glass industry, due to its resistance to the eroding effect of molten glass, and in spark-plug insulators and electrical porcelain, where it increases electrical resistivity and widens the burning range. Dumortierite is utilized without previous calcination, since it expands only slightly on conversion to mullite. Both dumortierite and andalusite have come into commercial use since 1920.

Domestic Sources of Supply and Production. No domestic production of sillimanite has been secured. In a number of places in the Eastern United States, this mineral occurs in impure sillimanite schist which is difficult for commercial exploitation, owing to the association with fine needles of quartz. Aluminum silicate refractory minerals, largely andalusite and kyanite, have been steadily increasing in output since 1920 in California and in several Eastern states, but production figures are not regularly published.

In the Black Hills, South Dakota, several small occurrences of andalusite have been reported. The mineral resembles masses of splintered wood, in fibrous, crystalline aggregates associated with quartz in metamorphic rocks.

Possible domestic production was being investigated by the U.S. Bureau of Mines in Georgia, South Carolina, New Hampshire, and Utah, in 1945. In the Southern states, 20 bodies of sillimanite schist have been traced from Talbotton, Ga., to Spartanburg, S. C. These have been reported to offer

greater promise than New Hampshire deposits of the Monadnock region and Idaho deposits near Troy, Latah County. In South Carolina, the schist ranges in width up to 200 ft.

Andalusite production in 1942–1944 was secured by only one company, Champion Sillimanite, Inc. Output was slightly lower in 1943–1944 than the record output of 1942, from mining operations at White Mountain, Mono County, California, the world's leading andalusite mine. Shipment was made to Champion Spark Plug Company, Detroit, Mich., for the manufacture of electrical porcelains, particularly spark-plug cores. Before being crushed and treated, andalusite is mixed with a small percentage of dumortierite.

Other production of andalusite has been secured from Hawthorne, Mineral County, Nevada (formerly operated by Tillotson Clay Products Company) and from localities on Oak Hill, near Littleton, Mass. The latter deposit occurs in fine-grained schist.

Dumortierite was produced in 1944 by only one company, Champion Sillimanite, Inc. This material, mined at Oreana, Pershing County, Nevada, is shipped to Champion Spark Plug Company for use in electrical porcelains.

Domestic output of andalusite and dumortierite ranged from 400 to 2,000 tons annually before 1942, and no sillimanite was known to have been produced commercially.

The Humboldt Queen deposit, in Nevada, is reported to be the only known occurrence in commercial quantity. Production is secured from surface boulders and from veins and lenses cutting quartz.

World Production, Imports and Exports. Found only in remote districts of India, commercial concentrations of sillimanite occur in the Khasi Hills, Assam, and near Pipra, Rewa. The mineral is white, gray, or brown and occurs chiefly in massive form. Some of the fibrous variety is found, similar to that reported in South Dakota. The isolated location of the large Rewa deposits has prevented their exploitation.

In Australia, a large sillimanite deposit located in the Broken Hill district, New South Wales, was investigated in 1942 by Board of Economic Warfare through the War Supplies Procurement Mission of Australia. A 200-ton sample from this deposit was received in the United States in January, 1943, and tests were made in the manufacture of high-temperature refractories. Shipments received in 1943 totaled 514 short tons, but the material was found to be unsatisfactory for heavy-duty refractories. Selective mining methods may lead to recovering an acceptable product.

Prices. U.S. Bureau of Mines reported that no prices were available in 1943 for domestic output of sillimanite products. Nominal values of $10

to $15 a ton were listed for andalusite and dumortierite. The price in 1932 of P.B. sillimanite refractories in 9-in. brick was $500 a thousand.

In England, the price of sillimanite dropped from £14 to £11 per ton, in 1929.

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SILVER

(Foreign)

Properties. The whitest of all metals, silver has a perfect metallic luster. Silver is one of 16 industrial nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. It is the most malleable and ductile of all metals except gold. It is so malleable that it can be rolled and hammered into thin foil or leaf. As an example of ductility, a grain of silver can be drawn into a wire 400 ft. in length. (Ag, atomic number, 47; atomic weight, 107.88; melting point, 960.5°C.) Its specific gravity is 9.87 to 10.55. Its boiling point of about 2000°C. and general ease of working have made silver useful in industry and the arts.

This metal is by far the best conductor of heat and electricity, rated at 105 for volume conductivity and 88.2 for mass conductivity (copper, 100). It does not oxidize at ordinary temperatures or under arcing conditions, which makes it an essential contact metal. For a conductor of given weight per unit length, it is inferior to copper. In the chemical industry, silver has high resistance to the attack of ammonia, caustic alkalies, acetic acid, citric acid, and other chemicals.

The scarcity and indestructible character of silver have made it a medium of exchange. In the bullion market, "fine silver" is 99.99 per cent pure. The fineness of silver coinage in different countries varies from 500 to 900. Industrial applications are only of recent development, stimulated by low price. Silver produced by electrolytic refining is too pure for certain purposes. Silver is handled in world markets in bars weighing from 1,000 to 1,100 troy ounces.

Uses. Use of foreign silver was restricted to "direct and essential war needs." Foreign silver is considered as all metal other than newly mined domestic silver or that sold by the U.S. Treasury. Higher priced domestic or treasury metal was allocated to the manufacture of silver, jewelry, and photographic film which, in 1943–1944, took less than one-third of the total industrial consumption. These outlets are normal in peacetime and are unlikely to show any postwar decline. Consumers of silver, as a peacetime utility metal in the war years, manufactured electrical goods, laboratory equipment, dental and surgical supplies, and medicines. Much of the use in jewelry was banned during the war. Industrial uses since 1940 multiplied to a degree that overshadowed demand for silver as a currency medium.

Fundamental war uses of silver were in the field of military photography, based on the reaction of halogen salts to the action of light, in electrical goods and laboratory equipment, and for medical and dental work. Industrial use was made of lead, tin, and zinc with silver in bearings, and in solders and brazing alloys. Lead-silver alloys are used in anodes for producing electrolytic zinc. Silver-thallium 2 per cent alloy is employed for bearings, because of its antifriction qualities and the low rate of corrosion. Hundreds of special applications were developed for military equipment, in addition to the important substitutions for other metals that were in short supply. Essential uses were in many kinds of instruments, guns, bombs, torpedoes, shells, and other weapons.

Both lead-silver and silver-cadmium solders have advantages over lead-tin solders of considerably higher strength at both room and elevated temperatures. Silver-rich alloys of the silver-copper series are not softened under the heat of soldering; hardness when warmed is assured for commutator bars of these alloys.

An outstanding war application was in the manufacture of the atomic bomb. The Clinton Engineer Works, near Knoxville, Tenn., made use of 27,680,000 lb. of silver valued at $400,000,000. This metal replaced copper for use as winding coils and bus bars, the silver wire having a total length of more than 900 miles. Research involving the electromagnetic method for concentrating uranium 235 was carried out under government contract at the University of California, under the direction of Professor E. O. Lawrence, by a staff which, in 1943, numbered 1,266 workers. The $2,000,000,000 production plant for the atomic bomb in the Tennessee Valley is operated by Tennessee Eastman Corporation.

Silver-tin alloys are employed for dental amalgams, silver being an improvement over copper. Silver possesses peculiar antiseptic properties that are invaluable for certain types of operative work. There are also various important bactericidal uses. It has been said that no modern use of silver, with the exception of its position as a monetary standard, affects as many people as the use of silver nitrate and emulsions in the photographic industry. Photographic records of vital military objectives, films for X-ray work, and motion pictures are all dependent on these essential applications of silver. In the chemical industry, the use of equipment manufactured with silver is constantly expanding.

The manufacture of many food and chemical products utilizes the resistance of silver to alkalies and to organic acids. Various compounds are used in pharmaceutical preparations. The use of silver in insignia required 5 million ounces in 1943–1944; unclassified uses required 32 million ounces

in these two years, which was more than the whole industrial consumption in 1930.

The substitution of silver released thousands of tons of copper, nickel, chromium, aluminum, and tin for vital war production, regardless of comparative cost. The fabrication of electrical conductors for factories engaged in war work accounted for most of the silver distributed under lease by the U.S. Treasury. Silver busbars installed in plants built by the Defense Plant Corporation made use of almost 900 million ounces of silver, saving a large quantity of copper for use, chiefly in aluminum and magnesium plants. All metal so used was to be returned after the war to the Treasury Department, under the agreement of May 6, 1942. "Free" or unconsumable silver was loaned to the DPC and allocated by the War Production Board. The use of silver for contact points in electrical appliances requiring make-and-break circuits has increased greatly in recent years. Arcing has been eliminated in heavy currents through the use of silver in facing large clapper controls.

Essential war applications of silver were in the manufacture of penicillin (as silver-plated plant) and in the production of fine chemical and medicinal products. Silver chemicals played a vital part in saving life at sea, rendering sea water fit for human consumption. This application required many tons of silver salts. Silver or silver-plated vessels or pipe lines are employed when chlorine is used to sterilize water. Silver powder is employed in a new ceramic-type composition as a coating on electrically nonconducting materials, such as glass and wood, to give the surface high electrical conductivity and low electrical resistance.

Silver and silver-alloy contacts, in the form of rivets, turned parts, and pressed parts formed from silver inlaid in copper, have been used for essential equipment. "Liquid silver" deposited on mica for electrical condensers has given satisfactory performance. Insulators, contacts, and containers for electrical equipment that must be kept free from moisture and atmospheric corrosion have also filled important requirements in the manufacture of war materials and essential civilian equipment.

Silver alloyed with either tungsten or molybdenum is used as a material for electrical contacts in heavy-duty switchgear for use where great hardness and resistance to electrical erosion are required but where high electrical conductivity is important. Silver solders have been used for low-temperature brazing, where high first cost was compensated by far greater efficiency than other solders employed by the munitions industries.

War uses of silver included solders and brazing alloys, which are among the most important engineering uses of this metal. Tin was replaced by 40 to 50 per cent of silver in these alloys. The formulas using 20 to 70 per cent

of tin were replaced by a silver content of 2.5 per cent in solders. In babbitt, a small amount of silver or arsenic replaced the tin formerly used. Solders and brazing alloys, electrical appliances, bearings, and other articles containing silver were essential equipment in all aircraft, tanks, submarines, battleships, cargo ships, and field kitchens. Silver brazing alloys contain 15 to 80 per cent of silver.

Postwar uses of silver are expected to continue many of the special applications developed for strategic reasons. The silver plating of aircraft bearings is regarded as well established. Except for special applications, silver is not expected to be used in solder replacing tin, the latter to be available at about one-tenth the cost of silver. It appears probable that silver in the postwar years will retain a considerable proportion of its gains in industry. Large postwar requirements of silver will be used in rehabilitated countries for subsidiary coinage.

Domestic Sources of Supply and Production. In the United States, arts and industry, in 1944, used an estimated 159 million ounces of silver, about 400 per cent higher than normal prewar consumption; in 1945, 125 million ounces. Domestic and foreign sources were estimated to provide less than 100 million ounces in 1945. The supply of foreign silver increased immediately after the Office of Price Administration advance in the price of foreign metal; but in November, 1945, reduced supplies were reported. The unsold portion of free treasury silver, made available under the Greene Act, was reported at 436 million ounces of unpledged metal of which 183 million ounces were authorized for monetization.

The U.S. Treasury held 253 million ounces of unpledged silver; the DPC held about 900 million; 300 million were held by lend-lease recipients. Sales of unpledged silver by the Treasury Department were 139 million ounces for the first 11 months of 1945 compared with 46 million in all 1944 and 20.8 million in 1943. From Pearl Harbor to the end of 1944, the U.S. Treasury supplied 1,220,300,000 fine ounces of silver to industry. War production accounted for 65 per cent of domestic consumption of silver in 1943. Under lease arrangements, nonconsumptive uses in war plants accounted for 903 million ounces, plus about 37 million ounces of foreign silver. Industrial users were supplied with 5 million ounces by the U.S. Treasury in cooperation with the DPC. Leasing of silver to industry was started in April, 1942. On July 31, 1946, Secretary of the Treasury Snyder stated that about 50 million ounces of "free" Treasury silver were available for sale and within a year about double that amount would be available after the DPC had returned about 16,000 tons of the metal that had been used in war plants.

Small amounts of oil, sulfur, and other impurities would not affect the use of such silver for coinage.

The Metals Reserve Company, in 1942, made a first commitment for the purchase of foreign silver for stockpiling. Ranking nineteenth among stockpile items, silver costing $8,010,259 was purchased by the MRC. The market value of the inventory on Oct. 31, 1944, was $2,224,816. Government stocks of silver, on Oct. 31, 1945, held by the Reconstruction Finance Corporation through the Office of Metals Reserve amounted to 7,446,209 troy ounces; on June 1, 1946, 374,667 troy ounces.

The WPB reported on Nov. 1, 1944, that civilian goods manufacturers could not expect controls on silver to be relaxed in the near future. Increased supplies of foreign metal, in March, 1945, were made available for war materials by the WPB.

Strict control measures for silver were continued through 1944. On Aug. 20, the WPB revoked Order M-199, freeing foreign silver and domestic scrap of all controls on uses. Following that order, the OPA reported that it was no longer practical to continue separate prices for foreign and domestic silver, and a uniform price of 71.11 cents per ounce was adopted. Import controls were removed on Sept. 4, 1945. All metal controlled by markets in New York and London had previously been reserved to meet the needs of essential war industry. No price change had been made since Apr. 3, 1942, although the method of quoting was altered on Jan. 2, 1945, applying to per ounce troy 0.925 fine rather than 0.999 fine. On Sept. 20, 1945, the OPA increased the price of foreign silver to parity with the domestic price.

The basic silver-conservation order of the WPB, Order M-199, was issued in July, 1942. This was amended three times in 1943 in order to hold manufacturers to half of their consumption in 1941 or 1942, whichever amount was higher, placing further restrictions on the use of silver for nonessential purposes; restricting foreign silver to medical uses, to the photographic industry, and to other uses carrying ratings of AA-5 or higher; and limiting Treasury silver to engine bearings, official military insignia, brazing alloys, and solders.

Under a lend-lease agreement on June 15, 1944, the U.S. Treasury supplied 100 million ounces to the government of India in order to maintain an adequate supply of coinage for India's expanded war production and to support stable prices and for the large number of armed forces of the United Nations in India. The silver was to be returned within 5 years after the official ending of the war on an ounce-for-ounce basis. Foreign governments were

supplied under lend-lease with 285 million ounces of silver for coinage purposes.

A reduction of silver held by the U.S. Treasury in 1944 was mainly accounted for as follows: 203 million ounces were disposed of under lend-lease agreements; 44 million ounces of "free" silver were released, under the Greene Act, for industrial consumption; 8 million ounces were absorbed by coinage. For the second year since 1934, when the Silver Purchase Act went into effect, United States silver holdings declined to about 3 billion ounces, at the end of November, 1944. On Jan. 31, 1946, the Treasury Department held pledged and unpledged silver amounting to 2,713 million ounces. This includes 475 million ounces of the pledged silver released to aluminum and magnesium plants in the war years for bus bars and transformers, the silver being returnable to Treasury vaults.

Silver holdings by the Treasury Department reached a peak at the end of 1942 of 3,340 million oz. Since then, there has been a reduction of almost 700 million ounces, due to sales under the Greene Act and lend-lease commitments. Lend-lease silver and other unpledged metal amounted to about 500 million ounces at the end of May, 1946; most of the Treasury's profit on silver transactions had been realized through issuing silver certificates secured by the bullion at $1.29 an ounce and subsidiary coinage at $1.38. On July 31, 1946, President Truman signed a bill increasing the price of silver and continuing the principle of the wartime Greene Act which authorized the Treasury to sell "free" silver for industrial uses. Up to Dec. 31, 1945, the Treasury had acquired 2,723 million ounces of the metal under the program initiated by the Silver Purchase Act of 1934. At the end of 1945, "free" silver not used as backing for paper currency or employed for coinage amounted to 403 million ounces.

The WPB removed all controls on the use of domestic silver in May 1945, while continuing restrictions on foreign metal. The order canceled quota provisions limiting users of domestic silver to a percentage of consumption in a base year. The WPB reported wire, sheets, and semifabricated metal to be very tight, while the supply of foreign silver continued short of demand for war purposes.

It was reported in September, 1945, that supplies of foreign metal had tightened considerably since the WPB had revoked Order M-199, removing restrictions on the metal. Foreign silver imported amounted to 29,601,000 oz. in the first 9 months of 1944 compared with 39,829,000 oz. in the same period of 1943. Total imports in 1944 were about 50 million ounces, of which 15 million came from Mexico. After silver restrictions were removed by the WPB, demand for foreign metal was reported to be far in excess of

supply, due to efforts by manufacturers to rebuild inventories with low-priced foreign metal. In prewar years, industry and the arts were supplied mainly by foreign silver, the U.S. Treasury buying domestic mine output.

Domestic production in the first 9 months of 1945 was 55,653,000 oz. (including 31,006,000 from foreign sources) compared with 63,931,000 oz. in the same period of 1944 (32,010,000 from foreign sources). Domestic production of silver was the lowest in 1944 since 1935, as reported by the U.S. Bureau of Mines, amounting to 34,551,235 oz. valued at $24,569,696. In 1943, silver from domestic sources, not including Puerto Rico and the Philippine Islands, amounted to 41,460,826 oz. valued at $29,483,254; in 1941, 69 million. The total estimated for 1945 was down to 28,300,000 oz. as a result of labor shortage. Major production came from Idaho, Utah, Montana, and Arizona as a by-product from mining copper, lead, and zinc ores. Only five straight silver mines are included with the 25 leading silver-producing mines in the United States, which holds second place as a silver-producing country.

Postwar domestic silver production is expected to increase to the prewar rate of more than 60 million ounces a year, provided fair prices prevail for base metals. Elmer W. Pehrson, U.S. Bureau of Mines, has estimated that only 18 per cent of the original domestic reserves of silver ore remain to be mined, which would provide for only 11 years' supply at normal prices, at the 1935–1939 rate of consumption. In the postwar economy, it appears essential that a stabilized silver price be maintained, rather than two separate prices for domestic and foreign metal which prevailed from 1932 to Sept. 20, 1945.

Harold L. Ickes, Secretary of the Interior, stated in December, 1945:

> We have less than a 35-year peacetime commercial supply of silver and twenty other minerals . . . which we shall have to import in larger quantities.

Silver legislation passed by Congress on July 19 and signed by the President on July 31, 1946, authorized the U.S. Treasury Department to purchase silver of domestic origin mined after July, at 90.5 cents a fine troy ounce and to sell to industry at not less than that price government-owned bullion

CONSUMPTION OF SILVER IN DOMESTIC INDUSTRY, IN THOUSANDS OF FINE OUNCES
(After U.S. Bureau of Mines)

1940	1941	1942	1943	1944	1945*
44,498	72,432	101,398	129,940	159,000	125,000

* Estimated.

MINE PRODUCTION OF DOMESTIC SILVER, IN THOUSANDS OF FINE OUNCES
(After U.S. Bureau of Mines)

1941	1942	1943	1944	1945*
72,336	56,090	40,820	34,551	30,000

* Estimated.

which is not used for monetary purposes. These prices are based on silver 1,000 fine; when converted to the commercial basis of 0.999 fine, the price was equivalent to 90.41 cents an ounce for the buying price and 90.91 cents for the selling price.

World Production, Imports and Exports. The United States supplied 410 million ounces of silver to Allied countries in the Second World War. England, in 1944, used 14 to 18 million ounces of silver for war purposes. In Canada, arts and industry utilized a record supply of 5 million ounces, 25 per cent higher than in 1943. In India, no silver was used by industry; but in 1944, hoarding accounted for about 38 million ounces. In Mexico, the arts used about 6½ million ounces. "Silver is probably in the greatest demand in history," it was stated on Oct. 7, 1945, by *The New York Times.* Demand was chiefly for hard silver money and for silverware and ornaments. Silver was produced in 1938 by 66 countries, the recovery totaling 267.7 million ounces; in 1940, 275.7. Total world output of silver in 1493–1941 amounted to 17,507,210,287 fine ounces, as reported by the Bureau of the Mint.

Mexico, the world's leading silver producer, had recovered about 210,000 tons of the metal up to 1942, as estimated by the Mexican Department of Mines. Of world output in 1938, Mexico recovered 30.3 per cent; the United States, 23 per cent. Output was 71,200,000 oz. in 1943; in 1944, approximately 63 million ounces; in 1945, production was reduced to an estimated 60 million ounces. Howe Sound Company, Fresnillo, Dos Carols, Pochuca, San Francisco, and Santa Maria de la Paz were reported to be the chief producers in 1945. Mexico lowered the production and export taxes on silver from 12.02 to 8.32 pesos per kilogram in January, 1945. The circulation of silver money in Mexico was valued at about 500 million pesos.

As a result of the Washington increase in the price of silver, effective Sept. 20, 1945, Mexico increased taxes to absorb half of the 26 cents increase and placed exports under control. Mexico canceled the agreement affecting exports of silver to the United States. Cost rises in Mexico tended to offset the price increase.

A standard silver price for both North and South America was expected

to result from the Inter-American Conference on Problems of War and Peace in Mexico City, Feb. 21 to Mar. 8, 1945. An improved price would eliminate the need for government aid in Mexico and Peru, making silver mining more profitable than formerly.

Canada, ranking as third largest silver-producing country, following Mexico and the United States, recovers silver mainly as a by-product of other metals. Almost 75 per cent of the 1944 output was used in Canada, producers being required to supply the domestic market before offering any of the metal for export. The combined output for Canada and Newfoundland in 1945 was estimated at 14 million ounces.

Canadian silver is produced largely by Consolidated Mining and Smelting Company, Ltd., which secures over half the total output, the main source being silver-lead-zinc ores of the Sullivan mine at Kimberley, British Columbia. The other major producers are International Nickel Company of Canada, Ltd.; Hudson Bay Mining and Smelting Company, Ltd.; and Noranda Mines, Ltd. Five companies produce refined silver. Other Canadian producers are in a position to ship concentrates to the United States and to obtain the higher U.S. price. Canada, although keeping the low silver price, granted export permits on silver concentrates without restrictions.

Canadian production was estimated by the Dominion Bureau of Statistics at 12,778,859 oz. for 1945 compared with 13,627,109 in 1944. The Canadian silver surplus, in September, 1945, quickly changed into a shortage as a result of heavy demands from consumers for jewelry, silverware, and industrial uses. The Canadian government in 1944 purchased 4 million ounces from Dominion producers for coinage, and an additional 400,000 oz. were recovered from unrefined gold deposited at the Royal Canadian Mint, Ottawa.

On Aug. 2, 1946, the pool of Canadian refiners of silver, handling distribution of the metal to the Ottawa mint and to other Canadian consumers, stated that the price would rise to the level of 90.5 cents an ounce established by the U.S. Treasury for purchases of foreign silver.

In 1944, Peru reported about 15 million ounces; in 1943, 15,100,000, ranking fourth as a world producer. Australia follows Peru in fifth place. Japan is sixth, followed by Russia. In Bolivia, silver represented 7 per cent of the value of 1939 exports. Production was 6,400,000 fine ounces in 1938. Burma produced 5,900,000 oz. in 1938.

In Alaska, total mineral production, to the end of 1944, included gold (70 per cent), copper (25 per cent), and eight other minerals including silver (5 per cent). Postwar expansion in the output of silver can be secured through systematic development, as reported on May 7, 1945, by the U.S. Geological Survey.

In the Philippine Islands, silver valued at $948,388 was exported in 1939; in 1940, $976,662. Output has not been reported for 1941. The islands came under the Japanese occupation early in 1942.

Under lend-lease, the U.S. Treasury Department disposed of 2,402,807,000 oz. in 1944, to the governments of Australia, Ethiopia, Great Britain, India, the Netherlands, and Saudi Arabia. No foreign silver was acquired in 1944 by the U.S. Treasury. It was reported in October, 1945, that much silver had been seized from the Japanese by the United States forces of occupation.

WORLD SILVER PRODUCTION, IN THOUSANDS OF FINE OUNCES
(After American Bureau of Metal Statistics)

Country	1939	1940	1941	1942	1943	1944
Mexico	75,869	82,638	78,362	84,864	87,000	63,000
United States	57,808	67,013	69,128	54,486	44,812	34,551
Canada	23,164	23,834	21,754	20,695	17,345	13,627
Central and South America	36,351	34,946	31,529	31,795	31,153	*
Total world	258,101	273,972	263,000	*	*	*

* Not available.

U.S.S.R. is dependent on imports for no metals and minerals except silver and tin, it was reported in Washington in January, 1946, based on information submitted by the Office of Strategic Services. World superiority in minerals was made possible in Russia as the result of a policy of importing minerals rather than using the known domestic deposits, leaving untouched the vast reserves of essential materials.

Prices. The New York price for imported bar silver, as regulated by the OPA, 1943 through Sept. 19, 1945, averaged 44.75 cents an ounce. The price averaged 38.333 cents in 1942; in 1941, 34.783 cents; in 1940, 34.77 cents. The price of foreign metal 0.999 fine was increased by the OPA to 71.111 cents a fine ounce on Sept. 20, 1945, the ceiling price for domestic silver at the U.S. Mint. The record high price of $1.37½ was reached on Nov. 25, 1919; the record low price of 31 cents on Dec. 29, 1932. The U.S. monetary price is $1.29 an ounce.

The London price held at 23½*d.*, 1942 to Jan. 2, 1945, when the selling basis was changed to conform with New York specifications. Bullion dealers altered the quotation from a basis of 0.925 to 0.999 fine, per troy ounce, increasing the price to 25½*d.* This price advanced to 44*d.* (73.87 cents), following the advance on Sept. 20, 1945, for foreign silver in the United States. The Bank of England continued its former practice of releasing only small amounts of silver for essential manufacturing and for jewelry. In 1941, the average price was 23.44*d.*; in 1940, 22.277*d.*; in 1939, 20.57*d.* On Aug. 6,

1946, the official silver price was raised from 44 to 55½*d.*, a premium of 1.6*d.* intended to attract silver on world markets. The London free silver market advanced to about 60*d.*; on Sept. 30, 1946, 55½*d.*

Under the OPA regulations, foreign silver was priced at 45 cents an ounce. In 1945, foreign consumers were buying Canadian and South American silver at 58 cents, f.o.b. refinery or at port of shipment, equal to 60 to 65 cents delivered to the foreign user. Withdrawal of the Greene bill on Dec. 31, 1945, which made available for the use in war industry some of the surplus U.S. Treasury silver at 71.11 cents, was subject to WPB approval. Under the Greene Act, the President was authorized, on the recommendation of the WPB, to sell government silver for war and civilian manufacturing at 71.11 cents an ounce. Only minor amounts were actually released for civilian goods. Extension of the Greene bill was being considered by Congress in February, 1945. This would give the Treasury authority to sell "free" silver to manufacturers for 2 years at not less than 71.1 cents an ounce. Members of the silver bloc in Washington urged that domestic silver be increased in price to the full monetary level of $1.29 a fine ounce.

On Aug. 1, 1946, the OPA advanced silver ceiling prices to conform with the new Treasury Department prices authorized by Congress. The price for standard commercial bar silver was fixed at 90.5 cents per fine troy ounce or the Treasury's selling price, whichever is higher. The OPA reported that silver was being kept under control to assure that the price of foreign silver did not exceed the Treasury selling price for domestic metal. Maximum prices for semifabricated silver articles and for silver scrap were at the same time raised to reflect the increased bullion price. The maximum price for silver scrap per fine troy ounce of silver content, delivered free of all charges, was fixed at one-quarter cent below the maximum base price for standard commercial bars. On Aug. 23, the OPA ruled that manufacturers using silver in wire and cable that they make might raise their ceiling prices for these products by the same amounts as their silver costs were increased.

Under the Silver Purchase Act of 1934, the Treasury was authorized to acquire silver from domestic and foreign sources in an effort to bring monetary metal stocks to three-fourths gold and one-fourth silver. The metal purchased from domestic producers ranged from 64.64 to 77.57 cents an ounce; metal from foreign sources averaged 51 cents.

In Bombay, the price of silver dropped, on Aug. 27, 1945, from Rs. 135 per 100 tolas fine to Rs. 118. The Bombay quotation, on Sept. 27, reached the equivalent of 65½*d.* per ounce. In June, 1946, the Bombay price was $1.34 an ounce at the prevailing rate of exchange. In Mexico, the price of silver in June, 1946, was quoted at 88 cents an ounce.

Canada maintained the price of silver at 40 cents through November, 1945, but advanced it to 71.11 cents in January, 1946; on Aug. 2, 1946, to 90.5 cents. The Wartime Prices and Trade Board set the maximum domestic price of refined silver in January, 1943. This price was later adjusted by the Metals Controller, Department of Munitions and Supply. The average price was 45.3 cents in 1943; in 1944, 43 cents.

The New York price, as determined by Handy & Harman on the basis of market prices for bar silver, 50,000 oz. or more, was 90.125 cents on Sept. 30, 1946. The Treasury price for purchase of newly mined domestic silver continued at 90.5 cents. The price of silver was decontrolled on Nov. 1, 1946.

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SODIUM

Properties. A silvery white, alkaline, metallic element, sodium always occurs in combination with other elements, as in rock salt or borax. It is one of the eight elements that account for about 98.5 per cent of the composition of the outer 10 miles of the earth's crust, of which sodium represents 2.85 per cent. This is one of the 16 industrial nonferrous metals used essentially as alloying constituents. (Na, atomic number, 11; atomic weight, 22.997; melting point, 97.5°C.) Sodium metal is made by electrolysis of fused salt.

Natural sodium carbonate (soda ash) is recovered from brine and in the form of natron (sodium carbonate with 10 molecules of water; its specific gravity is 1.46; its melting point, 34°C.). Soda ash has a melting point of 852°C.; its specific gravity is 2.48. This heavy chemical is the most important of the alkalies and is produced in greater quantities than other chemicals except sulfuric acid and common salt. Soda ash made from salt supplied 96 per cent of domestic requirements in 1941. Trona (sodium sesquicarbonate; specific gravity, 2.11) occurs in California and Wyoming. Burkeite is a double salt from which both sodium sulfate and sodium carbonate are recovered; it occurs in California.

Natural sodium sulfate occurs in crystals or in the form of highly concentrated brines. Dried salts produce hydrated sodium sulfate (Glauber's salt) and anhydrous sodium sulfate (salt cake). Sodium sulfate is also an important chemical raw material, the chief source being common salt (sodium chloride) as raw material. Salt is used for making a great variety of sodium salts, such as the acetate, benzoate, chromate and bichromate, bromide, chlorate, citrate, and many others.

As essential raw materials of the chemical industries, salt, lime, and sulfur are employed in great quantities, either as active reagents or as components of finished products. The abundance and availability at low prices of sodium have been decisive factors in expanding the chemical industries to enormous proportions in the years since 1915.

The Solvay (ammonia-soda process) and the electrolytic processes are the two methods of manufacturing soda ash, using salt as a raw material. Electrolytic soda ash, with chlorine as a by-product, is secured by drying and calcining sodium bicarbonate, which is precipitated by passing an

electric current through a cell containing a saturated solution of salt. Salt in brines and in rock-salt deposits is required for the manufacture of soda ash, with limestone to furnish carbon dioxide and lime for the recovery of ammonia.

Manufactured and natural soda ash are refined to an Na_2O content of 58 per cent, the equivalent of sodium carbonate content of about 99 per cent. The sodium carbonate group includes sodium bicarbonate (monosodium carbonate; specific gravity, 2.21), sodium carbonate decahydrate, sodium sesquicarbonate, and sodium carbonate monhydrate (specific gravity, 1.55). Caustic soda (sodium hydroxide) is not a carbonate but is closely connected with the soda-ash and alkali industries.

Uses. Domestic production of metallic sodium is essential for the manufacture of tetraethyl lead and of synthetic indigo. The synthesis of dyes and other organic chemicals accounts for about half the domestic use of sodium metal, with minor applications in alloys and in the liquid phase as a heat-transfer medium. The metal is also used as a scavenger.

Sodium sulfate (natural and synthetic) is employed in the glass, dye, and textile industries: in the manufacture of kraft paper; and in stock feeds. In mining, it is employed in the form of niter cake as a flux used in smelting copper-nickel matte and in the recovery of antimony. Minor amounts are used for medicinal and tanning purposes and for control of caustic embrittlement of boilers. Sodium carbonate and trona are employed chiefly in glassmaking, in alkali cleansers, and in the metallurgy of tungsten, molybdenum, vanadium, and antimony. Nonferrous metallurgy consumed about one-tenth of the sodium carbonate used in the United States in 1943. The carbonates are employed as a precipitant of magnesium carbonate from sea-water bitterns.

Wartime demands of new munition plants, expanded aluminum production, the increased mining and treatment of low-grade ores, and other industrial consumption greatly increased industrial demands for soda ash. Synthetic salt cake (a sintered product of soda ash and sulfur) was reported in 1940 to be utilized as a substitute for sodium sulfate in the Southern states. Soda ash is used in increasing quantity by the glass industry. The important war developments in glass continued to rely on the traditional method of combining silica with oxides of sodium and calcium.

A major use is in the production of caustic soda. Dense ash is used chiefly by manufacturers of glass and as a carrier in the manufacture of dyes. Granular ash is used in foundries and glassworks. Fused blocks of soda ash weighing 4 lb. each are used in metallurgy.

Sodium bicarbonate is widely used in medicines and in soap powders;

it is the chief ingredient in many forms of baking powders. Sodium carbonate monohydrate is used in the manufacture of chemicals, in photography, in cleaning and boiler compounds, and in laundry and textile cleaning. Caustic soda is used chiefly by the rayon and cellulose-film industries and for chemicals, soap manufacture, and petroleum refining.

Other important applications are in the production of modified sodas, water softeners, silicate of soda, bicarbonate and other chemicals, for insulation, and in the pulp and paper industries. Essential uses of sodium carbonate include the purification of bauxite for the production of aluminum, about 150 lb. of soda ash being used per ton of bauxite treated. In the flotation of various minerals and in smelting iron ores, substantial quantities are used.

Soda ash in Canada in 1942 was reported by the Dominion Bureau of Statistics to be used for the following industries: manufacture of nonmetallic minerals (coke, gas, petroleum, and glass); explosives, salts, acids, and soap; pulp and paper; dyeing and cleaning; textiles; and sugar refining.

Domestic Sources of Supply and Production. Sodium metal production in the United States in recent years has been estimated at 8,000 to 10,000 tons. The manufacture of sodium cyanamide resulted in annual production of an additional 5,000 tons or more of sodium metal, as an intermediate product. Domestic production of the metal is limited to E. I. duPont de Nemours & Co., Inc., Wilmington, Del., and Ethyl Gasoline Corporation, New York City.

Sodium was designated by the War Production Board on Mar. 1, 1944, as sufficient for war uses plus essential industrial demands. The metal was placed under allocation control on Nov. 15, 1943, in order to assure sufficient supplies for the manufacture of tetraethyl lead.

Natural sodium sulfates and carbonates are inadequate from domestic sources; but under war conditions, manufactured sodium sulfate was produced in volume adequate to meet the requirements of chemical plants. Domestic requirements are supplied largely by manufactured sodium sulfate produced in chemical plants. Sodium carbonates manufactured by the Solvay process amounted to 3,788,583 short tons in 1942; in 1943, 4,407,618, as reported by Bureau of the Census.

Domestic output of salt cake in 1937 amounted to 269,177 tons, of which 241,347 tons were for sale at a total value of $2,367,616. Production of natural sodium carbonate in the United States has been limited to Searles Lake and Owens Lake, California, where borax and other products are recovered also. Sales of natural sodium carbonates (chiefly soda ash, but including bicarbonate and trona) increased to 124,745 tons in 1939; in 1944, sales reached a new record value of $1,577,982.

NATURAL SODIUM SULFATES AND SODIUM CARBONATES SOLD OR USED IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

	1940	1941	1942	1943	1944
Sodium sulfates.....	184,571	154,327	169,870	160,622	168,923
Sodium carbonates.....	130,034	146,677	150,619	165,993	184,826

Domestic production of soda ash was first secured in 1884, at Syracuse, N. Y., shortly before the natural soda industry was started in California. Natural Soda Products Company (American Potash & Chemical Corporation), Owens Lake, California, installed a complete new unit for the recovery of sodium carbonate in October, 1945, increasing output to more than 60 tons a day. Brine is pumped from below the dry lake bed into open vats for evaporation. The brine solution is composed chiefly of sodium chloride, sodium sulfate, and sodium carbonate. The carbonate and other salts have been produced continuously from the Owens Lake region since 1910. Soda is a coproduct of boron and potash salts made from the brines.

Other producers in California are as follows: Pacific Alkali Company recovered soda ash and trona from the brines of Owens Lake for Pittsburgh Plate Glass Company. Sodium carbonate was produced from Searles Lake by West End Chemical Company. Soda ash and desiccated sodium sulfate were recovered from the Searles Lake brines at Trona by American Potash & Chemical Corporation. The Dale Lake plant of Desert Chemical Company also produced desiccated sodium sulfate.

Production was also secured in Texas, where Arizona Chemical Company recovered desiccated sodium sulfate from well brines at O'Donnell and Brownfield, for the sulfate pulp market. Sodium sulfate was produced by Ozark Chemical Company at Monahans, largely for sale to sulfate paper mills. In Wyoming, Iowa Soda Products Company produced Glauber's salt for stock feed, at Rawlins. Near Caspar, Glauber's salt was also produced by W. E. Pratt. In Maryland and Virginia, soda is manufactured by the electrolytic process; the ammonia-soda process is employed by 10 plants located in Texas, Michigan, Ohio, Louisiana, and Virginia.

World Production, Imports and Exports. Imports of crude sodium sulfate (salt cake) were made primarily because of economic advantage. Only small quantities of special reagent-grade sodium carbonate are imported, chiefly from Britain. Imports amounted to 154,753 tons valued at $1,494,624 in 1939, including 468 tons of crystallized sodium sulfate (Glauber's salt) and 5,491 tons of anhydrous sodium sulfate.

Canada is one of the largest producers from natural deposits. Horseshoe Mining Company (a subsidiary of International Nickel Company) produces sodium sulfate in Ormiston, Saskatchewan. The following producers are located in the same province: Natural Sodium Products, Ltd., Bishopric and Hardene (daily capacity of 750 tons); Midwest Chemical Company, Palo;

PRODUCTION OF SODIUM CARBONATE AND SODIUM SULFATE IN CANADA, IN SHORT TONS
(After Dominion Bureau of Statistics)

	1940	1941	1942	1943	1944
Sodium carbonate	220	186	256	468	44
Sodium sulfate	94,260	115,608	131,258	107,121	102,421

and Sybouts Sodium Sulphate Company, Gladmar. Canadian output of sodium sulfate in the war years ranged from 131,258 tons in 1942 to 86,643 tons in 1945. Imports of salt cake amounted to 13,535 tons in 1945; 20,459

ESTIMATED WORLD CAPACITY FOR PRODUCING SODA ASH, IN SHORT TONS
(After U.S. Bureau of Mines)

	1939
United Nations:	
United States	3,500,000
Britain	1,500,000
U.S.S.R.	700,000
Canada	40,000
British East Africa	40,000
China	20,000
British India	20,000
Total	5,820,000
Axis-dominated Nations:	
Germany	1,250,000
France	500,000
Japan	200,000
Italy	100,000
Czechoslovakia	90,000
Belgium	80,000
Poland	60,000
Austria	45,000
Rumania	35,000
Norway	18,000
Yugoslavia	10,000
Total	2,388,000
Neutral nations:	
Spain	40,000
Switzerland	33,000
Sweden	13,000
Argentina	4,000
Total	90,000
World total	8,298,000

tons in 1944; in 1943, 11,904; in 1942, 7,071. Imports of Glauber's salt were 1,016 tons in 1945; 777 tons in 1944; in 1943, 566; in 1942, 75.

Canadian output of sodium carbonate was valued at $5,148 in 1943; in 1945, $2,629. Total production is secured in British Columbia and is shipped to Vancouver for soap manufacture. Supplies of soda ash for eastern markets is obtained from chemically prepared material made from salt by the Solvay or ammonia process in Ontario (Brunner Mond Company, Amherstburg) and imported material from the United States. Canada imported sodium carbonate (soda ash or barilla) amounting to 2,229 tons in 1945; 20,141 tons in 1944; in 1943, 70,557; in 1942, 65,589. Consumption of soda ash in Canada in 1942 amounted to 89,400 tons.

In 1865, ammonia-soda plants were established in Belgium and in other European countries, England, the United States, and Canada by Solvay et Cie. Prior to the First World War, the Solvay Syndicate controlled world sources of soda. Affiliated producers in the United States, Britain, and Russia withdrew after the war, and the syndicate was reorganized as International Alkali Cartel, controlling soda-ash production and sales in Europe.

Soda-ash capacity of the United Nations was probably more than double that of the Axis. In Japan, salt for soda-ash manufacture must be imported.

Prices. Sodium was quoted on May 10, 1945, by *E & M J Metal and Mineral Markets*, at 15 cents a pound, in drums, carload lots; smaller lots, 15½ cents. Sodium metal is sold in 2½- or 12-lb. bricks packed in drums.

Quotations by the U.S. Bureau of Mines, in 1938, were as follows: crude sulfate, $9.50 a ton; Glauber's salt, $5.40 a ton; anhydrous, $17.77 a ton. Natural sodium carbonates (soda ash, bicarbonate, and trona) were quoted at $12.25 a ton in 1939. Soda ash was quoted at $1.05 to $1.13 per 100 lb. of 58 per cent Na_2O, light ash and extra-light ash; dense ash, $1.15 in bags; $1.35 in barrels; 95 cents in bulk.

Oil, Paint and Drug Reporter quoted the following prices, 1942–1944: domestic salt cake, $15 a short ton, in bulk, f.o.b. works; anhydrous sodium sulfate, $1.70 to $1.90 per 100 lb., at works; Glauber's salt, $1.05 to $1.25 per 100 lb.; soda ash, calcined sodium carbonate, 90 cents to $3.25 per 100 lb., according to grade.

The tariff act of 1930 maintained a duty on soda ash of ¼ cent a pound. Sal soda, under this act, is dutiable at ¼ cent a pound. Sodium bicarbonate is on the free list.

United States Alkali Export Association, Inc., is an independent body representing domestic producers of sodium carbonates and caustic soda for the purpose of eliminating competition among American exporters in foreign markets. Tonnage of soda alkalies is supplied the association by the

members on a percentage-allocation basis, each member receiving the same unit price regardless of the tonnage furnished.

In Canada, soda ash was quoted at $2 per 100-lb. bag in 1944 by *Canadian Chemistry and Process Industries.* Natural anhydrous sodium sulfate from deposits in western Canada was quoted at $9 to $10 per short ton, f.o.b. plant.

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STRONTIUM ORE

(Celestite)

Properties. Strontium is the essential constituent of celestite (natural strontium sulfate). (Sr, atomic number, 38; atomic weight, 87.63; melting point, 800°C.)

Celestite is a white, reddish or pale blue, massive mineral, coarsely crystalline, fibrous bladed, very fine-grained or earthy in texture. Its density is 3.95 to 3.97; its hardness, 3 to 3.5. It occurs in relatively small deposits of replacement origin. Celestite is insoluble in acids.

Strontianite (strontium carbonate) is a secondary mineral occurring as the weathering product of celestite or in concretionary masses formed by the precipitation of the strontium content of ground waters. It is massive and coarsely crystalline, white, green, or yellow in color, and transparent to translucent. Its density is 3.68 to 3.71. It is more soluble in hot water than cold and can be distinguished from celestite by solubility in hydrochloric acid. Strontianite occurs in veins in limestone and marl.

Strontium salts are more easily converted from strontianite than from celestite, but they have limited use when calcium carbonate is contained. Strontianite contains 70.3 per cent of strontia; celestite contains 56.4 per cent.

In the United States, the origin of commercial deposits of strontium minerals was as precipitates formed by the drying of Tertiary lakes or as replacements of calcium in limestone. Strontium is present in very small percentages in soluble derivatives of rock weathering; so the presence of large deposits of celestite in a high degree of purity suggests that other processes were involved in their formation than the concentration of normal ground and surface waters in enclosed basins.

Uses. Strontium compounds and salts have many vital wartime applications, including the use of strontium oxalate in tracer bullets to control the burning rate of the tracer composition. Strontium nitrate is essential for military flares, rockets, and shells. Requirements of celestite in signal flares and tracer bullets declined sharply in 1944. Celestite is used in the manufacture of strontium compounds and as a filler. Strontianite is also a source of strontium compounds and salts and is employed in the steel industry. The chief military use of strontium salts (strontium nitrate, peroxide, and oxalate)

is in tracer bullets. The expanded use of 0.30- and 0.50-caliber machine guns, in which every fifth bullet fired is a tracer bullet, greatly increased the quantity of strontium salts required in the Second World War for use of aircraft, tanks, and ground forces. Military flares, Very pistols, and aviation, marine, railroad, and highway signals also require strontium salts, particularly strontium nitrate.

The minerals celestite and strontianite are chiefly employed in the manufacture of strontium chemicals. Ground celestite is used for purifying caustic soda for the rayon industry. It is also a substitute for barite as a weighting agent in oil-well drilling fluid. The petroleum industry has been the main consumer of domestic celestite, but barite was reported to be giving increasing competition for use in well-drilling muds in 1944. Small quantities of higher grade domestic celestite are sold for the purpose of absorbing iron from caustic-soda liquors and for conversion to strontium chemicals, both with and without beneficiation. Ground celestite has been substituted for barite in colored paints, sealing compounds for electric batteries, asphaltic compositions, rubber, and sealing wax. Celestite has also substituted for lithopone in the manufacture of pigments.

Ground strontianite is used for desulfurizing and dephosphorizing steel, acting as flux in the open-hearth furnace without damage to the furnace lining. It increases fluidity of the slag without reducing its basic character. This is particularly important in treating low-quality pig iron and scrap, from which most of the sulfur and phosphorus are removed by the strontianite.

In prewar years, strontium hydroxide was used in Europe primarily for desaccharizing beet-sugar molasses. The chlorate, chloride, nitrate, oxalate, oxide, peroxide, and sulfate all are utilized in pyrotechnics. Eleven of the strontium compounds are employed in medicine. The carbonate, oxide, and sulfate all are used by the glass industry. Strontium sulfate is also used for ceramics and paper; the oxide, as a photographic reagent and as a paint filler.

Strontia, as one of the most promising substitutes (with lithia and the fluorides) for lead in glazing pottery, was reported in 1944. This application may compensate for part of the loss of military uses in the postwar period. Peacetime requirements of strontium compounds are relatively small.

Domestic Sources of Supply and Production. The beneficiation of low-grade crude Texas strontium ore was developed by the U.S. Bureau of Mines to produce a high-grade concentrate with high recovery of celestite. The concentrates produced by flotation grade 90 to 93.5 per cent strontium sulfate. Adequate domestic reserves are reported to be available, chiefly in Texas, California, Washington, and Arizona, but shipping costs to eastern

consumers are at present prohibitive. Two operators were reported to be mining deposits in Texas, producing low-grade ore averaging 73 per cent of $SrSO_4$; two properties in California were also in production.

Western deposits were opened in the First World War, about 250 tons of strontium minerals being produced in 1916; in 1917, 4,035 tons, of which 10 per cent was strontianite and the balance celestite; in 1918, domestic mines closed after producing 400 short tons of strontianite. Producers reopened old deposits in 1940, anticipating large domestic requirements for strontium salts, and produced 350 tons.

In California, production of strontium ore was secured near Ludlow and in the Fish Mountains, Imperial County (the latter operated by Pan-Chemical Company); in Texas, production of the abundant subchemical grade celestite was secured near Blanket, Brown County, and in Nolan County (operated by Milwhite Company, Inc., and Bennett-Clark Company, Inc., respectively). Limited production of celestite is reported for Ohio and Washington, and deposits are known in six other states.

The domestic industry, developing extensive western deposits of celestite and strontianite, was reported by the U.S. Bureau of Mines to have limited opportunity for postwar survival, due to heavy shipping costs. Impure grades of celestite found in Texas are inferior to the 92 per cent quality produced by England, Mexico, and Spain at about half the cost of Texas ore. Ore of good quality is available in California, but high freight charges place this at heavy disadvantage for delivery to Atlantic seaboard consumers.

Celestite lump, fines, and powdered material are put through a primary crusher, dried, crushed in a secondary crusher, then pulverized to 90 per cent minus 325-mesh. The product is air-floated and bagged.

Annual consumption averaged 1,000 to 3,000 tons in prewar years, except 1938 and the depression years 1930–1932, requirements being supplied by imports from Britain, Tunisia, and Germany.

Shipments of domestic chemical and nonchemical grades of celestite dropped to 3,005 short tons in 1944; in 1943, 7,566; in 1942, 4,041. Higher grade domestic deposits were reported to have been depleted, with available reserves requiring beneficiation. Consumption of foreign and domestic celestite in strontium chemicals totaled 13,387 tons in 1943; in 1944, 6,000.

The Metals Reserve Company made a first commitment in 1943 for the purchase of strontium (celestite) for stockpiling. Stocks of celestite for chemical use, held by the MRC, amounted to 13,732 tons on Dec. 31, 1943. Ranking thirty-sixth among stockpile items, strontium valued at $302,774 was purchased by the MRC. The market value on Oct. 31, 1944, was shown by the inventory at $299,940, after sales amounting to $40,118.

Government stocks of celestite held by the Reconstruction Finance Corporation through the Office of Metals Reserve on Oct. 31, 1945, amounted to 9,210 short tons, as reported by the Civilian Production Administration.

Strontium metal and salts were placed under export control in 1940.

World Production, Imports and Exports. Strontium minerals, although imported in relatively small quantities, are key products that filled important industrial and strategic military requirements in the war years. Britain had previously been the world source of celestite. Adequate material from foreign sources continued to be available in the war period.

High-grade celestite has been imported from newly developed properties in Mexico since 1941. New deposits were reported in 1944. Mexico developed as the main source of celestite used in strontium chemicals in the United States, followed by sources in Spain. An important new source was discovered in India in 1940.

IMPORTS OF CELESTITE FOR CONSUMPTION IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Country	1940	1941	1942	1943
United Kingdom	2,729	3,306	2,682	1,367
Mexico	.....	987	6,201	11,060
Spain	.....	.....	1,475	4,454
Total	2,751*	4,293	10,358	16,881

* Includes 22 tons from Tunisia.

Prewar production was secured in the Bristol district, England, which shipped celestite to Germany and imported strontium chemicals. Germany imported 4,000 to 5,000 tons a year before the First World War; imports averaged only 2,000 to 3,000 tons annually in 1920–1939. Germany had dominated the strontium-chemicals field from production of strontium ore in Westphalia since 1840. Production gradually declined after 1884, when British celestite gained control of the strontium-minerals industry. New uses in the iron and steel industry led to a revival of German production on a limited scale in prewar years.

The mining method in Westphalia consists of overhead stoping. Nearly vertical veins of strontianite have average widths of 1 ft. or less. Run-of-mine material contains 10 to 15 per cent of strontianite, this being concentrated to 85 per cent strontium carbonate. In England, mining is carried on in shallow pits, the celestite being roughly hand-trimmed into lumps 9 to 12 in. across and stockpiled.

Prices. The price of celestite, 92 per cent of $SrSO_4$, finely powdered, was quoted at $45 a ton, in carload lots, by *E & M J Metal and Mineral*

Markets, on Apr. 12, 1945. Celestite, chemical-grade, lump, delivered in the Philadelphia area was $30 to $35 a ton, 1942–1944. Crude domestic celestite was quoted by the U.S. Bureau of Mines at $15 to $20 a ton, f.o.b. mines, in 1940. Chemical-grade strontium sulfate, finely powdered, 90 to 92 per cent, advanced to $45 a ton in September, 1940.

Powdered strontium carbonate (strontianite), 84 to 86 per cent of $SrCO_3$, was $55 a ton in 1945. The same rate applied to the lump form, in carload lots. Technical carbonate was quoted at 25 cents a pound in 1940.

The price of celestite was $6 a ton in 1914; in 1917, $20, delivered at New York. Shipping charges from California to Philadelphia and New York are $16.40 per short ton compared with the ocean rate of $5.90 per short ton from England. Postwar prices in the United States are expected to drop below $15 a ton. Imports of strontium minerals are duty free.

The average price of celestite, f.o.b. Bristol docks, was about $12 per short ton; delivered at New York, $16. The price at Bristol declined to $10 to $11 a ton in 1940; in 1941, $13.

Celestite from Mexico, in 1941, was valued at $16 a short ton at port of origin, with shipping rates similar to transatlantic charges from Britain.

Celestite is a strategic and critical material to be acquired and guarded in accordance with the stockpile bill passed by Congress in July, 1946; the Procurement Division of the Treasury Department was designated to buy reserve supplies of this mineral, together with titanium (rutile), talc (steatite, block, or lava), tantalite, tin, tungsten, vanadium, and zirconium ore, aided by the Office of Metals Reserve and other agencies.

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SULFUR AND PYRITES

Properties. A yellow, brittle, nonmetallic crystalline element, native sulfur, or brimstone, was one of the nine elements known and used in ancient times. Sulfur is one of the six nonmetallic or semimetallic elements used for alloying purposes. (S, atomic number, 16; atomic weight, 32.06; melting point, 119°C.)

Pyrites is the trade name for three minerals containing more than 25 per cent of sulfur: (1) Pyrite, a native iron disulfide of brassy color, contains, when pure, 53.4 per cent of sulfur and 46.6 per cent of iron. Small amounts of arsenic, cobalt, nickel, copper, gold, zinc, and tin are sometimes contained with the mineral. (2) Marcasite, a pale yellow to white mineral, has the same chemical composition as pyrite. (3) Pyrrhotite, brownish bronze in color, contains 38 to 39 per cent of sulfur, which is too low for use as a source of the element unless commercial value is due to contained nickel, copper, or cobalt. Cuprous pyrites is the trade name applied to pyrite ores mined in Spain and Norway as a source of copper.

The Freeman process of flash-roasting is designed for by-product flotation fines obtained from the treatment of copper ore. In smelting sulfide ores, sulfur dioxide gas is produced, which can be used either for the production of elemental sulfur or, directly, for the manufacture of sulfuric acid or liquid sulfur dioxide. The contact process is used in the manufacture of sulfuric acid from converter gas in copper smelters, for the recovery of portions of the smelter gases.

The Frasch process recovers sulfur of 99.5 per cent purity. Superheated steam is pumped through pipes of large diameter down 600 to 1,000 ft., melting the sulfur. By means of compressed air, the liquid is drawn to the surface and discharged into great bins. After solidifying, the sulfur is blasted down and loaded on cars. Sulfur deposits of large extent occur along the coast of Louisiana and southeast Texas, associated with gypsum and salt. Production has been secured from nine salt domes in this region.

Uses. Essential wartime applications of sulfur are in the manufacture of explosives and sulfuric acid. A great range of industrial uses of strategic importance has been reported for this element, including medicines, disinfectants, fungicides, and fertilizers and in petroleum-refining. Other major wartime uses include steel pickling and galvanizing, tinning, and enameling;

as an ingredient of the solution used in storage batteries; in the refining of copper as an electrolyte; and for the manufacture of certain chemicals.

Peacetime applications of sulfur are mainly in the manufacture of sulfuric acid, which is used primarily as a reagent in the production of commercial fertilizers, and in a large number of chemical and processing industries. Distillation of petroleum; the production of acids, chemicals, and industrial explosives; vulcanizing rubber; and the manufacture of paints, varnishes, and various dyes and coal-tar products are all major peacetime applications.

In the United States, more than 75 per cent of the sulfur and pyrites produced are converted into sulfur dioxide, the base for the manufacture of sulfuric acid, which is a nitration aid for the nitration of cotton, in the manufacture of nitrotoluenes and other explosives. In the manufacture of sulfuric acid, which is generally the cheapest and most effective reagent in industrial processes requiring acid, pyrites competes with native sulfur and with by-product acid derived from the smelting of ores.

The large production of sulfur and pyrites available from the easily accessible domestic sources has been directly related to the expansion of the chemical industries since the First World War. The chemical processing industries require sulfur and pyrites and certain other nonmetallic minerals such as salt, chemical lime and limestone, fluorspar, barite, and boron minerals. Domestic production of pyrites, which is a low-priced material, is used chiefly by companies that manufacture acid locally, close to the source of supply.

In Canada, sulfur is used in the production of sodium sulfite and in making rayon; in the manufacture of wood pulp, sulfur is employed for sulfite liquor. The pulp and paper industry, both in the United States and Canada,

DOMESTIC CONSUMPTION OF SULFUR BY USES, IN LONG TONS
(After U.S. Bureau of Mines)

Uses	1940	1941	1942	1943	1944
Military explosives and chemicals	800,000	1,060,000	1,260,000	1,320,000	1,535,000
Fertilizers and insecticides	410,000	450,000	475,000	500,000	580,000
Pulp and paper	320,000	360,000	365,000	305,000	300,000
Explosives	74,000	83,000	90,000	90,000	88,000
Paint and varnish	54,000	65,000	70,000	80,000	90,000
Dyes and coal-tar products	51,000	65,000	60,000	65,000	75,000
Rubber	47,000	55,000	35,000	45,000	55,000
Food products	6,000	6,000	6,000	7,000	7,000
Miscellaneous	86,000	95,000	110,000	120,000	140,000
Total	1,848,000	2,239,000	2,471,000	2,532,000	2,870,000

is the third largest consumer of sulfur. Sulfur is used to a large extent in the manufacture of sulfuric acid, in Canada, and for explosives, rubber vulcanizing, and fertilizers.

There is no satisfactory substitute for the principal uses of sulfur, particularly as a source of sulfuric acid and in vulcanizing rubber.

DOMESTIC CONSUMPTION OF SULFURIC ACID (BASIS 100 PER CENT) BY INDUSTRIES, IN SHORT TONS
(After U.S. Bureau of Mines)

Industry	1942	1943	1944
Military explosives and chemicals	2,145,000	2,285,000	2,425,000
Fertilizers	1,835,000	2,500,000	2,620,000
Petroleum refining	900,000	940,000	1,020,000
Coal-tar products	605,000	580,000	620,000
Iron and steel	510,000	535,000	560,000
Other metallurgical	350,000	360,000	340,000
Paints and pigments	475,000	495,000	530,000
Rayon and cellulose film	390,000	415,000	450,000
Industrial explosives	120,000	115,000	110,000
Textiles	90,000	85,000	75,000
Miscellaneous	350,000	350,000	340,000
Total	7,770,000	8,660,000	9,090,000

Domestic Sources of Supply and Production. Native sulfur holds a dominant place in the American market, with commercial reserves sufficient to last 55 years at the rate of use in 1935–1939. Speculative and submarginal reserves adequate for over 500 years were reported by Elmer W. Pehrson, U.S. Bureau of Mines. Sulfur is available for export owing to the large, rich, well-located deposits on the Gulf coast. Profitable foreign markets have been developed as a result of low production costs. This is one of the major nonmetallic exports of the United States, production amounting to a total of 17,118,000 tons from Jan. 1, 1940, to Jan. 1, 1945.

Sulfuric acid was placed under allocation by the War Production Board in November, 1943, but this order was later canceled. The WPB placed sulfuric acid under Schedule 74 of General Allocation Order M-300, on Dec. 1, 1944, following a serious shortage of acid. General Maximum Price Regulations were maintained on sulfur under the Office of Price Administration. No serious supply problems were reported in the war period.

Domestic production of sulfur in 1944 was 3,218,156 long tons compared with the record 1942 output of 3,460,686 and 27 per cent above the 1943 production of 2,538,786 tons. Production in 1945 marked the most active year in the history of the domestic sulfur industry at 3,753,188 long tons and

apparent sales of 3,849,591, as reported by the U.S. Bureau of Mines. Shipments in 1944 reached the all-time record of 3,518,990 long tons. This rate was exceeded in the first half of 1945; in July, 1945, shipments were higher than in any previous month at 457,970 long tons. Monthly average production was 319,441 tons in 1945 compared with 293,249 in 1944. Demand resulted in reducing producers' stocks below 4 million tons for the first time since 1937. Consumption was in excess of output.

Texas supplies about 75 per cent of the domestic output, and the balance comes from Louisiana, except for small amounts recovered for agricultural purposes and for sulfuric acid from sulfide ores containing 10 to 15 per cent of sulfur. The Gulf coast region has 99 per cent of the sulfur reserves of the United States. Minor deposits have been mined in Wyoming, Colorado, Nevada, and Utah. In the last state, sulfur of the solfatic type is mined at Sulphurdale.

In spite of the large increase in plant capacity for the production of sulfuric acid during the war, additional plant construction was given WPB authorization, in 1944, for a 500,000-ton increase in annual output. All new plants for the war emergency were designed to make use of native sulfur. Half of the new capacity was for the purpose of supplying sulfuric acid for military explosives and chemicals, and one-third was for fertilizers.

Production of sulfur was at the high level of 318,722 long tons in January, 1946; in January, 1945, 275,722; in January, 1944, 179,226; in January, 1943, 231,086. Production for the first half of 1945 (1,748,442 long tons) was higher than for any similar period since 1942, when a half-year record of 1,778,269 long tons was established; 1,780,803 in the first six months of 1946. Producers' stocks were 4,060,461 tons in January, 1946; in January, 1945, 4,034,453; in January, 1944, 4,360,018; in January, 1943, 5,148,206.

Domestic production of pyrites has an average sulfur content of about 42 per cent which is recovered chiefly as a by-product in the dressing of copper, lead, and zinc ores. Smelter gases were the source of the equivalent of 284,000 tons of sulfur in 1944. Pyrites is also marketed by coal mines in Illinois, Indiana, and Kansas. Imported pyrites is burned, and the residual metallic products are recovered from the cinder at Wilmington, Del. A new record for the fourth successive year was marked by the output of pyrites in 1943, 11 per cent higher than in 1942. Domestic production in 1944 was 788,530 tons valued at $2,598,000; in 1943, 802,384 tons valued at $2,844,000; in 1942, 720,363; in 1941, 645,257.

Tennessee ranked first of the 10 states reporting production of pyrites, the Tennessee Copper Company, Ducktown Basin, converting flotation concentrates into other products for marketing. New York produced 62,907

long tons; Colorado, 15,215 tons secured from five mines. In Wisconsin, Vinegar Hill Zinc Company recovered pyrites from the flotation concentrates from ore produced at mines in the Platteville district.

Pyrites production was also secured in Virginia (Gossan mine of General Chemical Company, Carroll County); Pennsylvania (Bethlehem Steel Company, Lebanon County); Montana (flotation concentrate produced by Anaconda Copper Mining Company, Anaconda); California (Hornet mine of Copper Mountain Company, Shasta County); Illinois (Midland Electric Coal Corporation, Henry County); Indiana (Telleydale mine of Snow Hill Coal Corporation, Vigo County).

Coke-oven, refinery-still, natural, and other gases are the source of elemental sulfur and its compounds, recovered by the Thylox, Ferrox, and Nickel processes. Fuel gases yield hydrogen sulfide through the phenolate, phosphate, and girbotal processes, the sulfide being largely converted to sulfuric acid.

DOMESTIC PRODUCTION AND CONSUMPTION OF SULFUR AND PYRITES, IN LONG TONS
(After U.S. Bureau of Mines)

Year	Sulfur			Pyrites		
	Production	Exports	Consumption	Production	Imports	Consumption
1939	2,233,817	627,784	1,606,033	519,497	482,336	1,001,833
1940	2,558,742	746,468	1,812,274	626,640	407,004	1,003,644
1941	3,401,410	31,312	3,370,098	645,257	368,838	1,028,336
1942	3,128,559	17,030	3,111,529	720,363	300,140	1,020,503
1943	2,953,845	25,079	2,928,766	802,384	256,308	1,058,692
1944	3,218,156	21,546	3,497,537	788,530	180,763	968,293
1945	3,753,188	—	—	—	—	—

President Truman, by a proclamation and an executive order on Sept. 28, 1945, took jurisdiction over the natural resources of the continental shelf contiguous to the coasts of the United States. Although no minerals have ever been discovered in the subsurface lands of the continental shelf, evidence has been found indicating their presence in the inland sands around Jacksonville, Fla., and along the Gulf coast of Texas and Louisiana. Sulfur was one of five minerals, in addition to petroleum, that have been indicated in offshore areas. "The rapid development of technical knowledge and equipment occasioned by the war now makes possible the determination of the resources of the submerged lands outside of the three-mile limit," the proclamation stated. An orderly development of these resources was to be undertaken. Prior to the Second World War, advanced technology had made possible the

exploitation of a limited amount of minerals from submerged lands within the 3-mile limit.

World Production, Imports and Exports. World reserves of sulfur were estimated, in 1933, at 170 to 177 million tons of which the United States had 140 million. Authentic information on production by Axis-dominated countries was lacking during the war years. National self-sufficiency in sulfur is held by the United States, Spain, Italy, and Japan. Russia has supplies inadequate to meet domestic demands or so located as to require imports. Sulfur was one of six nonmetallic materials available in Europe in supplies adequate for export.

In Spain, the Rio Tinto district, formerly an important source of copper, was operated in 1945 mainly for the recovery of pyrites. Half the output of Spanish sulfur is recovered from the Albacete district, from bedded deposits in Tertiary sediments. Sulfur mines are also located in Granada and Murcia provinces. Huelva mines of the Rio Tinto Company, Ltd., and the Tharsis Sulphur & Copper Company, Ltd., produced most of the Spanish pyrites in 1944, when four other companies were also active. Production was also secured in Seville province. The freight rate offered on shipments from Huelva to the United States was $7.50 a ton in 1944.

In Portugal, production of pyrites is secured from three groups of mines, operated chiefly by British and Belgian capital, located in Boixo Alentjo province. Output was reduced, in the war years, from about 500,000 to 130,000 tons gross weight, which was the minimum required to keep the mines open.

Sweden increased the production of sulfur and pyrites during the war period in order to meet domestic requirements. Pyrites produced from mines in the Boliden and Falun areas amounts to about 400,000 tons a year; elemental sulfur recovered from smelter gases and shale-oil plants total an estimated 20,000 tons annually. The cupriferous pyrite deposits of Sweden are rich in copper, zinc, and magnetite.

In Norway, production declined from about 1 million tons, in 1939, to about 800,000 tons in 1944. Pyrites and associated copper ores form the principal part of Norway's mineral production. Pyrites resources are second in importance only to those of Spain, among the occurrences in Europe.

Sicily was taken over by Allied troops in 1943, when sulfur stocks amounted to about 25,000 tons. The Allied commission reported stocks of about 24,000 tons at the end of 1944, after exporting 13,000 tons to Britain and 19,000 tons to North Africa. Fighting in Sicily resulted in flooding many of the mines. Of the 106 mines producing in 1935–1936, only 31 were active in the fiscal year 1943–1944. The Sicilian type of brimstone cannot be dis-

solved by steam, as in the Frasch process, but must be mined, and the sulfur extracted by a method involving higher costs than in the Frasch method. The Frasch process is used only in the United States, where costs are considerably lower than in Sicily or elsewhere.

Cyprus, in the war years, reported only minor production of pyrites.

In Australia, the use of domestic sulfide ores appears to be established as a new postwar industry. Production of sulfuric acid amounted to 244,787 tons in 1943–1944, of which brimstone supplied 33 per cent; pyrites, 37 per cent; zinc concentrates, 27 per cent; and spent oxide, 3 per cent.

Argentina, using about 30,000 tons of sulfur a year, has established a mine and a plant in the Andes at a high altitude. This is expected to make the country self-sufficient. Production was reported at 8,000 tons in 1944.

In Chile, high-cost production of sulfur is secured from deposits on the walls or craters of volcanoes of the high Andes, unfavorably located in competition with deposits in the United States and Italy. Temporary demand was stimulated in South American markets when imports were cut off by submarine warfare in 1942–1943. Exports were sharply reduced in 1944.

In Mexico, a government-assisted project is being carried out to explore sulfur domes in the state of Veracruz, where it is proposed to secure production by means of the Frasch process as employed in Texas and Louisiana.

In Canada, sulfur is computed as the sulfur in pyrites shipped, plus the sulfur from nonferrous smelter gases. Production was 245,859 tons valued at $1,860,860 in 1945; 248,088 tons valued at $1,755,739 in 1944; in 1943, 257,515 tons. No exports of elemental sulfur are recorded; imports of crude sulfur, brimstone, etc., were 248,846 tons valued at $4,063,324 in 1945; 235,955 tons valued at $3,875,649 in 1944; in 1943, 218,527 tons valued at

WORLD PRODUCTION OF PYRITES (INCLUDING CUPREOUS PYRITES), IN METRIC TONS*
(After U.S. Bureau of Mines)

Country	1942	1943	1944
Algeria	15,716	†	†
Canada	165,813	126,505	†
Portugal‡	57,720	49,500	54,560
Spain‡	263,300	370,100	214,750
South Africa	17,959	16,195§	8,042§
United States	311,885	333,442	337,790
World total‡	3,900,000	3,900,000	3,000,000

* Sulfur content.

† Not reported.

‡ Estimated: U.S.S.R. was reported to be a leading producer of pyrites, with output of about 1 million tons in 1938.

§ January to June, inclusive.

$3,524,006. Sulfuric acid imported in 1944 amounted to 180 tons; in 1943, 220. By-product pyrites in Canada is recovered in the treatment of sulfide ores at the Noranda and Waite Amulet mines, in Quebec, and at the Britannia mine, in British Columbia. No lump pyrites has been produced in Canada for several years. Sulfuric acid is manufactured by Canadian Industries, Ltd., from waste gases of the nickel-copper smelter at Copper Cliff, Ontario.

Sulfur reserves in Britain had been drained by stimulated demands in the war years, it was reported in January, 1945. Empire sources would have increased responsibility to supply England with this and other essential minerals in the postwar period, requiring long-distance hauling from Canada, Australia, India, and other Empire countries.

WORLD PRODUCTION OF NATIVE SULFUR, IN LONG TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943	1944
Argentina	.....	.....	367	2,148	11,810	*
Bolivia (exports)	2,126	4,065	2,315	3,535	7,079	6,151
Chile	26,999	32,440	28,745	33,825	36,310	*
Italy (crude)†	224,091	204,997	192,178	145,604	91,773	9,292
Spain‡	3,770	3,560	6,230	5,000	5,511	5,700
Turkey	2,560	2,600§	2,600	2,600	2,600	*
United States	2,090,979	2,732,088	3,139,253	3,460,686	2,538,786	3,218,158
World total§	2,700,000	3,300,000	3,700,000	4,000,000	3,000,000	3,500,000

* Not reported.
† Production of Sicily for year ended July 31.
‡ Not including sulfur made from pyrites.
§ Estimated.

The Foreign Economic Administration reported in August, 1945, that pyrites made up the largest part of almost 350,000 tons of minerals and metals available from Norway, in spite of the extended military occupation by the Nazis. In the last 4 months of the year, it was estimated that 1 million tons of metals, minerals, and fertilizers would move out of Norway.

Imports of pyrites in 1939 exceeded $1,000,000 in value. Pyrites satisfies a need that can be supplied only with difficulty from domestic sources. The value of imports was $1,479,516 in 1941; in 1944, $339,643, largely from Canada and Spain. Imports of sulfur dropped from $487,758 in 1941 to $9,942 in 1944. Prewar imports from Spain amounted to more than 300,000 tons a year. Allied ships were required for more essential services, and the price offered in the United States was not attractive in the industry in Spain.

In Alaska, sulfur has not yet been brought into commercial production, as reported on May 7, 1945, by the U.S. Geological Survey, but favorable possibilities have been indicated for important advances in the postwar period.

Prices. The price of Spanish pyrites was quoted on Sept. 30, 1946, by *E & M J Metal and Mineral Markets* at 12 cents per long ton unit of sulfur, 48 per cent of sulfur minimum, c.i.f. Atlantic ports. The price of domestic pyrites, 1939–1945, averaged $3.06 to $3.09 per long ton, f.o.b. mines.

In Canada, there is stated to be no standard price for sulfur in pyrites. Contracts there are based on a price of upward of 5 cents per unit of 22.4 lb. of sulfur per long ton, f.o.b. cars at point of production. Sulfur prices vary from $20 to $32 per long ton at consumers' plants, according to location. The Canadian sulfur price in 1943 averaged about $27 per long ton.

The price of Texas sulfur has remained unchanged at $16 per long ton, f.o.b. mines, 1941–1946, as reported by *E & M J Metal and Mineral Markets.* The average price in 1935–1939, was $17.40. The price of sulfuric acid, 66°Bé., at works in tank cars, was $16.50 per short ton in 1939–1946.

The policy of maintaining a stabilized sulfur price has been a factor favorable to many consuming industries. The geographic monopoly in natural sulfur held by the United States must meet competition from high-cost sources of supply where government protection is given producers, regardless of cost.

The Sicilian Sulphur Consortium, in effect from 1923 to July 31, 1932, was an agreement with American exporters. A new agreement was negotiated in July, 1934, providing for allocation and sales in world markets, excluding North America and Italy. A nonprofit Sicilian sales organization, Ente Zolfi Siciliani, was formed in 1944 to market sulfur through a cooperative marketing concern which pays producers 83 per cent of the price on delivery. Ente Zolfi Siciliana divides among the producers the proceeds of its sales, after reimbursing the warehousing concern for advances. The Allied commission fixed the price of sulfur at $24 per long ton alongside ships at seaport.

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TALC

(Steatite, Indian Block, Pyrophyllite)

Properties. An acid metasilicate (hydrous magnesium silicate), talc is soft (hardness 1) and slippery to the touch. It dissociates at 1100°C. Talc is one of the most stable of minerals under aqueous conditions. It is monoclinic; its specific gravity is 2.7 to 2.8; its molecular weight, 380.8; its molecular volume, 138. Talc and soapstone are formed by the alteration of magnesian rocks, both sedimentary (such as dolomite) and igneous (such as peridotite).

The name talc is commonly applied to foliated varieties of rock, white to green in color. Soapstone is the term referring to coarsely crystalline, greenish or gray-bluish rock containing impurities with the talc. Pyrophyllite, sometimes classed as one of the kaolin minerals, is a hydrous aluminum silicate which resembles talc in certain physical properties and often requires chemical analysis for identification. When fired, pyrophyllite does not flux, as does talc; this property makes the mineral of value in refractories and a wide range of high-grade ceramic products. Ground pyrophyllite can be adapted to many of the industrial uses of talc.

Steatite is a general term for the fine-grained, massive mineral rich in talc, as compared with the small percentage present in soapstone. Both types are too varied for a simple definition. Steatite can be sawed, turned, drilled, and otherwise machined into any desired form. The critical and strategic material, steatitic lump lava talc (block or lava-grade) is low in calcium and iron. Specifications call for compact texture, good structural strength, and freedom from hair cracks, parting lines, and gritty impurities. Grade and suitability are usually determined by machinability and firing behavior and tests for electronic performance.

Uses. The strategic steatitic lump lava talc is used to produce fired shapes for radio insulators, as grid spacers in high-frequency radio transmitters for ships and tanks, and for the cores, bushings, and resistors in radio, radar, and other electronic equipment. Distinctive properties of steatite insulators are electrical resistivity and a high degree of hardness. Lava talc also has an important use for carbon-black burner tips. Natural steatite is largely replaced for many of these uses by die-pressed powdered talc, owing to the high cost of steatite and excessive machining and fire losses. War

demand greatly increased the uses of steatitic talc in specialized bodies for which most talcs are unfit.

Of a wide variety of uses for this material, ceramic talc, although imported in relatively small quantity, is a key product filling important industrial needs. Highly absorptive bodies employed for electrical-heater plates require a lime-free talc. Talc-base special low-reflectance camouflage paints are used by the Army and Navy. Information is not available regarding uses of Indian block talc.

The paint industry was the leading market for talc, pyrophyllite, and ground soapstone, accounting for 24 per cent of total sales in 1940 compared with 27 per cent in 1939. Talc is used in paint as an inert extender, in competition with other finely ground mineral substances. Fibrous talc used in nonreflecting paints for ship camouflage was in critically short supply in 1944. The ceramic industry increased requirements of powdered talc in 1940 to 18 per cent of total output. Ceramic talc is now a standard material for electrical and other porcelains, porcelain enamels, wall and floor tile, and refractories. Larger purchases were made by roofing, paper, and foundry-facings industries and for high-frequency insulators for radio communication. Talc is essential for certain plastics. It is employed in pharmaceuticals, soaps and cleaners, insecticides, and polishes.

Metalworkers' marking crayons for the steel industry were in unusually heavy demand in 1943–1944. Material sawed from compact, massive block talc was supplemented by extruded crayons made from a mixture of ground talc and a suitable filler. Soapstone is used for switchboard panels and laboratory benches and for brick and slab liners of fireboxes, stoves, and ovens.

The rubber and toilet-preparation industries made smaller purchases in 1940. Use as a filler for synthetic rubber increased in the war years. Talc is employed mainly for dusting rubber molds and finished rubber products. In cable insulation, talc increases tensile strength and toughness. It is also applied as an ingredient of both natural and artificial rubber for body reinforcing.

Canadian consumption of ground talc was reported for the following uses in 1943: paints, 34 per cent; roofing products, 23; rubber, 11; pulp and paper, 9; cosmetic and pharmaceutical, 7; insecticides, 5; soaps and cleansers, 3; miscellaneous, 8. Canadian kraft pulp and paper mills used 11,956 cu. ft. of soapstone furnace blocks in 1943, for lining the alkali-recovery furnaces and kilns.

Pyrophyllite, interchangeable with talc in some uses, is of value in a wide range of high-grade ceramic products, including refractories. It is

principally applied as a filler in rubber and composition battery boxes. A major war use was as a carrier in DDT personnel insecticidal dusts, for the control of typhus in foreign areas. One-fourth of the 1944 production of pyrophyllite was required as a DDT carrier and for agricultural insecticides. Pyrophyllite was in short supply early in 1944, leading to increased production. Pyrophyllite is also used in the manufacture of floor and wall tile, reducing moisture expansion.

Other materials can be substituted for many of the uses of talc. There is no known substitute, however, for the strategic uses of steatitic lump lava talc or for other grades of talc for insulators and in the manufacture of paper. Specialized uses for pyrophyllite were developed in the war years. A talc substitute for use in paint is ground, pale yellow serpentine, which resembles the tremolitic talc of the Gouverneur district, New York. High-grade powdered talc substituted for steatite must be low in iron and lime. Talc is superior to china clay as a paper filler.

Postwar talc requirements are expected to be reduced, particularly from domestic sources. For electronic equipment, it was reported that mica may be replaced by steatite, which would result in requirements larger than in prewar years, possibly exceeding $6,000,000 annually.

USES OF TALC, GROUND SOAPSTONE, AND PYROPHYLLITE SOLD BY DOMESTIC PRODUCERS, IN SHORT TONS
(After U.S. Bureau of Mines)

Use	1943	1944
Paint	129,238	110,767
Ceramics	47,900	31,932
Rubber	48,994	51,833
Roofing	47,500	45,535
Paper	34,449	27,161
Toilet preparations	17,682	15,965
Insecticides	24,462	21,454
Foundry facings	10,348	6,703
Crayons	1,446	1,358
Chemical war service, etc.	29,528	40,046
Others	21,321	46,109
Total	412,868	398,863*

* Includes pinite.

Domestic Sources of Supply and Production. The Metals Reserve Company made a first commitment for the purchase of steatite talc for stockpiling early in 1943. Ranking thirty-seventh as a stockpile item, talc costing $296,609 was purchased by the MRC. A market value of $164,550 was shown by the inventory on Oct. 31, 1944. Government stocks of talc

held by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, amounted to 6,541 short tons of steatite and an estimated 120 short tons of usable block talc, as reported by the Civilian Production Administration.

To provide adequate supplies of steatite talc for military, food, and medicinal uses, the War Production Board issued Conservation Order M-239 on Oct. 13, 1942, forbidding other applications. This order was modified early in 1943 to permit certain additional essential uses, in electrical- and heat-insulating products (not including refractories, electric-light bulbs, and experimental work). Improved supplies led the WPB to set up an inventory control in April, 1943. Frozen stocks of steatite were released.

Mine output of talc, ground soapstone, and pyrophyllite reached a record high value in 1943 and was slightly less the following year. The U.S. Bureau of Mines developed methods for treating domestic talcs and, in 1942, processed several million radio insulators.

Certain grades of talc were included by the WPB, in June, 1945, with a list of materials and products that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and it was anticipated that further changes in controls would be announced.

Steatite mixes for ceramic application are being treated on air tables to control bulk density of the material used in dry-press mixtures, where the mix is pulverized extremely fine. To be suitable, this material must be cut and machined, then fired at temperatures of 1600 to 1800°F., without appreciable shrinkage and no cracking.

Talc output (including pyrophyllite) increased to 415,000 tons in 1944, as a result of larger uses as a filler for synthetic rubber. Domestic output of talc, pyrophyllite, and ground soapstone is reported by the U.S. Bureau of Mines as follows: in 1944, 398,863 short tons valued at $5,017,462; in 1943, 412,868 tons valued at $5,121,414; in 1942, 387,963; in 1941, 416,369. These figures do not include cut-dimension soapstone. Fluctuating military requirements caused temporary shortages. Increased output was expected in 1945, particularly for California talc, produced in Death Valley, and the fibrous talc produced in New York state. Crayons manufactured from powdered talc have been approved for use in metal marking; these were expected to relieve the 1944 shortage of natural talc crayons.

Talc produced in New York was more than twice the production from any other state. California advanced from fourth to third place among producing states. Of total domestic output from 14 states, New York, North Carolina, Vermont, California, and Georgia were the major sources. North

Carolina was the principal state marketing pyrophyllite; California and Nevada were sources of small quantities.

TALC, PYROPHYLLITE, AND GROUND SOAPSTONE SOLD BY DOMESTIC PRODUCERS, IN SHORT TONS
(After U.S. Bureau of Mines)

Year	Crude*	Sawed and manufactured	Ground	Total
1940	17,724	1,894	261,757	281,375
1941	43,823	4,186	368,360	416,369
1942	33,837	1,505	352,621	387,963
1943	30,200	1,669	380,999	412,868
1944	45,654	938	352,271	398,863

* Includes pinite from Nevada.

Adequate reserves of domestic steatite talc for strategic requirements were reported after surveys were conducted by the U.S. Bureau of Mines in cooperation with the Geological Survey. It was unnecessary to depend on lower grades or on imported material. In 1943, 27 tons of critical material were produced from the Johnnie Gulch property, Madison County, Montana, in addition to a large supply of nonstrategic ceramic talc. A second property in California was preparing to start production. Samples from both properties were tested in 1944 by Westinghouse, General Electric, American Lava Corporation, and Kirchberger & Sons, Brooklyn, N. Y. Steatitic talc in sawed shapes was also produced in Maryland. Smaller requirements by the Army and Navy improved the supply in 1945, after a very tight market had developed.

All-time peak output of talc was established in 1940, after foreign sources were cut off. Domestic production totaled 255,258 metric tons in 1940; in 1939, 193,025, largely from Georgia, North Carolina, New York, and California. In the last state, one property supplies material suitable for insulators.

Pyrophyllite production has been secured from the Deep River region of Moore and Chatham counties, North Carolina, the major source of world supplies. War requirements led to expanded output, amounting to 5,683 tons of crude valued at $52,343 and 60,560 tons of ground valued at $504,739, in 1944. Eastern Magnesia Talc Company, Johnson, Vt., uses froth flotation to reclaim talc from waste material, recovering 95 per cent pure talc and nickel concentrates amounting to 150 lb. a day. Beneficiation of domestic talcs was under consideration to make the material suitable for radio insulators.

World Production, Imports and Exports. Talc was imported for paint and paper filler in 1940, primarily because of economic advantage. Imports amounted to 28,146 short tons in 1940, including talc, steatite or soapstone, and French chalk (ground, washed, or pulverized materials). Imported crude and unground material came chiefly from China and the Union of South Africa, and the cut and sawed varieties from Italy and Japan. Imports were distributed in 1940 as follows: Italy, 9,456 short tons; France, 5,732; Canada, 4,725; China, 3,550; Japan, 1,414.

The United States produced more than half the total prewar world output of talc. Manchuria ranked second with about 100,000 tons, followed by Italy and France, each with about 50,000 tons. Other countries, in order of importance, were Norway, British India, Canada, and Germany (including Austria).

United States exports in 1939 included 9,047 short tons of talc, steatite, and soapstone, crude and ground. Block talc imported from British India amounted to 287 tons in 1938; in 1939, 892; in 1940, 3,103. A postwar increase is expected in steatite and cosmetic talc imported from Europe and Asia.

One small test shipment of strategic lump steatite was received from Sardinia in 1944. New deposits were reported in India. Prewar imported talc came from Sardinia and from two localities in India. Indian block talc was designated by the WPB, on Mar. 1, 1944, as insufficient for war uses plus essential industrial demands. General Imports Order M-63 placed controls on steatite talc imports, as amended Nov. 23, 1942. British India and Sardinia were reported, in 1944, to be the chief sources of steatitic talc in sawn shapes. Imports in 1942 included 286 tons of crude block steatite and considerable ground steatite.

In Newfoundland, important deposits of pyrophyllite are worked by Industrial Minerals Company of Newfoundland, Ltd. Shipments in 1942–1943 amounted to about 500 tons of ground material; in 1944, 140 tons.

In Canada, ground talc and soapstone, talc crayons, and sawn soapstone furnace blocks and bricks have amounted to total production of about 600,000 tons since 1886. Output averaged about 30,000 tons a year in 1940–1944, half the material being exported. Production of talc ranged from a maximum of 18,171 tons in 1941 to 13,000 tons in 1945. Prime white powdered talc containing considerable carbonate is recovered in the Madoc area, Hastings County, Ontario. The Thetford mines area, Quebec, produces sawed soapstone blocks, talc crayons, and off-color ground talc, partly from soapstone waste. The material contains considerable iron. Special qualities of ground talc required by the ceramic, paint, and cosmetic industries are imported from

the United States, amounting to about 5,000 tons a year. Canadian exports of talc in the war years were subject to export-permit control, except for consignments to the United States and to the British Empire.

The British Ministry of Supply imported Canadian talc in the war years to replace former sources in France, Italy, and Norway. Talc was placed under strict control and allocation by England in 1943, and prices were established. Talc Importers Association was organized in April, 1944, to control sales and distribution to approved customers.

WORLD PRODUCTION OF TALC, PYROPHYLLITE, AND SOAPSTONE, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Argentina	303	1,168	1,975	4,950	*
South Australia	1,115	1,349	2,972	*	*
Canada	11,924	21,583	31,417	27,096	22,811
Manchuria (exports)	93,772	72,495	*	*	*
Egypt	833	2,212	5,229	1,875	2,054
Newfoundland	*	284	508	*	*
Spain	*	28,643	29,148	*	*
Transvaal	449	1,757	1,379	1,985	4,094
United States	230,402	255,258	377,722	351,952	374,546
Uruguay (exports)	1,111	1,699	1,867	2,192	*

* Not reported.

Prices. Quotations on ground domestic talc in carload lots, f.o.b. works, were given on May 14, 1945 by *Oil, Paint and Drug Reporter*, unchanged since 1942, as follows: Georgia, gray, 98 per cent through 200-mesh, $6; white, packed in paper bags, $8; New Jersey, ground mineral pulp, $8.50 to $10.50 (bags extra); New York, short fiber, double air-floated, 325-mesh, 93 to 94 per cent, $13 to $18; 98 to 99.5 per cent, $15.25 to $19.25; 99.85 to 99.95 per cent, $17 to $21 (Sept. 30, 1946, $12 to $15). Fibrous, coarse, off-color, $13. Vermont, extra white, 100 per cent through 200-mesh, bulk basis, $11 (Sept. 30, 1946, $9.50 to $10.50); medium white, 99.5 per cent through 200-mesh (paper bags extra), $9.50 to $14; Virginia, 200-mesh, $5.50 to $6.25; 325-mesh, $7 to $7.75; crude, $4.25 to $4.50; California, finely ground, $17.40 to $43; Pennsylvania, $11 to $13.50.

Special prices were in effect on Feb. 1, 1944, f.o.b. Ennis, Mont., as follows: strategic lump talc, $160 per ton for acceptable lumps weighing 5 lb. or more; lumps weighing 3 to 5 lb., $80 per ton. Ceramic grade was $19.50.

Quotations on Indian block talc are not available.

Crude talc produced in Esmeralda County, Nevada, was quoted at $17.50 per ton compared with normal prices of $8 to $15.50. Pyrophyllite pro-

duced in North Carolina was quoted in 1944 at $10 a ton, 200-mesh; 325-mesh, f.o.b. mill, $13.

The following ceiling prices on Nevada crude talc, effective on Nov. 16, 1944, were announced by the Office of Price Administration as Amendment 62 to Order A-1, Maximum Price Regulation 188. These prices are based on the price level effective in March, 1942, f.o.b. Zurich, Nev.: No. 1, Selected Cosmetic Talc, $15.25 per ton; No. 2, Mine-run White Talc, $13; No. 3, Mine-run Talc (Blue or Blue and White Mix), $10.25; No. 4, Talc Filler (Blue), $8.

Talc prices for other producing states were also governed by Maximum Price Regulation 188.

Pyrophyllite prices were quoted on May 14, 1945, by *Oil, Paint and Drug Reporter*, as follows: standard, 200-mesh, in bulk at mines, carlots, $10 to $11.50 per ton; 325-mesh, $13 to $13.90; No. 3, 200-mesh, $9.50; 325-mesh, $11.50.

Amendment 17 and Order 50 modifying Order A-2 under Maximum Price Regulation 188, effective on Aug. 24, 1944, provided a method for pyrophyllite producers to apply to the OPA for price adjustment.

The United States tariff on imported ground talc or soapstone is 17½ per cent ad valorem on material valued up to $14 a long ton; over $14, 35 per cent. Crude talc is subject to a duty of ¼ cent a pound; 1 cent a pound must be paid on cut soapstone or talc in the form of bricks, crayons, and blanks.

The prices of ground talc in Canada, in 1944, were as follows: Madoc white, finer mesh sizes, $12 to $18 a ton; coarser sizes, $8 to $10; minus 400-mesh, $44; gray talc for roofing, rubber, and paper use, according to fineness, $8 to $11.75 a ton; coarser, gray or off-color talc, including soapstone powder or sawing dust for roofing and foundry uses, $5 to $7 a ton, f.o.b. rail. *Oil, Paint and Drug Reporter* quoted Canadian talc, in bags, at $24 to $30 a ton, carlots. Talc imported into Canada from the United States is subject to a 20 per cent duty. Talc imports under the Intermediate and General Tariff are subject to 25 per cent duty; under British Preferential Tariff, 15 per cent.

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TANTALITE

Properties. A black, tough, ductile mineral, tantalite (Fe_2Ta_6O) has a hardness of 6 and a specific gravity of 5.4 to 7. It has a high fusion point between 2250 and 2300°C. Pure tantalite contains 86.1 per cent of tantalum pentoxide or 70 per cent of tantalum. Tantalum is one of the 16 nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. (Ta, atomic number, 73; atomic weight, 180.88; melting point, 2850°C.)

The melting point of tantalum is exceeded only by carbon, tungsten, and rhenium; tantalum carbide has the high melting point of 3875°C. Tantalum or an alloy of tantalum competes with the diamond and tungsten carbide as the hardest known substances. Tantalum and columbium are acid-forming elements that enter into the composition of a considerable number of pegmatite minerals. Tantalite and columbite are salts of iron. Tantalum and columbium ores are invariably mixtures and are designated by the relative content of Ta_2O_5 and Cb_2O_5. Tantalum or a mixture of tantalum and columbium is marketed as powder, ingot, wire, or sheet.

Uses. Tantalum was reported to be one of the most critical metals of the Second World War. It was widely used in the production of war materials, particularly in connection with nitriding steels. Metallic tantalum is almost indispensable for large power tubes used in radios, tantalum-nickel and tantalum-tungsten being used in the manufacture of radio and electronic tubes and fountain pens. Tantalum is reported to be unequaled by any other known material as a "getter" in vacuum tubes. It was reported that half the consumption in 1943 was for radio and other electronic tubes, which were being produced at a rate eleven times as great as in 1941. Tantalum, because of its high melting point, was being used in 1946 in covering the external parts of jet-propulsion engines, in gas turbines, and for certain furnace developments.

Substitution of the much cheaper ferrocolumbium has resulted in less demand for ferrotantalum. Direct and indirect applications are in the production of portable radio transmitters, radar, television, and munitions. Metallic tantalum is used as a substitute for the carbon filament in incandescent electric lights.

Cemented carbides of tantalum are used increasingly in wear-resistant parts of machines, cutting tools, and corrosion-resistant apparatus and equip-

ment in chemical plants and laboratories. In laboratory ware for applications where heating is not required, tantalum is more resistant to acids than platinum. Resistance to acids under high temperatures has resulted in increased application in the chemical industry. In industrial chemical equipment, the following properties and limitations of tantalum have been cited:

1. It is resistant to attack by most acids, but unsatisfactory for alkaline solutions.
2. Its hardness and strength are close to those of mild steel.
3. It must not be worked at temperatures above 400°C. but is subject to cold-working and machining.
4. It can be welded to itself or other metals.
5. It is easily hardened to hold an edge or wearing surface.
6. Major changes in physical properties take place at red heat, when common gases are absorbed. In various electrical units, tantalum is employed as cathode, plate, and grid-control elements, although these and other applications are limited by the higher cost of tantalum as compared with tungsten or molybdenum.

Copper or steel pipes can be lined or covered with a thin layer of tantalum. It has proved the most economical construction material to transfer heat efficiently in various processing operations where corrosion conditions are severe, particularly in chemical equipment.

Tantalum hydrochloric acid condensers have been used in replacing fused silica condensers. Potassium-tantalum fluoride is a catalyst for butadiene synthetic rubber. It is also a platinum substitute in catalysts. Tantalum carbide is used in making aerial camera lenses. The glass for such lenses (nonsilica glass which combines tantalum, tungsten, lanthanum, and boron oxides) combines high refractivity and low dispersion. The lenses can function without loss of definition or coverage at high altitudes. Uses in plastic surgery are reported to be increasing rapidly because of nontoxic properties, tantalum implants, plates, bolts, joints, and wire being adapted for repairing bone and skull fractures and for nerve and tendon injuries in battle. Postwar uses in the field of electronics are expected to increase.

Domestic Sources of Supply and Production. Tantalum was designated on Mar. 1, 1944, by the War Production Board as insufficient for war uses plus essential industrial demands, but all restrictions were removed in February, 1945, because of increased supplies and reduced demand for tantalum in finished products. The WPB placed import controls on tantalum and ores by Amendment 4, Order M-63, on Apr. 9, 1942. Full allocation control was placed on all forms of tantalum by Order M-156, on May 22, 1942.

The Metals Reserve Company, in 1942, made a first commitment for the purchase of tantalum for stockpiling. Ranking twenty-sixth as a stockpile item, tantalum was purchased at a cost of $1,975,371. Market value of inventories, on Oct. 31, 1944, was $1,378,407. On Oct. 31, 1945, government stocks held by the Reconstruction Finance Corporation through the Office of Metals Reserve amounted to 420,861 lb. of tantalite and 680,000 lb. of tantalum-columbium slags. The government stockpile held 427,756 lb. of tantalite at the end of 1942; on Mar. 8, 1943, 321,867 lb.; 376,441 lb. at the end of 1943.

Output in 1944 was lower than 1943. In 1941, manufacturing facilities in the United States were enlarged by the pioneer producer of tantalum metal, Fansteel Metallurgical Corporation, and its subsidiary, Vascaloy-Ramet Corporation, the source of small domestic production being South Dakota and New Mexico. Tantalum Defense Corporation, subsidiary of Fansteel, erected facilities in North Chicago having annual capacity of 35 tons of tantalum oxide and metal, financed by the Defense Plant Corporation at a reported cost of $5,342,000. The Harding mine, Taos County, New Mexico, produced 464 lb. of tantalite in 1943, plus 6,137 lb. of microlite (71 per cent of Ta_2O_5) and 1,075 lb. of microlite (65 per cent of Ta_2O_5). Production was reported in 1945 from the Montgomery mine, near Dixon, Rio Arriba County, New Mexico. In Wyoming, production of tantalum ore totaled 542 lb. in 1938–1941.

DOMESTIC PRODUCTION OF TANTALITE AND IMPORTS, IN POUNDS
(After U.S. Bureau of Mines)

Year	Mine shipments	Imports
1939	340	56,561
1940	...	490,460
1941	250	403,464
1942	200	575,799
1943	...	643,080

World Production, Imports and Exports. Imports of strategic tantalite by air from South America, Africa, and Australia were larger in 1944 than in 1943, as reported in April, 1945 by the Foreign Economic Administration. Two-thirds of tantalite imports in 1943 were shipped by aircraft. Imports of tantalum ores in 1940 totaled 490,460 lb. compared with 56,516 lb. in 1939; in 1942, 575,799; in 1943, 643,080. Exports amounted to 266 lb. of tantalum metal and alloys and 179 lb. of tantalum metal compounds in 1942.

Brazil holds first place in production of tantalite and, in the war period, advanced output from 20 to 200 tons a year, far exceeding normal require-

ments; in 1941, 94 tons of tantalite-columtite. Of world supply in 1943, 52 per cent came from Brazil (180.8 metric tons), and output in 1944 was almost 400 tons. The mineral occurs in pegmatite dikes at Alto Taboa, state of Rio Grande do Norte, and in the state of Paraiba, the most important producing regions. Volume of output, stimulated by war prices, has also been increased in the central and southern areas of the state of Ceara, northeastern Brazil.

SOURCES OF TANTALUM ORES IMPORTED BY THE UNITED STATES, IN POUNDS
(After U.S. Bureau of Mines)

Country	1941	1942	1943
Argentina	.....	.. .. .	2,420
Australia	29,574	1,470	10,708
Belgian Congo	146,904	309,843	157,073
Brazil	161,996	237,210	416,874
India	.....	.....	1,805
Mozambique	.....	.....	3,567
Nigeria	.....	.....	5,757
Southern Rhodesia	64,773	18,971	40,481
Uganda	..... .	. .....	3,063
South Africa	217	.....	1,332

The Belgian Congo and Western Australia were important sources of supply in 1940; production was reported at 160 metric tons in 1943. The WPB reported production in 1942 at about 11 metric tons a month. New discoveries were reported in 1944 in Nigeria, East Africa, and Australia. Scandinavia was reported to be the principal source of tantalite in the 1920's.

In Nigeria, prospecting and developing tantalite-columtite deposits was placed under government license control in 1943. Argentina produced 5 metric tons of tantalum-columbium ore in 1942. The discovery of tin-tantalum deposits in Canada, in the Northwest Territories, was reported in 1943. In prewar years, only one producing property in the world was operated for tantalite-columtite ore, located in West Australia.

In 1944, the FEA followed the policy of withdrawing from public purchase of foreign tantalite when possible, returning the trade to former private channels if no impairment to the war effort resulted. Postwar potential supplies are described as being vastly greater than formerly, when demand was limited.

Prices. Tantalum metal was quoted at $65 to $73 a pound in 1942–1946, by *E & M J Metal and Mineral Markets*, at a base price of $143 to $160.60 per kilogram for C.P.; sheet, $143 (discounts on volume business). The earlier base price of tantalum was $200 a pound.

Tantalum ore was quoted at $2 to $3 per pound of Ta_2O_5, 60 per cent concentrate, the price depending on the source. In 1940, high-grade tantalite was in good demand at prices up to $2.50 a pound of contained tantalum. The MRC purchased tantalite at $1.75 per pound of contained Ta_2O_5 for 40 per cent material, $2.25 for 50 per cent, $2.75 for 60 per cent, $3.25 for 70 per cent.

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TIN

(Ore, Slag, Reclaimed)

Properties. One of the seven metals known to the ancients, tin is believed to have been produced at the dawn of the Bronze Age, about 4500 B.C. Tin is a malleable, silvery-white element. It is one of the 16 nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. It is the least common and most expensive of the nonprecious metals. (Sn, atomic number, 50; atomic weight, 118.7; melting point, 231.85°C.)

In electrical conductivity of metals, tin has a value of 15 for volume conductivity and 18.3 for mass conductivity compared with 100 for copper. A variety of tin-copper alloys having broad industrial application contain 8 to 16 per cent of tin. Bronzes high in tin can be cold-worked and wrought; low-tin bronzes are suitable for the production of castings of all kinds. Gunmetal alloys (10 per cent of tin and 2 per cent of zinc) are used for castings of high strength and resistance to corrosion. Bronze containing the maximum of 33 per cent of tin is used chiefly in the production of reflectors for certain types of telescopes. Tin is indispensable to the food industry as the only nontoxic industrial metal.

A cast bronze, composed of a solid solution of tin dissolved in copper, is reported to be the ideal bearing structure as well as an excellent material for gearing. Tin is the chief constituent in white metal alloys known as babbitt. These have a structure essential to bearing metal, being more plastic than the tin bronzes and having a low melting point. Tin-bearing alloys containing small amounts of copper and antimony meet a wide range of conditions under severe service in engines and machines. Solders include a series of lead-tin alloys, in which the tin ensures satisfactory adhesion to iron, copper, and various other metals. Plumber's metal, a solder containing 65 per cent of lead and the balance tin, is employed in jointing up lead pipes and lead cable sheathing in electric transmission or telephone lines. Printers' alloys consist of 2 to 20 per cent of tin, 10 to 30 per cent of antimony, and the balance lead. The presence of tin is essential to make the alloy flow freely in the rapid casting of type faces, to refine the structure, and to toughen it. Thermal conductivity and extreme ductility give tin important applications in antifriction metals.

Tin is widely distributed, but deposits of commercial importance are

found in only a few countries. Stream tin consists of rounded pebbles and grains found in alluvial deposits weathered from granites and quartz grains. This is the source of about 75 per cent of world output. Tin is supplied in the form of cassiterite from sources more remote than for any other strategic metal.

Cassiterite (SnO_2), the common source mineral, is brown to nearly black in color. Its hardness is 6 to 7; its specific gravity, 6.8 to 7.1. In the pure state, the mineral contains 78.6 per cent of tin. Cassiterite is chemically stable and not subject to alteration, as is the case with the complex tin sulfide minerals. Of minor importance are stannite (tin-iron-copper sulfide), franckeite, and cylindrite. In Bolivia, the metal occurs in complex sulfide lode deposits averaging 1 to 2 per cent of tin.

Tin-smelting centers are located in the British Empire at Liverpool, Singapore, and Penang, in the Netherlands at Arnhem, in Belgium at Hoboken, and in Germany and China. In the United States, tin ores were smelted in 1916–1924; the new plant in Texas started production in 1941.

Uses. For military purposes, tin was widely adapted from peacetime industrial uses. It is one of the 23 metals and minerals most vital in war. About 94 per cent of the consumption of new metal was for metallurgical purposes, equally divided between the pure metal and alloys, particularly for bearings and bronzes. The outstanding use was in the production of tinplate for cans and various containers, for which substitutes were developed in order to ease the heavy demand. Smaller amounts were used for lead-tin coating on steel (terne plate), for pipe and tubing, and for coating other metals. Pure tin is also employed in making foil for wrapping foods and other perishable materials and in making collapsible tubes. Tin is essential in all transportation, communications, water supply, and the gas and electric industries. It provided one of the worst problems of scarcity in the whole range of major war materials.

Tin in alloys is employed chiefly for solders, babbitt, and other antifriction metals; for bronze; and for the production of die castings. Uses for tin in babbitt metal are particularly important in naval construction and mobile army equipment. Almost all the so-called "white metals" contain tin as an alloy.

Chemical uses accounted for about 6 per cent in 1938, the oxide being employed as an opacifying agent in white glasses and enamels. Tin chloride is used as a weighting agent in fabrics.

Collapsible tubes, formerly 100 per cent tin, were replaced by an alloy using only 10 per cent of tin, thus conserving annually about 1,000 tons of the metal during the war years. Tin cans were replaced where possible by

cardboard having metal ends and plastic-coated interior and by glass jars and cellophane packages. A successful substitute for tin cans was "bonderized" steel (an iron phosphate coating finished with lacquer).

By far the largest and most important use of tin is in making cans. A major move in the conservation of available metal stocks was the rapid development of electrolytic tin-plating which increased from 82,000 tons in 1942 to an estimated 1,500,000 tons from 28 plants in 1944. Electroplating, having the advantage of saving one-half to one-third the weight of tin, as in the hot-dip plating method for sheet steel covered with a film of copper, was applied to an increasing extent. The wise program of substitutions led to a minimum of difficulty with tin through the war period, although tin resulted in the most critical of the metal shortages.

DOMESTIC USES OF TIN, PRIMARY AND SECONDARY TIN CONTENT IN LONG TONS
(After U.S. Bureau of Mines)

Product	1941	1942	1943
Tin plate	44,854	28,522	21,726
Terne plate	2,046	882	434
Solder	28,225	13,924	12,676
Babbitt	10,599	6,099	7,753
Bronze and brass	23,170	27,655	29,755
Collapsible tubes	4,445	1,099	591
Tinning	4,132	3,015	3,014
Foil	4,292	576	372
Chemicals (except oxide)	970	246	411
Tin oxide	1,490	131	
Pipe and tubing	1,325	161	200
Type metal	1,815	1,153	1,081
Galvanizing	967	82	4
Bar tin	2,133	722	961
Miscellaneous alloys	617	814	926
White metal	2,561	239	145
Miscellaneous	1,054	367	281
Total	134,695	85,687	80,330

Under war conditions, the application of substitutes has been successful for various uses. Solder alloys (50 to 70 per cent of tin with lead) were replaced by a 95 per cent lead alloy containing 2½ per cent of tin and 2½ per cent of silver. Cadmium has been applied in some solders as a satisfactory substitute. Other solders contain 20 to 30 per cent of tin. The standard tin-bronze gear material was replaced by a copper alloy containing 7.5 per cent of antimony and 2 per cent of nickel. Motor parts were redesigned when automobile manufacture was resumed in the fall of 1945, in order to reduce the use of tin from 4 to 2 lb. per car. Tin was reduced in various bronzes by

careful segregation and use of scrap and by lowering the tin content in certain products not adversely affected. Railroads conserved tin by reusing bearings and reducing the section thickness. War demands demonstrated that tin could be reduced in many applications and in others entirely replaced by substitute materials.

Tin control was continued after the war in order to avoid chaotic conditions in supply, price, and demand. Favorable postwar prospects are indicated as a result of failure in both Axis and Allied countries to develop satisfactory substitutes for the major industrial applications.

Domestic Sources of Supply and Production. The Metals Reserve Company made a commitment, in 1940, for the purchase of tin, one of the first seven minerals and metals designated for stockpiling. Tin ranked second in relative value of deliveries to the MRC, tin purchases costing $211,656,861. The tin inventory, as of Oct. 31, 1944, had market value of $91,989,736. On Oct. 31, 1945, government stocks of pig tin held by the MRC through the Office of Metals Reserve amounted to 21,163 long tons; on Sept. 30, 1945, 53,551; on June 1, 1946, 55,579. Total stocks of tin in the United States amounted to 95,000 tons at the end of 1945, equivalent to more than a year's supply. Domestic sources of tin were adequate for less than a year's supply. The MRC extended the time limit to Dec. 31, 1944, for purchases of tin for the stockpile at Fairbanks, Alaska.

As reported July 17, 1944, by *The Wall Street Journal*, government stockpiles held 1,011 net tons of reclaimed tin, 44,558 tons of refined tin, 117,675 tons of tin ore, and 893 tons of tin oxide. The War Production Board designated tin as insufficient for war uses plus essential industrial demands; the metal remained in this category through the war years and into 1946.

The Longhorn tin smelter of Tin Processing Corporation, Texas City, Tex., having an original rated capacity of 50,000 tons, equal to 18,000 tons of metal, was reported to be producing at the annual rate of more than 44,000 tons in December, 1945. The total 1945 output was 40,591 tons; in 1944, 30,619; in 1943, 20,727; in 1941, 63. The concentrate treated was imported from Bolivia, the Belgian Congo, French Cameroons, and other sources. Concentrates on hand amounted to about 36,500 tons in September, 1945. Negligible domestic sources of tin are known. In postwar years, the United States faces the prospect of requiring imports in increased volume.

Although industrial production in the United States increased 20 per cent in 1943 and was more than three times the 1919 rate, apparent tin consumption was lower, at 32,000 tons, than in any year since 1910. Domestic tin consumption exceeded new supplies by an estimated 12,000 to 13,000 tons in 1944. Consumption of primary and secondary tin and metal contained in alloys was about 90,000 tons in 1944; in 1943, 81,840 tons. Consumption

in the first half of 1945 was about 47,000 tons. Stocks of tin in the United States on July 1, 1944, were reported at 123,000 tons, lower by 20,000 tons than stocks reported on Jan. 1, 1942. Consumption in that period amounted to 212,600 tons.

CONSUMPTION OF TIN-BASE SCRAP IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Source of scrap	Stocks on Jan. 1, 1945	Consumption January–June, 1945	Stocks on June 30, 1945
Tin babbitt	465	2,505	270
Tin scrap	78	375	67
Pewter	12	44	11
Tin residues	329	117	184
Tin scruff and dross	449	1,453	629
Total	1,333	4,494	1,161

Recoverable tin in white-metal scrap consumed in bronze amounted to 778 short tons in the first half of 1945; primary tin consumed in lead and tin products, 8,303 tons. Greater recovery of tin from scrap metals in secondary smelters resulted in receipts of 6,209 short tons in the first 9 months of 1945 compared with 5,931 tons in the same period of 1944.

Tin restrictions were increased by the WPB in December, 1944, in an effort to strengthen controls. Tin was reported tight throughout 1945, and stockpiles were considered adequate only for 9 months. No increase in production of tin from concentrate was possible. Detinning plants were unable to acquire supplies of prepared cans, as reported by the WPB in January, 1945. Detinning was complicated by the high cost of collecting a bulky product having a tin content of only 1.5 per cent. Continuation of tin-can collections to meet part of the tin deficit was urged by J. D. Small, Chairman of the Civilian Production Administration, on Nov. 16, 1945. The tin division of the WPB, which was transferred to the CPA on Nov. 3, urged communities to continue the collection of tin cans owing to the urgent need for tin scrap. Refuse collectors were not required to segregate household tin cans from other material after Oct. 16, 1945. Tin-can salvage, up to Sept. 19, 1945, had added about 6,000 tons to the tin stockpile, the WPB reported.

Specific controls of tin scrap and prepared used tin cans in the hands of scrap dealers were established by the WPB on Oct. 23, 1945. This was the first instance of reimposition of controls following VJ-Day, under Direction 5 to Priorities Regulation 32 (inventory control.) Inventory control of tin scrap was necessary in order to assure the flow of this scarce material after Tin and Lead Scrap Orders M-72 had been revoked on Aug. 20. This did not

apply to smelters, manufacturers, detinners, or other users whose inventories were controlled by Orders M-38, M-43 and other sections of Regulation 32. A monthly report to the U.S. Bureau of Mines, as agent for the WPB, was required of all scrap dealers having an inventory of 20 short tons or more of scrap. Order M-43, as amended on Sept. 12, 1945, prohibited the use of tin in tablets, memorials, hardware, electrical and other fixtures, braces, handles, and levers. Moderate reductions in tin quotas for the fourth quarter of 1945 were ordered for tin plate, solders, babbitts, bronzes, and cast alloys. Order M-43 continued in effect at the end of 1945 as a distribution control; the CPA was to maintain this restriction until tin supplies improved.

The WPB amended Tin Order M-43 in an effort to smash black-market operations at the retail level and to stop the sale of jewelry and similar products containing tin. On Mar. 6, 1945, the WPB reported further restrictions on uses, including tin in the manufacture of automobile solder for the repair of automobile bodies and fenders. Government reserves were at a "dangerously low level." Current imports were reported to be less than 75 per cent of requirements. All tin-mill products would continue in short supply for nonessential uses, it was announced in June, 1945, by Erwin Vogelsang, director of the tin-lead-zinc division, WPB. The nation's tin stockpile was in danger of complete exhaustion if consumption continued at the high rate.

Reserve stocks of pig and recoverable tin were reported by the WPB at 23,754 long tons on May 1 and 48,600 tons on Aug. 31, 1945; on Jan. 1, 1944, 46,441 tons in addition to a small government stockpile. The tin stockpile was 70,000 tons on Apr. 24, 1945, the lowest level since 1942 (105,000), as reported by the WPB. Inventory controls of all production and distribution levels were expected to last longer than most of the L and M orders of the WPB, as a move to avoid inflationary procedure.

Tin, antimony, lead, and uranium were the only strategic metals continued under government control for use and distribution after August, 1945. Tin, pig tin, babbitt, and solder were specified on Aug. 22, 1945, as remaining subject to restrictions on special sales and on export special sales. Export controls were retained by the WPB for fabricated tin, tin plate, and products. Import controls for tin were reinvoked by the CPA on Nov. 30, 1945, by placing tin under Order M-63.

The tin controls were not expected to ease until supplies again became available from formerly Japanese-held areas. Tin was included by the WPB in June, 1945, on a list of materials and products that were expected to continue in short supply for an indefinite period. WPB controls were being removed from other materials, and it was anticipated that further changes in controls would be announced. Export pig tin was exempted from price

control by the OMR, effective Dec. 31, 1945. Import control was reimposed on tin in December, 1945.

Continuation of distributive controls of scarce materials, including tin, was outlined in a joint statement issued on Dec. 10, 1945, by President Truman and the Prime Ministers of Great Britain and Canada. A tin committee was to be established by the CPA taking over functions relating to tin of the Combined Raw Materials Board, which was discontinued at the end of 1945.

The CPA reinstated wartime restrictions on tin plate, as a result of the nation-wide steel strike, on Feb. 7, 1946, by issuing Direction 9 to Conservation Order M-21 and M-81. This required tin-plate manufacturers to give first preference to orders for the production of cans and closures (covering devices for glass containers) essential to the packaging of food products, drugs, medicals, biologicals, or products to be delivered to certain government agencies and for use either in the United States or Canada. Direction 9 included terne plate or tin-mill black plate for production of cans, as listed in Schedule A, Order M-81.

The CPA on Aug. 9, 1946, stated that allocations of tin plate for export in the final quarter of the year had been fixed at 136,000 tons, to be used entirely for the preservation of food in or for famine-stricken countries. This allotment was larger than that for the third quarter by 24,000 tons.

The CPA announced on Mar. 7, 1946, that only about 42,000 tons of tin would be imported in 1946, close to the 1945 level. At the end of 1946, government stocks were expected to be reduced to about 15,000 tons. The CPA reported on Mar. 29, 1946, that 6,550 tons of pig tin had been made available for the United States by the Combined Tin Committee for the first half of 1946. In 1945, the total allotment for the United States was 9,413 tons; in 1944, 13,388 tons. Approximately 90,000 tons of tin were expected to be available to the United States in 1946, including secondary recovery from scrap and tin from the government stockpile. The Combined Tin Committee announced on June 3, 1946, an additional allocation to the United States of 2,350 tons; France, 2,840; Canada, 1,070; other countries, 2,800.

The Combined Tin Committee reported the following allotments for the first 6 months of 1946: France, 4,260 tons; United Nations Rehabilitation and Relief Administration, 3,000; Canada, 1,500; India, 960; Switzerland, 400; Middle East, 350; Netherlands, 360; Norway, 220; Sweden, 200; Denmark, 200. These tonnages were made obtainable from sources of supply in Britain and Belgium; the Texas smelter made available 200 tons for South America.

Third-quarter tin supplies were estimated on July 8 by the CPA at 11,900 tons against requirements of 17,840 tons. The calculated deficit of 6,440 tons was compared with the 4,700-ton deficit in the second quarter.

The Office of Price Administration on June 19, 1946, adjusted regulations for distribution of tin-mill products in order to bring them into line with the emergency plan for distributing steel. Tin-can manufacturers were granted a 9 per cent price increase by the OPA, effective June 4, 1946. Exports of tin plate were to be limited to 112,000 short tons in the third quarter of 1946 compared to requests by foreign nations for 302,000 tons, as reported on June 13, 1946, by the Bureau of International Supply of the CPA.

American industry should be encouraged to extend its operations in foreign fields to include tin and other essential minerals, such as chrome and tungsten, it was reported on Sept. 11, 1946, by J. A. Krug, Secretary of the Interior.

Charles B. Henderson, president of the MRC, in March, 1945, reported that stockpiled tin was equal to more than a year's requirements at the current rate of consumption. Imports of tin and 20 other metals and minerals would be required in increasing quantity in postwar years, it was reported by Harold L. Ickes, Secretary of the Interior, in December, 1945. Domestic tin requirements were expected to be met in 1946 by Bolivia's output in addition to 25,000 to 30,000 tons to be imported from the Far East. Government restrictions on the use of tin could be lifted only if 75,000 tons of metal were made available.

Studies of shortages in tin and other strategic materials had disclosed that an important underlying cause of inadequate supplies was the existence of cartel monopolies and artificial trade barriers, it was stated on Sept. 21, 1945, by Senator Mead of the Senate committee inquiring into shortages of tin which threatened to impede full-scale reconversion. Governments had withdrawn in the war years from commercial activities, but the way was left open on VJ-Day to restore trade barriers. The war had drastically altered the international trade position of the United States, it was testified by William L. Batt, vice-chairman of the WPB. Tin was an example, and "our position against cartels is well known," he said. "We have found no tendency on the part of representatives of other governments to question our position." There will be no more tin cartels with the United States frozen out. This country would receive its full, fair share of world supplies. Diplomatic negotiations with Britain, Holland, and Bolivia were stated to be then in progress, and it was urged that Presidential power be continued to control the distribution of tin and other scarce strategic materials.

World Production, Imports and Exports. Data are incomplete for world

WORLD SMELTER PRODUCTION OF TIN, IN LONG TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Argentina	1,080	881	768	709	552
Australia	3,300	*	5,000	3,000	2,500
Belgian Congo	2,124	7,832	15,000	14,400	12,000
British Malaya	81,536	126,945	125,000	10,000	15,000
Canada	.....	.....	29	560	347
China	10,850	13,000	10,000	7,000	5,000
Japan	2,000	1,800	*	4,000	*
Netherlands Indies	13,941	22,035	23,000	5,000	5,000
Portugal	30	781	1,481	2,381	3,058
South Africa	.....	*	143	535	526
United Kingdom	37,400	*	40,000	30,000	31,026
United States	.....	1,391	1,839	16,168	21,489

* Data not available. Other producing countries were Belgium, Germany, Italy, Netherlands, Norway, and Siam (Thailand).

tin production in the war years. Tin is one of the eight metals for which Europe is almost entirely dependent on imports. The capture by Japan of Far East smelters and tin mines placed the United Nations under a critical shortage of the metal, leading to greatly curtailed consumption.

World production in 1937 was 209,100 tons, as follows: Malaya, 95,200 long tons; Great Britain, 34,500 (exports in 1943, 12,251; in 1942, 10,164); Netherlands, 26,800; Netherlands East Indies, 13,900; China, 10,500; other countries, 28,200. Consumption in 1937 included United States, 86,700 tons; Great Britain, 26,000; U.S.S.R., 25,100; Germany, 11,600. World output in 1938 amounted 149,700 tons, of which Japan produced 1,900 tons and Germany 3,000 tons; smelter output was 39 per cent from British Malaya and about 22 per cent from Britain.

World tin production dropped rapidly from the 1941 peak of 245,500 long tons to 125,000 tons in 1942; in 1943, 121,500; in 1944, 109,000. Consumption in England in the war years was as follows: in 1939, 27,279 tons; in 1940, 29,225; in 1941, 30,000; in 1942, 23,478; in 1943, 17,631; in 1944, 18,435. In the United States, consumption was 70,315 long tons in 1939; in 1940, 75,000; in 1941, 100,870; in 1942, 60,000; in 1943, 56,000; in 1944, 65,000. These figures were reported in June, 1946, by the Combined Tin Committee.

U.S.S.R. is dependent on imports for no metals and minerals except tin and silver, it was reported in Washington in January, 1946, based on information submitted by the Office of Strategic Services. World superiority in minerals was made possible in Russia as the result of a policy of importing minerals rather than using domestic known deposits, leaving vast reserves of essential materials untouched.

The British Empire, Belgium, and the Netherlands have national self-sufficiency in tin. China produces tin adequate for domestic requirements. Other world powers are dependent on foreign sources to meet domestic needs. Britain imports tin ore, and the United States the refined metal, the two countries using 55 per cent of world output in 1938. The British Empire operates about 67 per cent of world smelter capacity, of which 48 per cent is in Malaya, 18 per cent in England, and 1 per cent in Australia. Germany ranked third in imports of refined tin in 1938, the metal drawn chiefly from the Netherlands and Netherlands Indies, amounting to 8 per cent of the world total, compared with 36 per cent imported by the United States.

For many years, Great Britain maintained a practical monopoly of the tin-smelting industry. Large accumulated stocks in the First World War, overexpansion of productive capacity in Malaya, the discovery of new sources in the Belgian Congo, and the construction of smelters outside the British Empire resulted in limiting British control of the tin industry. A joint understanding with other governments controlling production led to strengthening the market after 1934.

World trade in tin ore in 1938 amounted to 139,000 metric tons; in tin ingots, bars, and slabs, 138,000. The following table (after *World Minerals and World Peace*) shows the destination of 97 per cent of the ore and 89 per cent of the tin metal recorded in 1938 (in thousands of metric tons):

Tin Ore	
1. *Bolivia*	
To: United Kingdom	37.3
Netherlands	10.9
Germany	8.1
Belgium	2.3
Total	58.7
2. *Netherlands East Indies*	
To: Netherlands	22.9
Total	22.9
3. *Siam*	
To: British Malaya	19.2
Total	19.2
4. *Nigeria*	
To: United Kingdom	11.1
Total	11.1
5. *Belgian Congo*	
To: Belgium	9.8
Total	9.8

Refined Tin	
1. *British Malaya*	
To: United States	37.3
Japan	8.7
United Kingdom	5.5
France	3.3
Italy	3.0
British India	2.9
Germany	1.7
Canada	1.5
Switzerland	0.5
Total	65.5
2. *Netherlands*	
To: U.S.S.R.	6.8
Germany	4.0
France	2.8
United States	2.3
United Kingdom	2.1
Sweden	1.8
Poland	0.8
Hungary	0.5
Total	22.3

TIN ORE

6. *Indo-China*
To: British Malaya 2.6
Total 3.3

7. *British Malaya*
To: United Kingdom 2.9
Total 2.9

8. *Burma*
To: British Malaya 2.9
Total 2.9

9. *Argentina*
To: United Kingdom 0.7
Total 1.5

10. *Portugal*
To: United Kingdom 0.8
Netherlands 0.5
Total 1.3

11. *South Africa*
To: United Kingdom 1.1
Total 1.3

12. *Japan*
To: British Malaya 0.8
Total 0.8

13. *China*
To: British Malaya 0.6
Total 0.6

REFINED TIN

3. *China*
To: United States 3.7
Indo-China 2.0
United Kingdom 1.8
France 0.8
Germany 0.8
Netherlands 0.6
Total 11.8

4. *United Kingdom*
To: United States 3.3
U.S.S.R. 3.0
France 0.8
Canada 0.8
Sweden 0.7
Germany 0.7
Total 12.5

5. *Netherlands East Indies*
To: Germany 4.0
United States 3.1
Japan 0.7
Czechoslovakia 0.7
Austria 0.5
Total 10.5

6. *Belgium*
To: U.S.S.R. 2.8
France 1.2
United Kingdom 1.0
Italy 0.6
Total 8.5

7. *Belgian Congo*
To: Belgium 2.3
Total 2.3

8. *Argentina*
To: United States 0.6
Total 0.6

9. *Australia* .....
To: United Kingdom 0.7
Total 0.8

Tin ores are generally too low grade for direct treatment and require concentration. Concentrates are purchased on a basis of 60 per cent tin, the price being reduced for each unit or fraction below 60 per cent. Penalties are charged if the concentrates contain sulfur in excess of 1 per cent and iron in excess of 5 per cent. No penalty is charged for other impurities.

Tin reserves of the world are known, and there seems to be no prospect of

new discoveries of large ore bodies or rich placer areas. Capacity production would exhaust sources of low-cost production within reasonable time, and price reduction would not only dissipate these reserves but also eliminate recovery from high-cost properties. Tin ores mined in Bolivia, the principal wartime source of supply for the United States, are low grade and difficult to treat, as compared with easily recovered, purer ores from Malaya and the Dutch East Indies.

The problem of economically producing high-grade concentrate from Bolivian ore has not yet been solved, in spite of extensive research in recent years to develop effective reagents and procedures for the flotation of cassiterite. Higher recovery was expected to result from the installation of the sink-float process and other methods both at the Centonario property of Patino and the Hochschild Cerro de Potosi property. More than 28 per cent of Bolivian tin is produced by mines controlled by Dr. Mauricio Hochschild, who found it necessary because of the tin cartel to secure a market in the United States. After the end of the Second World War, tin output in Bolivia declined about 10 per cent as a result of high costs which forced certain mines to close. Yearly production can be increased to an estimated 40,000 tons of tin at 66 cents a pound and 45,000 tons at 70 cents. The Combined Raw Materials Board, which was responsible for controlling the flow of tin and other raw materials to the United States in the war years, allocated 7,500 tons of tin in Patino concentrates in 1945. In 1946, the entire Patino production was shipped to Britain, which delivered 5,000 tons of metal to the United States.

In Bolivia under war conditions, tin represented about 80 per cent of the value of exports; in 1939, 71 per cent. Cassiterite tin ore is distributed along a belt crossing the country from Peru, on the north, to Argentina, on the south. Ore occurs in quartz and fissure veins and in sheer zones within andesite, quartzite, and slate. Diminishing ore reserves were estimated in 1944 at 450,000 tons. Record output of 47,000 tons was secured from 10 districts in 1929 compared with recent annual production averaging about 40,000 tons. The reduced volume was caused by several factors: (1) decrease in ore grade, (2) higher taxes and wages, and (3) large metal losses resulting from inefficient mining methods and unskilled labor. Apathy and inefficiency of Bolivian labor result from dietary habits of the native workers and from the unfavorable climate.

Of Bolivia's output, about half is recovered by Patino Mines and Enterprises Consolidated, the world's largest operator. Patino, in 1943, treated 746,177 tons of ore averaging 2.47 per cent of tin and improved recovery by changes in mill practice at the Centanario property. Patino ore is shipped

to Britain under a 10-year contract, but 20,000 tons were diverted to the United States in 1944.

Bolivia produced 35,814 tons in the first 11 months of 1944 compared with 37,128 in the same period of 1943. Tin imported by the United States from Bolivia in 1944 amounted to 28,730 tons in ore and concentrates; in 1943, 38,000. Bolivia exported 35,475 tons in the first 10 months of 1945 compared with 32,494 tons in the same period of 1944. Bolivian producers hoped to secure a 3-year extension of the United States tin contract when it expired June 30, 1945.

High costs in Bolivia, compared with placer-mining operations in Malaysia and Nigeria, were due partly to the lack of coal and hydroelectric power, which have prevented construction of local tin smelters. Postwar production is considered to be dependent on cartel agreements, as in the prewar period, owing to the prospect of lower prices when tin is again available from Far East sources.

An extension of the agreement to June 30, 1946, for Bolivian tin was signed between the governments of Bolivia and the United States on Sept. 8, 1945. This involved total Bolivia production except some high-grade concentrate produced by Patino, at least half of which was to go to the United States and the balance to Britain. Disagreement over the price was reported to have caused the long delay in negotiating the new contract, which affected all Bolivian tin producers except the Patino interests.

In Argentina, tin for domestic use is produced from alluvial and vein deposits at Pirquetas, province of Jujuy; concentrates are shipped to the tin smelter at Buenos Aires.

In Australia, tin production amounted to 3,500 tons in 1939; in 1942, 3,000; in 1943, 2,800. Government assistance was given these operations in an effort to stimulate output. The Tasmania controller of mineral production acquired a dredge that had previously operated in Victoria and started dredging in the Ringarooma Valley. The Mount Bischoff Tin Mining Company also produced tin under government control.

Canada recovers the small tin content of zinc tailings produced from complex ores of the Sullivan mine at Kimberley, British Columbia. The concentration plant started production in 1941; and a year later, the tin refinery was placed in operation. Output in 1945 was estimated at 425 tons; in 1944, 258 tons valued at $299,643; in 1943, 388; in 1942, 619. Tin occurrences of possible value have been reported in the Northwest Territories and Quebec. Canadian imports in 1945 consisted of tin in the form of blocks, pigs, tin foil, and collapsible tubes valued at $5,122,147; in 1944, $2,178,118; in 1943, $1,766,344. Peacetime requirements are about 3,000 tons a year.

In Canada, the Metals Controller held jurisdiction in the war years over production and use of tin and nonferrous metal ingots containing tin, tin plate, and nonferrous metal scrap. These controls were transferred to the Administrator of Nonferrous Metals on Oct. 30, 1945. Orders of the Metals Controller were then replaced by a new administrative order that continued restrictions on the manufacture and use of tin-bearing ingots, not including nonferrous ingots having no tin content. Maximum prices of tin and all nonferrous metals were also retained. Any person was permitted to secure up to 15 lb. of tin or tin contained in alloys in any 3-month period upon submitting the required certificate for the purpose. No certificate was required for the purchase of solder containing not more than 30 per cent of tin.

The Belgian Congo advanced from the prewar production rate of 9,000 tons to about 21,000 tons in 1944; in 1943, 18,000; in 1942, 16,800. Exports to the United States from the Belgian Congo in 1944 were reported at 10,000 tons of metallic tin and 7,549 tons in concentrates; in 1943, 11,550 tons plus 4,094 tons in ore and concentrates. Output in 1932 was less than 500 tons. Detrital and lode deposits occur in Katanga in a mineralized zone about 250 miles in length.

In Nigeria, detrital tin deposits occur in Bauchi province over an area of 10,000 square miles. Sluicing and panning methods are required, the cassiterite being distributed too unevenly to justify the use of dredges. An ore estimate in 1943 indicated a life of about seven years at the expanded wartime rate for tin ore in Nigeria. The entire output is shipped to England.

In Mexico, small production is secured from cassiterite deposits in several localities, chiefly from small placers. Output in 1941 was 237 metric tons, of which half was exported; in 1942, 364 tons; in 1943, 426. Mexico, China, and the French Cameroons shipped tin to the United States during the war years.

Italy had a prewar production of about 200 tons per year from small mines in Tuscany and Sardinia. In Germany, tin reached the stage of critical shortage in 1943. Metallurgical treatment was designed to salvage the metal, and various substitutes were adopted. In 1943–1944, at least eleven blockade-running cargo ships from Japan were sunk, and little of the 20,000 tons of tin shipped was believed to have reached Germany.

Tin was one of the 17 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for the purchase of the entire exportable surplus from Mexico and Bolivia as part of the foreign procurement program initiated late in 1940. Tin valued at $267,000,000 was included in the total of $1,952,000,000 spent abroad for metals and minerals by the Department of Commerce in foreign financial and supply transactions, from July 1, 1940, through June 30, 1945.

In Alaska, postwar expansion in the output of tin from alluvial and lode deposits can be secured through systematic development, particularly in the Lost River, Cape Mountain, and Seward Peninsula areas. Tin is one of the eight minerals representing 5 per cent of total mine output in Alaska to the end of 1944. Production in the 34 years ended in 1943 was 1,443 tons, an average of 42 tons a year. Maximum output was recorded in 1937 at 166 tons; in 1943, recovery was down to 2.5 tons. Tin ore remaining in stockpiles of the MRC at the Fairbanks, Anchorage, Seldovia, and Nome depots was sold to private industry in June, 1945. The disposal included stocks of four other minerals, as reported by the Territorial Commissioner of Mines.

In China, some placer deposits are reported to have reserves adequate for 15 to 30 years' production. As alluvial deposits are depleted, increasing dependence will be placed on lode tin. One Chinese tin mine has been worked more than 500 years. The most important source at present is the Kochiu mines in Yunnan province, South China. About 3,000 tons of tin were shipped out of China in 1943, almost half the amount being carried by U.S.S.R. transport planes, as reported by Leo Crowley, Foreign Economic Administrator.

In advance of the Japanese conquest, Dutch and British mine officials had "scorched" most of the dredges and the workings at deep lode mines. The Allied blockade had almost halted tin production in Malaya within the 6 months preceding VJ-Day. It was found in December, 1945, that all of the 126 dredges in Malaysia were in varying stages of disrepair. Only 41 were expected to be in operation by August, 1946; 39 required complete replacement, which would take 2 years; the other 46 dredges were expected to be repaired and back in service by June, 1947, when tin production was expected to amount to about half the prewar rate of about 150,000 tons per year compared with total world output of 232,000 tons. A survey by the Dutch government reported in July, 1946, that prewar capacity production could not be secured until 1948 for tin mines in the Netherlands East Indies. Early in 1948 delivery was expected of eight 14-cu. ft. dredges, six of which were under construction in Holland and two in the United States.

The Belgian Ministry of Foreign Affairs announced in September, 1945, that improved possibilities of securing supplies of tin made it possible to satisfy all industrial requirements of tin and alloys. Industrialists were required to prove their needs for tin to their trade council.

Britain's position so far as tin and other raw materials were concerned did not give rise to anxiety, the Board of Trade reported on Dec. 28, 1945. Economy in the import of materials was required, particularly where these were of little aid to the export position. Tin consumption in the war years was

reduced 50 per cent; 5,000 tons of tin were to be made available to the United States, it was reported in October, 1945. The Directorate of Nonferrous Metals reported that consumption of tin in Britain in the first 9 months of 1945 amounted to 11,975 tons compared with 18,435 tons consumed in all 1944. The Cornish Tin Mining Advisory Committee attempted to secure government support for the industry in postwar years. Production in 1943 for the Cornwall tin mines was reported at 2,214 tons. Ore from Malaya was to be shipped to Britain for refining, British buyers dealing with Chinese miners who carried on operations under the Japanese, as reported in November, 1945, after the buyers had flown in from Borneo to operate the newly formed British tin-ore buying agency.

Tin mines in Yugoslavia were included with other Allied properties and concessions that had been taken over by the German economic dictator during the war and had been nationalized by Yugoslavia in October, 1944. Settlement late in 1945 was expected of ownership of the Bor mines, which was considered to be a test case affecting other central European mines.

The leading producing countries (Bolivia, Malaya, Netherlands East Indies, and Nigeria) were subjected to production controls by the International Tin Committee in March, 1931. Export quotas were later imposed on Siam, Indo-China, and the Belgian Congo. Expanded output of the Belgian Congo, Nigeria, and Bolivia was far short of war requirements in 1944. In prewar years, 80 per cent of United States requirements came from Malaya and the Netherlands East Indies. British Malaya, the world's largest tin producer, dropped to 12,000 tons shipped to Europe in the first half of 1946 compared with almost 127,000 long tons in 1940.

In London, United States representatives conferred with British and Dutch interests late in 1945 as to the possibility of obtaining tin as soon as the mines were released from Japanese control. Mines on Billiton Island, principal source of tin in the Netherlands East Indies, were almost intact, and production was to be resumed as early as possible, it was reported from The Hague in October, 1945. Japanese occupation had wrecked power installations, but restoration of the properties was to be made with equipment ordered from Switzerland and other countries.

On Bangka Island was found 5,000 long tons of tin valued at $6,800,000; this had been melted down and hidden by the Japanese because they lacked ships for transportation. The Klappakamit, the only deep mine in the area, had been flooded and its machinery removed by the Japanese.

The Penang smelter was reported to be in operation in December, 1945, but difficulties had resulted from the lack of certain gears and tools for the dredges. These essential parts had been stripped by the Japanese, and mines

had been flooded. The Japanese had operated the Penang smelter, but doubts were expressed as to whether or not they also required production from the smelter at Singapore, which was reported to need considerable repair. The Japanese moved electric equipment, diesel engines, and stores from Billiton Island to Sumatra, Malaya, Burma, and North Borneo. No hidden stock of tin could be located. Priorities were being set up for replacement and repair of damaged equipment, it was announced by the Colonial Ministry at London. First priorities were to go to those mines where production could be secured by August, 1946. The tin industry was believed to require 5 years for rehabilitation.

The second tin shipment since VJ-Day from Batavia, Netherlands East Indies, arrived in New York on Jan. 29, 1946, making a total of 23 tons. There was reported to be a prospect of receiving 25,000 tons or more from the Far East before the end of 1946. Several ships were loading tin in January at Indies ports and would soon sail for the United States, the tin to be divided with Britain. Production in Malaya amounted to 802 long tons of fine tin in the first quarter of 1946 compared with 19,500 tons in the same period of 1941. At the end of 1946, production was expected to be about 50 per cent of normal. The Texas City plant was receiving some tin concentrates from the Far East, it was reported on June 19, 1946.

Federated Malay States, the prewar source of about one-third of world tin supplies, secure production both from placers and from lode deposits. Pahang Consolidated is one of the greatest tin mines. In Burma, British India, tin ores are closely associated with granite mountain ranges that continue south through Siam into the Malay Peninsula. The principal producer in Burma is the Tavoy district. Siam tin is mined largely from alluvial flats adjacent to the granite mountains. Production in 1946 was estimated at 20,000 tons against 160,000 in 1941 from Burma, Siam, China, Indo-China, Malaya, and Netherlands East Indies.

Prices. The average quotation for Grade A Straits tin at New York was 52 cents per pound, Aug. 16, 1941, through Aug. 31, 1946; in 1940, 49.827 cents; in 1937, 54.24 cents; in 1925–1934, the average price of 45.27 cents was compiled by *American Metal Market.* For scrap tin, average New York prices were as follows (after *American Metal Market*): 1942–1945, 45.50 cents; 1941, 46.35 cents; 1940, 42.90 cents; 1939, 40.07 cents.

The Tin Sales Corporation, RFC agent, was given a new contract on Aug. 10, 1946, covering sales made under the August tin allotment at the OPA price of 52 cents a pound. The price prevailing in the open market was to apply if the ceiling price should be eliminated by the Price Decontrol Board.

Chinese, or 99 per cent, tin remained unchanged at 51.125 cents per pound, on May 1, 1945. Bolivian concentrates for sale to the United States, f.o.b. South American ports, were 60 cents a pound for contained tin. The price of Katanga tin was reported in August, 1945, at about 55 cents a pound, f.o.b. West African ports.

A price increase to 63 cents a pound was adopted in January, 1945, for tin from Bolivia, where no purchase contract had been in effect since June, 1943. A downsliding scale of prices for Bolivian tin was negotiated by the FEA in August, 1945, the new prices providing 62 cents a pound for the last quarter of 1945, 60.5 cents for the first quarter of 1946, 58.5 cents for the second quarter. A price increase to 65.5 cents a pound was reported on Sept. 13, 1946, as the result of further negotiations, including a bonus if production should amount to 18,000 tons.

The United States has no duty on tin in the form of ore, bars, pigs, black oxide, dross, and scrap.

The International Tin Committee, a cartel formed in March, 1931, assigned production and shipment quotas and operated two pools for withholding tin from the market. Production began to improve in 1934, with better prices and reduced stocks. Successful controls were continued by the cartel, which planned in September, 1942, for a 5-year extension. Countries holding cartel membership controlled 90 per cent of world production, not including French Indo-China and Siam (Thailand). This, the fourth International Tin-Control Scheme, was to have two nonvoting representatives of the United States, one a government appointment and the other representing consumers. Consuming countries outside the United States were to appoint one representative.

The Buffer Pool was created in Britain in June, 1938, for the purpose of stabilizing prices between £200 and £230. War disruption of imports caused increases in the tin price from £207 in October, 1938, to £230 in November, 1939. Government control was applied to smelters, shipping space, and prices. The control quoted tin at £300 ($1,200) per ton for refined tin on Sept. 1, 1945, which had been in effect through 1944. For 1939–1943, the following prices were in effect: 1942–1943, £275; 1941, £262 12*s.* 1*d.*; 1940, £256 8*s.* 6*d.*; 1939, £226 5*s.* 2*d.*

Conforming with requirements of the price-control law, the OPA on Oct. 26, 1946, raised ceilings for export sales of pig tin by jobbers and distributors buying tin from the OMR. Existing controls over tin, including importation only by the government, were to be continued through March, 1947, it was announced on Nov. 21, 1946, by Erwin Vogelsang, OPA.

The international Tin Research and Development Council, Amsterdam,

reported world tin production for the first half of 1946 at 43,250 tons; consumption, 56,000; world stocks at the end of June, 64,400.

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TITANIUM

(Rutile and Ilmenite)

Properties. A metallic element found in small amounts in many minerals and ores, titanium comprises about 0.65 per cent of the earth's crust. It ranks fourth in abundance among the metallic elements that are suitable for engineering uses, exceeded only by aluminum, iron, and magnesium. Titanium is one of 16 industrial nonferrous metals used essentially as alloying constituents. Cold-worked titanium has a tensile strength of 126,000 lb. per sq. in. Its density is 4.5 g. per cc. Titanium is prepared as an approximately pure metal by heating the chloride with sodium and heating the oxide with calcium. (Ti, atomic number, 22; atomic weight, 47.9; melting point, 1795°C.)

Both ferrotitanium and ferrocarbontitanium act as strong deoxidizers. For large-scale operations producing a metallic titanium sufficiently pure to be ductile, the Kroll process is considered to be the most practical. Cold-rolled titanium is harder than either hard-rolled stainless steel or hard-rolled magnesium alloy, because of the yield-strength-density ratio. This metal is characterized by higher elongation and excellent corrosion resistance. Low density and rather high tensile strength give the metal many potential advantages over others. Pure titanium metal is supplied as powder, ingot, and titanium hydride powder (TiH_2). The metal has qualities of electric resistivity, extreme hardness, and light weight. Information is not available on the application of this metal for structural purposes. A method for obtaining titanium on a commercial scale was perfected in the early 1930's. This requires reduction from the dioxide with carbon in the electric furnace.

Always occurring in nature in the combined form, chiefly as the oxide, titanium is often concentrated in beds of titanic iron ore. The commonest occurrences of the element are as rutile, ilmenite, and titanite. Ilmenite (titanic iron) is a black, lustrous mineral which occurs combined with iron and other oxides. Ilmenite has a specific gravity of 4.5 to 5 and a hardness of 5 to 6. Titanite ($CaTiSiO_5$) is yellow, green, red, gray, brown, or black in color. Its specific gravity is 3.54; its hardness, 5 to 5.5. Brookite (titanic oxide) is yellowish, reddish, brown, or iron-black in color. Its specific gravity is 4; its hardness, 5.5 to 6. Brookite alters to rutile, and rutile to ilmenite. Titaniferous magnetite contains 3 to 15 per cent of titanium.

Rutile (TiO_2) contains 54 to 60 per cent of titanium and varies in color from white, green, yellow, and reddish brown to nearly black. Its hardness is 6 to 6.5; its specific gravity, 4.2. It is insoluble in acids but is readily attacked by fused alkali-metal salts and is then soluble. An iron content up to 3 per cent is often present.

Made from one of the blackest minerals, titanium oxide is the whitest pigment, produces whiteness with less material and does not yellow with age.

Uses. Strategic uses of titanium include smoke screens, bombs, pigments, ferroalloys, hard-cutting and other nonferrous alloys, and the metal. Metallic titanium is essential in the manufacture of radio tubes. It combines surface hardness with light weight and high strength, properties that recommend it for aircraft construction in competition with both aluminum and magnesium. Semicommercial production of titanium steel for use in testing applications for aircraft construction has been recommended. Titanium is an alloying element and effective deoxidizer and cleansing agent in metallurgy.

Additions of titanium make the chrome-nickel steels more resistant to corrosion. Chromemolybdenum steels are more weldable after titanium has been added. Military construction has used welding to replace a large part of the riveting, a Liberty Ship requiring 250,000 lin. ft. of welding to replace 1 million rivets. Steel requirements for cargo ships were reduced 10 per cent by the use of welding. Titanium-coated welding rods produced in the United States amounted to 481,000 short tons in 1943 compared with 152,000 tons in 1941. Aluminum and other nonferrous alloys gain better structure through the addition of titanium, which refines the grain. Steel rails and structural steel treated with silicon are rated inferior to the product fabricated from titanium steel (0.1 to 0.25 per cent of titanium). In the ferroalloy industry, various new applications have been proposed for carbontitanium alloys. In steel manufacture, ferrotitanium (15 to 40 per cent of titanium) is used to introduce titanium as an alloying element. Titanium carbide is a constituent of hard-cutting alloys for machine tools. It is better than aluminum as a scavenger for oxygen and nitrogen in the steel industry. Commercial exploitation of titanium in the prewar period was largely restricted to the chemical industries.

A fine-grained titanium alloy, "TiNamel," was developed in the war years as a specialty steel. This is lacking in porosity and is well suited to enameling, making possible the direct application of vitreous enamels to steel without the use of a ground-coat enamel. Exceptional cold-working characteristics are claimed for this steel.

As an alloy-forming element, titanium has an important place in the stainless-steel industry. It prevents the intergranular precipitation of the

chromium-rich carbides, which takes place in welding operations and in certain heat treatments, and improves the stainless qualities. The nickel-iron-cobalt alloy "konel," containing 2 to 3 per cent of titanium and having high tensile strength at elevated temperatures, is used in vacuum-tube filaments. Copper-titanium alloys have also been developed.

The U.S. Navy was reported to have purchased 2,500 tons of titanium pigments in 1941, when camouflage lacquer for aircraft and other military requirements took 40 per cent of the supply of titanium dioxide. Titanium dioxide was finding increased application in paper manufacture as a pulp extender that reduced the paper weight as much as 50 per cent with no loss in opacity. Titanium tetrachloride and oxychoride were used by the Navy to produce smoke screens. Titanium oxychoride in powdered form is blown into the ship's firebox, resulting in instant large clouds of jet-black smoke belching from the ship's funnels.

A dense paint having good "hiding" quality results from the use of TiO_2. Principal consumption of titanium dioxide pigments is for the whitening of the following products: paints, inks, paper, rubber, plastics, leather, ceramics, linoleum, printing ink, textiles, cosmetics, and soap. Titanium white paints are noted for very high covering and wearing power and a high degree of opacity and reflectance. Titanium is widely substituted for white lead and has replaced zinc oxide, leaded zinc, and lithopone in certain applications. Titanium oxide gives porcelain enamels the highest acid resistance obtainable. Ilmenite is the source of all titanium pigments, for which other pigments were substituted for civilian uses under war conditions. Rutile-type pigments, made from ilmenite but possessing the crystal structure of rutile, have exceptionally high covering power and durability. Titanium pigments include the dioxide, mixtures of the dioxide and calcium sulfate, and titanium dioxide simultaneously precipitated with barium sulfate.

Demand for titanium pigments greatly exceeded capacity in 1943. Ilmenite is used only to a limited extent for making ferroalloys (3 per cent of 1943 consumption). The value of titanium pigments is about double that of any other white pigment. Ilmenite was used chiefly for white pigments and rutile for welding-rod coatings in 1942; both minerals also were consumed in ferrotitanium.

Rutile and brookite (titanium oxide minerals) have been utilized in the manufacture of titanium tetrachloride for making smoke clouds to cover war movements and in ceramics manufacture. Rutile is employed in enamels and as a welding flux for use in electric welding. It is the ore of titanium metal. Of consumption in 1943, 70 per cent of the rutile was for welding-rod coatings and over 29 per cent for alloys.

As a substitute for stainless steel and in other applications, titanium

metal was expected to have broad uses after the war. This and other metals have been studied by Dr. W. J. Kroll at the Electrodevelopment Laboratory of the U.S. Bureau of Mines, Albany, Oreg. In making titanium-bearing stainless steel, 1 part of ilmenite has been used to replace 1 to 4 parts of fluorspar as a flux. Postwar expansion of the paint industry is expected to result in greatly increased demand for titanium pigments.

Domestic Sources of Supply and Production. Flotation research has demonstrated a promising method of beneficiation for recovery of titanium minerals from certain types of beach sands in coastal waters of the United States. A substantial part of war requirements for titanium was met from domestic production of rutile and brookite, particularly from the major deposits in Virginia. Following unsuccessful attempts to treat brookite ore by gravity concentration and electromagnetic separation, a useful flotation method was developed. Florida in 1945 produced both rutile and ilmenite.

Deposits of titaniferous iron ore (ilmenite) are available as a source of raw materials for the manufacture of metallic titanium. These are found in many states, including New York, Wyoming, Montana, California, and Oregon. Titanium ore is available in almost unlimited quantity. Production of rutile increased from 34 short tons in 1932 to 2,316 in 1937. Domestic output of ilmenite amounted to less than 5,000 tons a year in the period 1929–1938. The domestic output of titanium pigments more than doubled between 1938 and 1941. Domestic output in 1943 was almost three times the rate in the previous year when the rate tripled the volume in 1941, and rutile was up 51 per cent, compared with a 15 per cent reduction in 1942.

Production and consumption of titanium reached new highs in 1945. The following domestic output of ilmenite concentrate (shipments) was reported by the U.S. Bureau of Mines: in 1944, 280,791 short tons valued at $7,371,279; in 1943, 211,715 short tons valued at $3,738,970; in 1942, 93,397 tons valued at $1,805,823; in 1941, 21,526 tons valued at $196,522; in 1940, 20,702 tons; in 1939, 16,872 tons; in 1945, 308,518 tons.

Rutile production amounted to 6,770 short tons valued at $1,088,112 in 1944; 3,941 short tons valued at $610,879 in 1943; in 1942, 2,649; in 1941, 3,431 tons valued at $493,782. Domestic mines, in 1941, shipped ilmenite concentrate containing 42 to 54 per cent of TiO_2 and rutile concentrate containing 92 to 95 per cent of TiO_2. Rutile is produced in the United States in much larger proportion of domestic consumption than ilmenite. Substantial quantities of processed rutile of both domestic and foreign origin are normally exported. Production (shipments) was 6,837 tons in 1945.

Since about 1902, most of the domestic rutile production has been secured by American Rutile Corporation. Production was reported to be

about 400 tons of crude ore daily in 1940, from which about 20 tons of rutile were recovered averaging about 93 per cent of TiO_2; a small amount of ilmenite was secured, grading about 50 per cent of TiO_2. Small-scale output has been secured from Arkansas and Florida. Beach concentrate containing rutile in commercial amount was reported in 1943, by the U.S. Bureau of Mines, near Pensacola, Fla. No production had been reported from these beach deposits up to June, 1945.

Southern Mineral Products Corporation, a subsidiary of Vanadium Corporation of America, was the major domestic ilmenite producer prior to 1943. Its plant at Piney River, Va., was built in 1930 and started production of titanium pigment in 1931. The ore, containing no rutile, is produced from nelsonite dikes of Nelson and Amherst Counties, averaging about 18 per cent of TiO_2 and containing about 7 per cent of P_2O_5 in the form of fluorapatite, which is processed to monocalcium phosphate for use in baking powder. Southern Mineral Products has been owned and operated since December, 1943, by the Calco Division of American Cyanamid Company.

Titanium Pigment Company, a subsidiary of National Lead Company, started production in 1942 at the MacIntyre mine, Tahawus, N. Y. The U.S. Bureau of Mines reported development of this deposit to be a war necessity, because of lack of shipping facilities for ilmenite imports from India. Mine output was rated at 5,500 long tons of ore averaging 16 per cent of TiO_2. The daily recovery of ilmenite concentrate averaged 800 long tons containing about 48 per cent of TiO_2. Output has expanded from 170,000 tons of ilmenite concentrate in 1943 to about 270,000 tons in 1945. This is rated as the world's largest titanium mine. Other major titaniferous iron-ore deposits occur in the Iron Mountain region near Laramie, Wyo. This country was reported, in November, 1944, to be self-sufficient in supplies of ilmenite, with domestic production of titanium pigments exceeding that of zinc and lead pigments combined.

Order M-63 of the Office of Production Management placed rutile under import control on Dec. 26, 1941. Amendment 2, Order M-161 of the War Production Board, removed inventory restrictions on ilmenite on June 26, 1942. Rutile dealers were requested, but no formal order issued, by the WPB in the spring of 1942 to divert rutile from ceramics manufacturers to welding-rod and alloy producers. Order M-353 strengthened government control of the distribution of titanium pigments on Dec. 24, 1943, including pigments containing over 12 per cent of TiO_2.

Producers of titanium pigments, under Order M-44 of the OPM, were directed on Dec. 1, 1941, to set aside a pool of 20 per cent of their production for allocation. The pool was later increased to 25 per cent, and the order

was revoked on Dec. 9, 1942. Effective Feb. 1, 1942, producers were required to set aside 25 per cent for allocation by the WPB. Effective on Mar. 1, 1942, prices were stabilized at levels of Oct. 1, 1941.

Titanium dioxide was one of the selected groups of materials listed on Apr. 4, 1946, by the Civilian Production Administration as Schedule 1 in Priorities Regulation 28. Manufacturers of building materials and other "critically scarce products" were granted a top priority for obtaining surplus materials held by the War Assets Administration. The CPA ruling provided for issuing "urgency certificates" to companies producing titanium dioxide, giving them preference over all classes of buyers, if producers demonstrated their need for titanium dioxide to sustain or increase production.

The Metals Reserve Company made a first commitment for the purchase of rutile for stockpiling in 1941. Ranking thirty-third among minerals in the government stockpile, rutile was purchased by the MRC at a cost of $804,085. The inventory of Oct. 31, 1944, showed stocks reduced to $280,800. Rutile amounting to 3,569 short tons was held in government stocks by the Reconstruction Finance Corporation through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration.

The domestic paint industry reported in December, 1945, that no serious reconversion problems were being faced. Inventories were low for titanium, lithopone, and other key materials. Thurlow J. Campbell, president of National Paint, Varnish and Lacquer Association, stated that lack of titanium pigments was a contributing factor in holding back the industry from utilizing its full productive capacity. The industry anticipated peak business through 1950, he stated.

By a proclamation and an executive order, President Truman on Sept. 28, 1945, took jurisdiction over the natural resources of the continental shelf contiguous to the coasts of the United States. Although no minerals have ever been discovered in the subsurface lands of the continental shelf, evidence indicating their presence has been found in the inland sands around Jacksonville, Fla., and along the Gulf coast of Texas and Louisiana. Rutile and ilmenite, together with three other minerals and petroleum, have been indicated in off-shore areas. "The rapid development of technical knowledge and equipment occasioned by the war now makes possible the determination of the resources of the submerged lands outside of the three-mile limit," the proclamation stated. This project is for the purpose of carrying on orderly development of rutile, ilmenite, and other resources. Prior to the Second World War, advanced technology had made possible the exploitation of a limited amount of minerals from submerged lands within the 3-mile limit.

World Production, Imports and Exports. World production of titanium ore is estimated at about 300,000 tons of ilmenite and 9,000 tons of rutile. The principal prewar ilmenite source was India, followed by Norway, Malaya, Portugal, Australia, United States, and Canada. Rutile production is secured mainly in Brazil followed by New South Wales and the United States. Imperial Chemical Industries was charged in 1943 with operating a titanium-pigment cartel.

In India, the world's principal source of ilmenite is the beach sand on the coast of Malabar, state of Travancore. These sands also yield rutile, zircon, and monazite. Australia increased production of titanium minerals from major deposits in 1941, when ships delivering war supplies in the South Pacific loaded rutile ore for the return voyage to the United States. Australia supplied 78 per cent of the rutile imported by the United States in the first 9 months of 1941. The balance of domestic requirements was purchased in Brazil, which shipped 10,508 tons of ilmenite in 1945 and 234 tons of rutile.

Titanium production in Australia is in the form of mixed zircon, rutile, and ilmenite mined and concentrated on the beaches of New South Wales, where ore reserves are estimated at 1 million tons of mixed concentrates. Queensland and South Australia have minor production.

In Brazil, rutile is mined in the state of Minas Gerais. Considerable tonnage of ilmenite is secured from beach deposits of Espiritu, and regular deliveries are made to producers, as reported by James S. Baker, of the Foreign Economic Administration, in May, 1945. Rutile was one of 10 minerals included in agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus from Brazil as part of the foreign procurement program initiated late in 1940.

Postwar plans were announced in September, 1945, for opening new titanium mines in Ceylon, Malaya, and Australia, as soon as the transportation of machinery could be arranged. The shipment from Norway of 25,000 tons of ilmenite was being negotiated in September, the first from that country since 1939. Prewar supplies from Europe and India amounted to about 400,000 tons a year.

Canada, in 1939, shipped 3,351 pounds of ilmenite; titanium ore (ilmenite) produced in 1942 was 10,031 pounds; in 1943, 69,437; in 1944, 33,973 pounds valued at $165,195; in 1945, 13,306 pounds. Canadian production is secured from two mines located at St. Urbain, 65 miles northeast of Quebec City, owned by American Titanic Iron Company and Loughborough Mining Company. The ilmenite (titanic iron) has a titanium content of 18 to 25 per cent. Output in 1943 marked an all-time record. Canada imports titanium dioxide pigments and rutile concentrates from the United States.

United States imports of rutile expanded from 787 short tons in 1939 to 10,465 tons in 1942. Higher shipping priority rating made it possible in 1942 to expand rutile imports from Brazil, using cargo space on military supply ships returning from Australia. Imported titanium concentrates in 1939 exceeded 250,000 tons. In the first 9 months of 1941, 139,144 long tons of ilmenite were imported, 95 per cent from British India, 3 per cent from Canada, and 1 per cent from Brazil and Portugal. Imports from India were greatly reduced in 1942. Exports in 1943 were valued at $2,499,284, including the following titanium products: concentrates, metal and alloys (including ferroalloys), dioxide and pigments, tetrachloride and other compounds. Exports in 1942–1943 were far greater than ever before recorded. Imports in 1945 amounted to 210,066 tons of ilmenite and 10,602 tons of rutile.

In Mexico, the rutile deposits at Pluma Hidalgo and Apango, state of Oaxaca, are regarded as possibly larger than deposits under production in Australia, Brazil, or Norway. The ratio of rutile to ilmenite in the extensive pegmatite dikes of the Oaxaca area is reported to be higher than in other countries. Other Mexican deposits are located southeast of Mexico City and in Lower California.

In Ceylon, zircon and monazite are associated with ilmenite containing 60 to 62 per cent of TiO_2 in large deposits of beach sands. Available ilmenite is estimated at more than 6 million tons. British capital proposes establishing a factory in Ceylon for processing titanium.

India has a pilot plant for making titanium dioxide. Ilmenite concentrate from beach sand contains up to 60 per cent of titanium dioxide. It can be delivered to the United States at a low price.

In 1944, the FEA followed the policy of withdrawing from public purchase of foreign rutile when possible, returning the trade to private channels if no impairment to the war effort resulted.

WORLD PRODUCTION OF ILMENITE, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
New South Wales	742	2,270	4,808	3,700	*
Brazil (exports)	10	12	4,471	*	*
Canada	3,351	4,114	11,477	9,100	66,880
Federated Malay States (exports)	11,098	2,596	*	*	*
British India	*	243,850	*	*	*
Norway	55,027	*	*	60,000	*
Portugal	502	899	798	.....	120
Senegal	*	5,798	895	*	*
United States	13,247	18,750	21,135	70,042	184,657

* Data not available.

WORLD PRODUCTION OF RUTILE, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
New South Wales	790	2,044	4,440	9,100	*
Brazil (exports)	489	499	2,369	4,615	4,557
French Cameroon	159	105	*	*	*
Norway	166	*	*	*	*
United States	*	2,620	2,839	2,402	3,617

* Data not available.

Russia is reported to be interested in producing high-grade titaniferous iron ores and vanadium. The major deposit, located in the Ilmen Mountains, contains reserves estimated at 400 million tons carrying 15 per cent of TiO_2. This can be concentrated magnetically to 43 per cent TiO_2 and a concentrate containing 65 per cent of iron.

Japan has titaniferous magnetite sands estimated at 10 million tons. The sand can be concentrated to 60 to 65 per cent TiO_2 from an average of about 25 per cent.

Prices. The price of metallic titanium, 96 to 98 per cent, was quoted on Sept. 30, 1946, and through the war years at $5 to $5.50 a pound, by *E & M J Metal and Mineral Markets.* Rutile sold at 8 to 10 cents a pound for 94 per cent concentrate; 88 to 90 per cent of TiO_2 concentrate, $60 to $75 a short ton, f.o.b. New York. Ilmenite, 60 per cent TiO_2, was quoted at $28 to $30 a gross ton, f.o.b. Atlantic seaboard.

Ferrocarbontitanium was priced at $142.50 per ton, f.o.b. producer's plant; 15 to 20 per cent of titanium, 6 to 8 per cent of carbon; 3 to 5 per cent of carbon, $157.50. Ferrotitanium in ton lots was $1.23 a pound of contained titanium for 40 to 45 per cent grade; 20 to 25 per cent grade, $1.35.

Manufactured titanium dioxide was quoted through the war period at a base price of 14.5 to 16.5 cents a pound.

Under Price Schedule 98, the Office of Price Administration stabilized the price of titanium pigments at levels of Oct. 1, 1941, the order becoming effective on Mar. 1, 1942. Later amendments allowed one producer to sell above the maximum price for 2 months. Additional means of enforcement were provided, and adjustable pricing for long-term contracts was permitted on Dec. 2, 1942. Ilmenite and rutile prices were fixed by OPA Regulation 327 at levels prevailing in March, 1942.

In England, the price of Indian ilmenite, 52 to 54 per cent of TiO_2, was quoted at 30*s.* per long ton, f.a.s. Rutile concentrates from India were £42 to £50 per long ton; from Cameroon, £54; from Australia, £45. Ferrotitanium, 2 to 3 per cent carbon grade (20 to 25 per cent of titanium) £100 per

long ton; carbon-free grade, 1*s.* 3½*d.* per pound. Sales of rutile were made subject to official control on May 1, 1942.

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TOPAZ

Properties. A basic aluminum silicate mineral, topaz gained importance for industrial applications under the war emergency because of its toughness and hardness (8), which recommended the stone for application as instrument bearings, and also because of chemical properties. Like minerals of the sillimanite group, topaz forms mullite when heated to a high temperature, with resulting changes in specific gravity and volume. Its specific gravity is 3.4 to 3.65; its molecular weight, 184.6.

Topaz of gem quality shows some fire and has a range of attractive colors: white, yellow, greenish, bluish, and reddish. A rose-pink variety is usually a yellow stone changed in color by careful heating.

Uses. The mineral topaz was defined as strategic and critical on May 13, 1943. Special uses for war materials were not made public, other than as substitutes for metallurgical fluorspar in steel mills and as calcined topaz or a product composed of domestic kyanite and topaz as refractory materials replacing Indian kyanite. These industrial applications were of strategic importance primarily as substitutes for more critical minerals.

This stone is the most useful of all fluorine-bearing minerals employed in making lead glazes and borosilicate glass. Applications for refractories and steel mills were being tested in 1943. Topaz was employed as a substitute for glass-grade kyanite, according to a report by the U.S. Bureau of Mines, on June 19, 1945. Mixing topaz and domestic kyanite was stated to produce a refractory having a high pyrometric cone rating, which gives off its fluorine at a temperature somewhat under the maturing temperature of the glaze. The use of calcined topaz as a substitute for Indian kyanite in refractories had been the object of research carried on by the U.S. Bureau of Mines since 1939, it was reported in 1944.

Topaz, together with the diamond and zircon, found various uses in the fabrication of war materials. Topaz was applied as watch and chronometer jewels, as bearings for meters and other scientific instruments, and for timing instruments such as mechanical fuses for bombs, switches, and microgears.

Domestic Sources of Supply and Production. The only known domestic source of massive topaz capable of commercial production is the deposit of the Brewer gold mine, near Kershaw, Chesterfield County, South Carolina. Following the shipment of a carload for experimental use in 1939, reserves

of 60,000 tons were reported in 1941. Production from this property was 583 short tons valued at $8,807 in 1942. Output increased in 1943–1944, operations being carried on by United Feldspar & Minerals Corporation. This material was first used entirely in refractories, but it was later reported that about 1,000 tons of topaz were applied as a substitute for metallurgical fluorspar.

The Metals Reserve Company made a first commitment for a trial purchase of topaz for stockpiling in 1943, at the request of the War Production Board. The cost to the MRC was $402, from which no recovery was reported.

The WPB confined the use of instrument jewels to essential war work, in Order M-50, effective Nov. 2, 1942. Controls and restrictions on instrument and jewel bearings were eased by WPB Order 4717, issued on Dec. 23, 1943.

The output of topaz and other gem stones from domestic sources was limited entirely to stones of gem quality until 1937, when the marketing of industrial stones was started. Topaz advanced to a new high level in 1940, after foreign supplies had been shut off by the war. At Topaz Mountain, Juab County, Utah, a quantity of sherry-color topaz was collected in 1940.

World Production, Imports and Exports. No records have been published on foreign production of topaz for industrial uses. Brazil exported 16,561 g. of topaz to the United States in the first 9 months of 1941, as reported by the U.S. Bureau of Mines. The gem topaz occurs in pegmatites in Brazil. Recovery of gem topaz is also reported from Siberia.

In Ceylon, where a variety of precious stones have been produced for the past 2,000 years or more, topaz is a by-product of sapphire mining. World production of gem topaz has not been reported since 1939.

Prices. South Carolina topaz was reported to have an average price of $15.10 a ton in 1942. Current prices are not available.

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TUNGSTEN ORE

Properties. About half as abundant as copper, tungsten is one of the 16 nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. It is one of the four major ferrous alloy metals essential in modern industry. Tungsten is a hard, heavy, grayish-white metallic element. (W, atomic number, 74; atomic weight, 184.) It has the highest melting point (3370°C.) of any element except carbon. It has the second highest reported modulus of elasticity (about 60 million pounds per square inch) and attains the highest strength recorded for any metal (about 600,000 lb. per sq. in. in 1-mil wire), in severely worked tungsten wire; the unworked bar shows a strength of 25,000 lb. It can be worked readily into suitable shapes. Tungsten has relatively low vapor pressure and sufficient strength for use as filaments in electric lamps, which require electrical resistance and an extremely high melting point. It conducts heat reasonably well. The extraordinary degree of efficiency in converting electric current into light is probably the tungsten function having the greatest value both in war and peace.

Four tungsten-bearing minerals are worked as ore: wolframite (76.4 per cent of WO_3), a dark brown to black, heavy mineral (tungstate of iron and manganese); ferberite (iron tungstate, 70 per cent of WO_3); hübnerite (76.6 per cent); and scheelite (natural calcium tungstate, 80.6 per cent of WO_3), a white to buff mineral having dull luster. It is heavy and fairly soft. Under ultraviolet light and purple filter, scheelite shows pale bluish-white fluorescence. Tungsten ores are generally associated with porphyry, pegmatite, and granite in veins and replacement, contact metamorphic, and segregation deposits. Wolframite is commonly associated with tin in placer deposits. In the United States and Canada, the ore is chiefly scheelite in contact metamorphic deposits of tactite or skam.

Tungsten ore requires concentration before it is shipped. Commercial grade of concentrates is 60 per cent of tungstic acid (WO_3, tungsten trioxide), low in phosphorus and copper and with a minimum of sulfur, arsenic, bismuth, or tin. Scheelite concentrate is sometimes added to the steel bath, the calcium forming a slag. Tungsten carbide (carboloy) and tantalum are exceeded in hardness only by the diamond and are the hardest cutting materials manufactured. Powdered cobalt serves as a binder in sintering

powdered tungsten carbide. Carboloy is brazed or cemented to a steel tool as a cutting edge. The critical value of tungsten as an alloying metal in steel results from its properties of hardness and toughness which persist under high temperatures. The element is added to steel usually as ferrotungsten.

Ferrotungsten is made in an electric furnace where the roasted concentrates are mixed with carbon and flux, then fused in an electric arc. This is further purified by remelting with an oxidizing flux.

Uses. Tungsten is of vital importance to war industry and, with molybdenum, was used in about 15,000 different types of war items, as reported Jan. 16, 1945, by Ralph C. Stuart, manager of the lamp division, Westinghouse Electric Company. The two metals have a major application as tungsten filament in almost every electric lamp and electric tube. In the field of hard alloys, tungsten has essential uses in armor plate, gun barrels, and the cores of small arms and large-caliber armor-piercing projectiles. Tungsten alloys (particularly tungsten carbide) are employed on a large scale in making armor plate. Other military uses include the manufacture of cores in small projectiles, as an erosion-resistant liner in heavy ordnance, and for gun breeches in naval work. Various unusual developments have been made in applications for war materials, but results have not been published.

The chief metallurgical use is in the production of high-speed tool steels having a tungsten content of 15 to 20 per cent, with 4 or 5 per cent of chromium or molybdenum and 1 per cent of vanadium. Tungsten high-speed steels, introduced about 40 years ago, have revolutionized the metal-cutting industries. "Self-hardening" or "air-hardening" steels contain 4 to 12 per cent of tungsten and smaller amounts of chromium and manganese. These can be hardened without quenching. High-tungsten steel is used in the manufacture of valve seats for internal-combustion engines, for valves and permanent magnets, and for razor blades, knife blades, hack saws, files, drills, and many other products.

Complex alloy steels are used for rails, car springs, electrical resistance wires, and other purposes. Stellite alloys containing 4 to 15 per cent of tungsten and higher percentages of cobalt and chromium are used in cutting tools and machine tools and for hard facing to resist abrasion and wear, because of their hardness which is preserved at high temperatures. Stellite consumed about 2 per cent of the annual total of tungsten used in the war years. Resistance to tarnish and corrosion has led to the application of stellite for surgical instruments and for mirrors in optical equipment.

Automobile makers standardized on 6-6 tool steel (6 per cent of tungsten, 6 per cent of molybdenum) which costs about 10 cents a pound less than 18-4-1 type high-speed steel (tungsten–chromium–vanadium). Age-harden-

ing carbon-free alloys of iron with 20 to 30 per cent of tungsten and 20 per cent of cobalt surpass the best grades of high-speed steel in metal-cutting service. The steel industry, in 1943, used about 10,000 tons of tungsten; about 80 per cent was employed in the manufacture of cutting tools. Molybdenum in high-carbon steel can be used as a substitute for more than half the tungsten employed in cutting tools.

Tungsten metal, like molybdenum, is always reduced in powder form, the working of these two metals having laid the foundation of powder metallurgy. The tungsten-copper alloy, in which a sponge of tungsten absorbs molten copper, combines hardness and strength with high conductivity and is used for contact material or electrodes for resistance welders. It is fitted for these purposes, since it does not soften at red heat. Carboloy (tungsten carbide), used to replace diamond dies in wire drawing, has a composition of 80 per cent of tungsten, 19.5 per cent of chromium, and 0.50 per cent of carbon. Powder metallurgy is used in the production of tungsten carbide, in which metallic alloys stronger than pure cobalt are sometimes used as a binder. In cutting tools, only the actual cutting face need be made of the tungsten carbide. Carboloy wire-drawing dies last from fifty to one hundred fifty times as long as the best steel wire-drawing dies, the cutting tools lasting from twenty-five to one hundred times as long as the best high-speed tungsten tool steels. Carbide tools can be used for cutting porcelain and other hard materials that are left unscratched by high-speed steel. Pure tungsten metal is used in ignition and horn contact points in automobiles, trucks, and buses.

Other tungsten alloys are employed in the filaments of radio tubes, electrical-contact points, and electrodes and in the form of tungsten disks mounted in a block of copper in X-ray tubes. Tungsten has the highest atomic number of any element practical for the fabrication of X-ray targets. These targets and X-ray tubes become hot very quickly. In ordinary radiographic tubes, the temperature at the tungsten surface rises to almost the melting point in a second or less. In the new high-speed tube, the temperature rise takes place in one-millionth of a second.

Fragile pressed tungsten, poorly adapted to mass production, was the most important advance in the manufacture of electric-light bulbs, replacing in 1906 the carbon filament used in the Edison incandescent lamp. General Electric Company worked out a system for converting tungsten briquettes into ingots and fine-drawn wire that was adopted all over the world. The development by General Electric of drawn tungsten wire for electric-bulb filaments created a revolution in the manufacture of the incandescent lamp, making possible the use of automatic high-speed machinery.

The chemical industry uses only a small tonnage of tungsten. Making flameproof cloth is one of the essential applications. Tungsten is also used in weighting fabrics and in preparing pigments for paint and ceramics. In preparing X-ray screens, fluorescent cadmium tungstate is used.

Steady expansion in both production and use is expected during the postwar period, although, in some alloy steels, tungsten has been replaced by other metals. In ordinary tungsten tool steel, molybdenum can be substituted for a large part of the tungsten. In armor-piercing shells, chromium, nickel, and molybdenum are employed as partial substitutes. There is no satisfactory substitute for tungsten filaments in electric lamps. In the war years, hard silver alloys were successful substitutes for tungsten and platinum contact points. Platenite (iron-nickel alloy coated with copper) has largely replaced tungsten in ignition devices, magnetos, and sparking points.

Domestic Sources of Supply and Production. Of all the strategic metals in the ferroalloy group, tungsten, a deficient mineral, is the most nearly on a self-supporting basis with reference to domestic output. Mercury is the only other strategic metal to have attained a similar position in domestic supply. All steel-producing countries draw on remote sources of tungsten, which is one of the eight strategic metals that involve supply problems.

Domestic production of tungsten was too small in prewar years to affect national requirements. The United States dropped to second place among world producers in 1918. Commercial reserves have an estimated life of 4 years, based on annual consumption in 1935–1939. Less than 35 per cent of domestic ore reserves remains unmined. Submarginal and highly speculative resources were stated by Elmer W. Pehrson, U.S. Bureau of Mines, to represent supplies good for 5 to 25 years. Although large submarginal domestic resources of tungsten are available in terms of prewar consumption under emergency conditions and at a high price, greater dependence on foreign sources has been indicated for the postwar period.

> The prodigal harvest of minerals that we have reaped to win this war [20,750 tons of tungsten between Jan. 1, 1940, and Jan. 1, 1945] has bankrupted some of our most vital mineral resources. We no longer deserve to be listed with the British Empire and Russia as one of the "have" nations. We should be listed with the "have nots," such as Germany and Japan. . . . We have less than a 35-year peacetime commercial supply of tungsten and 20 other minerals. . . .

This is according to Harold L. Ickes, Secretary of the Interior, in December, 1945.

Domestic tungsten ores, chiefly scheelite, contain 0.5 to 2.5 per cent WO_3 and are concentrated to a minimum of 60 per cent WO_3. Two-thirds of domestic output comes from three mines.

Prewar domestic consumption of tungsten averaged 1,700 tons a year, of which the United States produced less than half. The interruption of imports by submarine attacks led to an intensive investigation by the U.S. Bureau of Mines in 1940–1945. Of several hundred domestic tungsten deposits examined, the Bureau explored 27 properties to indicate ore amounting to 3,570,000 tons, of which 300,000 tons averaged better than 2 per cent and 1,200,000 tons of fairly good milling ore averaged about 1 per cent. One deposit was located in North Carolina; the others in five Western states (Idaho, Nevada, Arizona, Colorado, and Wyoming).

Some twelve producers in the United States employed flotation as the main or accessory form of beneficiation during the war years. The recovery of concentrate assaying 55 to 65 per cent of WO_3 was obtained by direct flotation as the result of recent progress in metallurgy. About half of all domestic production was secured from the Yellow Pine mine of the Bradley Mining Company, located near Stibnite, Idaho; operations were continued through 1944. Its 45 per cent concentrate was to be increased to 75 per cent tungstic oxide in the new processing plant under construction in 1945 at Boise, Idaho. Promising tungsten deposits were also worked near Bishop, Calif., and at the Nevada-Massachusetts mine in Nevada. Sources of supply in the First World War (Boulder County, Colorado, and Atolia, Calif.) are reported to be approaching exhaustion.

New tungsten deposits were discovered in 1943 as a result of extensive government exploration, but domestic production was inadequate. New discoveries included many smaller bodies of scheelite in the Western states and the hübnerite deposits of Virginia. Postwar domestic output is expected to be adequate for United States consumption; steady expansion is indicated, according to authorities who believe production possibilities to be in excess of the low Pehrson estimates.

In 1940, shipments of primary tungsten concentrate from domestic mines amounted to 5,319 short tons, an increase over 1939 of 24 per cent; in 1941, 6,567 short tons of 60 per cent concentrate valued at $9,223,726; in 1942, 9,333; in 1943, 11,945 valued at $17,973,685; in 1944, 10,282 valued at $14,408,519, as reported by the U.S. Bureau of Mines. At the close of 1943, the WPB reported that 9,349 tons of tungsten were available. The record 1943 production was the equivalent of only 59 per cent of domestic consumption. Production of tungsten concentrate in 1944 was reported for twelve states and Alaska. Of total output, 94 per cent was secured from Idaho, Nevada, and California. Initial production in North Carolina was secured in 1943. The U.S. Vanadium Corporation retreatment plant at Salt Lake City, operated for the MRC, was shut down in April, 1944, after starting operations in April, 1943.

The status of tungsten shifted in 1944 from a critically short material to one of adequate supply. Stocks at the end of 1943 were 80 per cent greater than at the end of 1942. During the year, no allocation control was applied to tungsten ore and concentrate, ferrotungsten, and most tungsten products. Tungsten in adequate supply for industrial needs was reported on Nov. 30, 1945, by the Civilian Production Administration.

In Order M-21-j, the alloy branch, steel division of the WPB, announced the restriction of tungsten for use in high-speed tool steels, in April, 1945. Order M-21-h, revoked on Aug. 21, 1944, had also restricted tungsten, but the new order differed slightly in that it required 85 per cent (formerly 75 per cent) of Class A and 15 per cent (formerly 25 per cent) of Class B high-speed steel for melting and delivering to fabricators. The new order was intended to meet increased military needs and to maintain adequate reserves. Tungsten ore and concentrate, ferrotungsten, and most tungsten products were freed from allocation control in 1944. The Office of Price Administration on June 12, 1946, suspended price controls from all products subject to tungsten and certain other alloys and metals regulation.

The MRC made a commitment in 1940 for the purchase of tungsten, one of the first seven minerals and metals designated for stockpiling. Ranking sixth in cost of deliveries to the MRC ($84,009,453), the inventory of tungsten showed a market value of $46,881,668 on Oct. 31, 1944. The Office of Metals Reserve on Oct. 31, 1945, reported the tungsten stockpile at 11,006 tons; on June 1, 1946, 2,943 tons.

The WPB announced on Mar. 1, 1944, that tungsten price payments to "eligible" producers of ore would be discontinued on Apr. 30; the limit for purchases for the stockpile at Fairbanks, Alaska, was extended to Dec. 31, 1944. The government stockpiles of tungsten ore amounted to 19,080 tons, as reported on July 17, 1944, by *The Wall Street Journal*. Production of 10,282 short tons of concentrate in 1944 compared with the all-time high of 11,945 tons of 60 per cent concentrate in 1943.

Withdrawal of premium payments by the MRC on Apr. 30, 1944, led to

TUNGSTEN METAL IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

	1939	1940	1941	1942	1943
Domestic shipments	4,080	5,062	6,250	8,882	11,359
Imports	1,485	4,833	6,576	7,705	9,339
Exports	195	238	196	*	*
Apparent consumption	5,370	4,978	8,349	8,695	9,657

* Data not available.

DOMESTIC PRODUCTION OF TUNGSTEN ORE,* IN SHORT TONS
(After American Metal Market)

1939	1940	1941	1942	1943	1944†
4,287	5,319	6,567	9,333	11,935	10,500

* 60 per cent concentrate.
† Estimated.

closing down a large part of the tungsten-mining industry in Boulder County, Colorado, it was reported in January, 1945. The retreatment plant at Salt Lake City was closed on Apr. 30, 1944, and two of the largest producers reduced operations.

The Defense Plant Corporation built a tungsten mill at Glen Cove, N. Y., at an estimated cost of $672,000. Operated by Wah Chang Trading Corporation, the mill had an annual capacity of 15,000 tons. At government expense of $421,000, a 17,000-ton tungstate plant was built at Salt Lake City, Utah, and operated by U.S. Vanadium Corporation.

"An adequate assurance of security can be gained through the maintenance of careful regulation and control [of tungsten], with all developments in potential national resources, and improvements in the use of substitutes, being made a matter of detailed record," stated Brooks Emeny in *The Strategy of Raw Materials.*

World Production, Imports and Exports. Postwar tungsten requirements in the United States will be dependent on imports in spite of expanded domestic output, with foreign sources continuing to be China, Malaya, Bolivia, Brazil, Mexico, Peru, Argentina, and Australia. The United States and 30 other countries produced tungsten in 1938. Leo Crowley, Foreign Economic Administrator, reported in March, 1945, that almost 6,000 tons of wolfram ore had been transported by plane in 1944 to U.S.S.R. from western China. The main Chinese wolframite deposits are located in Kiangsi and Hunon provinces and occur as float and in placers. Chinese capital controls nearly all deposits. Coolie labor makes this ore delivered in the United States equal about one-third the cost of domestic ore. Korea was the prewar source of 5 to 10 per cent of world supplies. Wolframite and scheelite are recovered from placer deposits. China produced 37.4 per cent of the world total in 1938, when Burma accounted for 17.7 per cent. Exports to the United States amounted to 9,138 short tons in 1943. China and the British Empire both have national self-sufficiency in tungsten; the United States and Japan have domestic sources inadequate to supply the demand and are dependent on foreign sources. Other world powers are almost entirely dependent on foreign sources.

Latin America became an important source in 1944, after supplies from China had been cut off. Bolivia is the leading South American producer of tungsten, which follows tin in importance in that country. Bolivia imposes an export tax on wolfram, as well as on tin, bismuth, and antimony. In the 3-year period 1941–1943, annual output averaged 5,630 tons of concentrates (in 1942, 5,606 metric tons; in 1943, 6,932). Termination of purchases by the United States led to a notable decrease in 1945. The main deposits are fissure veins in quartzite and slate, usually consisting essentially of wolframite with some scheelite occasionally present. Copper is generally associated with the tungsten, and tin occurs in some deposits. The tungsten content is generally 2 per cent or less.

In Brazil, the states of Paraiba and Rio Grande do Norte were reported by James S. Baker, FEA, to have "world potentialities greater than any others newly discovered." These areas supplied the United States with 1,167 metric tons of 65 per cent tungsten concentrates in 1943. Substantial deposits were developed in 1944. Tungsten has been produced from the central and southern areas of the state of Ceara, where the volume of output has been increasing, stimulated by war prices.

In Argentina, increased production of 68 per cent WO_3 was reported from the Sominar mines, near Cordoba. Developed ore reserves were reported to be adequate for several years' output at the 1944 rate. The Pampas Range is where the major deposits are located. Increased output in the prewar years resulted from the opening of additional small mines in the two main districts. The United States entered into a favored-nation trade agreement with Argentina in prewar years. Output follows Bolivia in importance in South America, amounting to 2,200 metric tons in 1943; in 1942, 1,923.

In Peru, tungsten production expanded to about 500 tons of concentrate in 1943; in 1942, 471. Exports in 1943 were 654 metric tons averaging 64 per cent of WO_3. In Mexico, although tungsten ores are mined, production is unimportant, amounting to 100 metric tons in 1941, largely semirefined and concentrate. Bolivia, Mexico, and Peru are regarded as essential sources of tungsten adequate to supply domestic requirements in time of national emergency. These sources are classified as having direct bearing on the emergency position of the United States in time of war.

Tungsten was one of 25 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus from Mexico, Peru, Bolivia, and other Latin-American countries, as part of the foreign procurement program initiated late in 1940. Foreign tungsten contracts, except for a few long-term agreements of the MRC, expired on June 30, 1944.

The MRC arranged for $30,000,000 worth of tungsten from China late in 1940, followed by another loan of $60,000,000 to be repaid by sales of tungsten, antimony, and pig tin to the United States. Imported ore and concentrates were received from 13 countries in 1943, with 91 per cent of the 19,534 short tons of 60 per cent WO_3 received from China, Bolivia, Argentina, and Brazil.

In Portugal, tungsten minerals associated with tin in lodes and alluvial deposits occur in Beira Baixa province. British capital controls the main production from this major source in Europe, located in Tras-os-Montes.

Burma, British India, was the major world producer in the First World War from tungsten deposits in the Tavoy region. Wolframite-cassiterite veins occur in granite forming the core of the mountain range extending south into Siam and the Malay Peninsula. Tungsten associated with tin is recovered by dredging operations in Malaya and Indo-China.

Britain normally requires upward of 12,000 tons a year of tungsten concentrates, Burma, Africa, and China being the chief sources. Former production from the Cornwall tin district is now reduced to a negligible volume.

The small amount of tungsten reaching Germany in 1944 from Spain and Portugal was stopped by the liberation of France, leaving Germany dependent on Norway as the only source of wolfram. Germany required an estimated 12,000 to 15,000 metric tons a year of tungsten concentrates, which was supplied from prewar stockpiles supplemented by imports from U.S.S.R. until that country was invaded by the German army. France has negligible domestic production and is dependent on Indo-China and other Far East sources. Tungsten is one of eight metals for which Europe is dependent on imports. Batelle Memorial Institute reported, in February, 1945, that Germany was short on this metal whereas Japan appeared to have substantial stockpiles, imported from China and Chosen (Korea). Japan secured about half of its war requirements of tungsten from Korea, as reported in March, 1945, by the U.S. Department of Foreign Commerce. This was one of five essential minerals and metals, in addition to coal and gold, developed for export to Japan in the war years, as the result of intensive development of Korean natural resources after 1936 by Japan.

Tungsten ore and concentrate imported for consumption in the United States in 1940 amounted to 2,805 tons, representing shipments from 16 foreign countries. More than half of this amount was shipped from China and Bolivia. Prewar imports were secured chiefly from China and British Malaya.

In 1944, Canada shipped 443.4 tons; in 1943, 754; in 1942, 260. Tungsten

concentrates produced in Canada, Sept. 1, 1939, to Sept. 1, 1945, amounted to 1,510 short tons valued at $1,786,500. Stocks at Welland and Niagara Falls, Ontario, amounted to 515 tons of contained tungsten at the end of 1944. The Emerald mine and the Red Rose mine, British Columbia, were the major producers, the 300-ton mill going into operation in July, 1943, at the Emerald. Ore recovered by both mines averaged about 1.7 per cent of WO_3. By-product recovery by a number of Canadian gold mines, usually representing no profit, was carried on through the war period. Canadian low-grade concentrates were shipped for chemical treatment to the Salt Lake City tungsten plant. Atlas Steels, Welland, Ontario, the only Canadian company making tungsten steels, uses the element in the form of high-grade scheelite concentrate. Consumption in 1944 was 232 tons; in 1943, 390. No tungsten concentrates were produced in 1945, when imports of ore and tungsten carbide were valued at $14,349.

WORLD PRODUCTION OF TUNGSTEN ORE,* IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Argentina	1,309	1,417	1,720	2,115	2,420
Australia	1,029	1,126	1,142	903	907
Bolivia (exports)	3,337	4,183	4,353	5,606	6,902
Brazil (exports)	7	9	35	9	1,264
Canada	4	6	32	244	798
China (exports)	11,580	3,118	†	8,624	12,040
Malay States, Federated	246	108	†	†	†
Malay States, Unfederated	362	427	†	†	†
Mexico	229	216	191	193	516
New Zealand	49	88	79	73	121
Peru	170	290	337	510	722
Portugal	3,851	4,858	5,834	5,220	7,477
Spain	368	393	415	1,462	3,902
Thailand	378	400	†	†	†
Tonkin	510	392	†	130	†
United States (shipments)	3,889	4,825	5,957	8,467	10,836

* Concentrate containing 60 per cent WO_3.
† Data not available.

In Alaska, postwar expansion in the output of tungsten can be secured through systematic development, as reported on May 7, 1945, by U.S. Geological Survey. To the end of 1944, 5 per cent of production in Alaska represented tungsten and seven other minerals. The U.S. Bureau of Mines carried on three exploration projects in Alaska in 1940–1944. Ore put in sight averaged about 1.2 per cent of WO_3, and substantial possibilities were

indicated. Tungsten ore remaining in stockpiles of the MRC at the Fairbanks, Anchorage, Seldovia, and Nome depots was sold to private industry in June, 1945. The disposal included stocks of four other minerals, as reported by the Territorial Commissioner of Mines.

U.S.S.R. has vast tungsten deposits and is paramount among world producers, according to information reported in Washington in January, 1946, by the Office of Strategic Services. World superiority in minerals was made possible in Russia as the result of a policy of importing materials rather than using known deposits, leaving untouched the vast reserves of essential metals and minerals. The major source of tungsten in 1940 was reported to be placer deposits in the Far East. Production in 1937 was reported at 2,200 metric tons, with reserves estimated to be good for 6 years in districts located in the southern Urals, the Caucasus, and Siberia. U.S.S.R. imported all tungsten in the early 1930's, reported at 4,032 short tons (60 per cent WO_3 content) per year, 1930–1932.

Prices. Prices quoted Sept. 30, 1946, by *E & M J Metal and Mineral Markets*, were as follows: Chinese, Bolivian, Portugese, etc., 60 per cent tungsten ore, duty paid, $22 f.o.b. New York; domestic scheelite delivered to buyer's plant, good known analysis, carload lots, 60 per cent tungstic acid and upward, $24 per unit. The average price paid for domestic primary concentrates was $25.07 per short-ton unit of WO_3 in 1943; in 1944, $23.36.

Average prices of tungsten ore at New York, duty paid, per unit, as quoted by *American Metal Market* were as follows: in 1939, $20.43; in 1940, $23.44; 1941–1943, $25; in 1944, $24.25. The duty on tungsten ore under the tariff act of 1930, corrected to Feb. 1, 1943, was 50 cents per pound of tungsten contained; ferrotungsten, 60 cents plus 25 per cent per pound of tungsten contained. Price stability of tungsten and other steel-alloy materials has been a notable achievement since 1941, in contrast to the inflation that marked the First World War.

Ferrotungsten, 75 to 80 per cent, was $1.90 per pound of contained tungsten. Tungsten powder, 92 per cent, was $2.50 to $2.75 a pound; 99.7 per cent, $4.50, on Sept. 30, 1946. The prewar price of wolfram in Spain advanced from under $200 a ton to more than $20,000 a ton in 1943, when competitive German and Allied bidding forced the price to a point where German sources exhausted their supply of Spanish currency.

Foreign purchases were made up to Apr. 30, 1944, at the premium price of $30 a unit, followed by a price of $24 a unit until June 30, 1944. Later, imports passed from government to private purchase but continued to enter over our tariff wall at foreign prices of $15 and lower.

Prices on Chinese ore increased from $24.50 to $26 a short ton in Decem-

ber, 1940, with the average price in all 1940 of $20.61 per short-ton unit of WO_3, as reported by the U.S. Bureau of Mines.

Canadian tungsten concentrates were sold through the Metals Controller, to the end of 1943, at a base price of $26.50 per unit of 20 lb. of WO_3, 70 per cent concentrate, delivered at Welland, Ontario.

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URANIUM

Properties. A lustrous, white, radioactive, metallic element, uranium has been described with four different atomic weights, all having identical chemical properties. (A, atomic number, 92; atomic weights, 233, 234, 235, 238.07; melting point, 1850° C.) The more abundant variety, U-238, occurs simultaneously with the other rarer forms. U-235 constitutes only 0.7 per cent of U-238 and occurs in the proportion of 1 part in 140. Both forms are isotopes, and chemical means are ineffective in separating them. No physical method was known for such a separation on a practical scale until the atomic bomb project solved this formidable problem as a result of industrial effort on a very large scale.

Uranium is ductile, malleable, and capable of taking a high polish. Its density is 18.7. It is the heaviest substance known (lead, 207; bismuth, 209; actinium, 226; radium, 226.05; thorium, 232.12) except plutonium (Pu, atomic number, 94; atomic weight, 239) and has the greatest amount of energy stored in its atomic structure. The metal in powder form, as obtained by reduction, is pyrophoric and on exposure to air takes fire spontaneously. Iron alloy containing more than 20 per cent of uranium is also pyrophoric, producing sparks when scratched or struck. In group VI-a of the periodic table uranium occupies a position below chromium, molybdenum, and tungsten.

The uranium-radium series is most closely paralleled by the thorium series. The thorium isotope closely approaches the atomic weight of the uranium isotope. In melting point (1845° C.), thorium closely approaches uranium. The only commercial source of thorium is monazite sand. Thorium, as a source of nuclear fuel, differs from uranium in containing no "inflammable" fraction corresponding to U-235. Thorium is more plentiful than uranium and can be used, theoretically, as an atomic explosive. In chemical behavior, uranium is most closely related to the chromium group.

In the course of its atomic disintegration, uranium produces a series of elements including helium, radium, actinium, and lead. From its salts are emitted different forms of radiation known as alpha, beta, and gamma rays. Uranium salts absorb energy from light, which may be given off in the form of fluorescence. The most remarkable property of uranium is radioactivity, which is shared to a comparable degree only with thorium. Alpha rays are positively charged nuclei of atoms of the gas helium; beta rays consist of

electrons; gamma rays are X rays, ether vibrations of the same nature as light rays, but of much shorter wave length. Alpha and beta rays are electrically charged particles or fragments of the original parent atom, thrown off by the radioactive substances at tremendous velocity. Gamma rays are described as high-intensity X rays, an electromagnetic wave motion of very short wave length moving at the speed of light and having great power of penetration.

In addition to the fast neutrons, each having energies of millions of volts, employed in the atomic bomb, there are slow neutrons, having energies of only a few volts and a speed of a few miles a second, that are thought to be adaptable for peacetime power development. The slow neutrons are about ten times more effective than the fast kind in producing the splits of cores of uranium or plutonium atoms.

Pitchblende (uraninite) is the chief source of uranium, but it is found in extractable quantity also in vanadium ores in connection with carnotite and, to a lesser extent, with the roscoelite and autunite ores of Colorado, Utah, Arizona, and New Mexico. Carnotite occurs as impregnations in porous sedimentary sandstones. Uraninite is sometimes obtained from metalliferous veins but is more generally of granitic association. All 55 of the uranium minerals contain lead resulting from the atomic disintegration of the uranium. Pitchblende is heavy and compact, with uneven fracture; it is greenish-brown in color when not cut and polished. The polished surface shows black and orange uranium oxide. Pitchblende occurs in veins related in origin to pegmatites. Workable deposits of uranium minerals are known to exist in all the continents. Thorium minerals have their principal source in monazite sand produced in India; supplies also have been secured in Brazil, Australia, the Malay States, and the United States (the Carolinas, Idaho, and Florida).

The discovery of uranium, with its associated radium, started the development of atomic science. The use of atomic power is an important advance toward the understanding of all energy relationships. When placed on a negative film, radium emanations react with silver chloride on the film to make a self-taken photograph. Out of a ton of highly concentrated uranium ore, some 11 lb. of U-235 can be produced. The discovery of "fission," or bursting, of uranium atoms, in 1939, gave the first hope of releasing atomic energy on a large scale. Uranium oxide is a source of U-235, which is used in large-scale separation of uranium isotopes in the construction of the atomic bomb. U-235 was first isolated in the research laboratory in 1940. U-235 and plutonium are safe until the instant when more than 2 lb. are brought together into a single, closely packed mass. The process of isotope separation is exceedingly difficult and requires large and elaborate installations.

The Hanford Engineer Works, a fabricating plant located on the Columbia River near Pasco, Wash., and operated by the du Pont Company, converts common nonexplosive U-238 into plutonium, using slow neutrons to produce its transmutation reactions. These neutrons can be controlled so as to prevent an explosion. The fast-neutron explosive effect becomes possible only when U-235 is extracted from uranium oxide and is concentrated into masses. Plutonium is created through the fission of U-235. The bursting, or fission, of a uranium atom is stated to be more than 10 million times more violent than the chemical forces involved in the bursting of a molecule of modern high explosive. The fission of a uranium atom when hit by a neutron causes a split into large parts that become two new atoms of chemically different elements. The neutrons fired at uranium atoms are subatomic particles lacking an electric charge and traveling at a rate of about 20,000 miles a second.

The Hanford Engineer Works was built to synthesize plutonium for the manufacture of atomic bombs. Production of 1 kg. of plutonium per day released up to 1,500,000 kw. The application of atomic power for industry is expected to be possible at such time as a solution is found for engineering problems of utilizing the heat equivalent of the energy released. The primary object of the nuclear plant of the future will be the liberation of energy in the form of heat or otherwise; the production of plutonium or other substances subject to nuclear fission will be secondary. Broad research programs have been contracted for by the Manhattan District of the Army Corps of Engineers for the purpose of improving chemical processes of the Hanford plant and to develop efficient methods for producing atomic power in substantial volume as "enriched fuel." The General Electric Company has a contract for long-range production of plutonium at the Hanford plant, it was reported in August, 1946. Three huge reactors and chemical separation plants at Hanford cover an area of 600 sq. mi. and cost $347,000,000.

Transmuting U-238 into plutonium increases more than one hundred times the source of available atomic energy. The story of the creation, production, and purification of neptunium and plutonium is described as "a distinct turning point in the life of man on earth." Not only has one element been transmuted into another in enormous quantities, but entirely new elements have been created by exposing uranium to neutrons. Plutonium, like U-235, is capable of fission and releases enormous amounts of atomic energy. Plutonium has the important advantage of being chemically different from uranium, which results in its easy separation from uranium by chemical methods. When uranium and heavy water are brought together in certain proportions and in sufficient quantity, a "chain" reaction is set up

and large quantities of energy are released from the uranium in a controlled and nonexplosive manner. A cost reduction resulted by burning U-235 in a low-level chain reaction to transform U-238 into plutonium.

The discovery of the neutron by Sir James Chadwick in 1932 ranks with the greatest scientific discoveries of all time, making possible the atomic bomb and giving promise of greater things to come. The comparatively inert U-238 atom has 146 neutrons in its nucleus, whereas U-235 has only 143 neutrons. The key to atomic energy was the discovery in 1939 that U-235 could be split and made to yield relatively enormous amounts of energy from the nucleus of its atoms. Certain crucial experiments in atomic development were performed in Europe.

One pound of U-235 is the equivalent of 1,500 tons of coal in the amount of energy released. Neptunium was produced in the Radiation Laboratory of the University of California early in 1940. Plutonium was discovered in March, 1941, by bombarding uranium with nuclei of heavy hydrogen. It was demonstrated on Dec. 2, 1942, that plutonium could be produced in large amounts by a special lattice arrangement of uranium and graphite. In September, 1946, it was reported to be a highly speculative possibility whether raw materials other than uranium and thorium might be found suitable for the production of "nuclear fuel," although a method less elaborate than in use at present might be found for separating U-235 from the common U-238.

Dr. John R. Dunning and his coworkers at Columbia University, on Jan. 25, 1939, carried out the first experiment in the United States showing evidence of the violence of the fission of the uranium atom. Later Dr. Dunning demonstrated that U-235 was the isotope that suffers fission under the action of slow neutrons, and he developed the diffusion method of separating the isotope. This pioneer work was marked by the award in March, 1946, of the Medal of Merit.

Steps to develop the atomic bomb were first recommended by Dr. Alexander Sachs, informal advisor to President Roosevelt, on Oct. 11, 1939. The action was prompted by Dr. Albert Einstein and Dr. Leo Szilard. Dr. Sachs stated that it was possible at that time to obtain a chain reaction when atoms are split in series. The explosion of one atom sets off another, until a large mass of uranium is converted into terrific explosive energy and heat.

Dr. Einstein outlined the progress of atomic research in a letter to Dr. Sachs in October, 1939:

It may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-

like elements would be generated. Now it appears this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable—though much less certain—that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port, together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

On the recommendation of President Roosevelt, a working committee was formed and met on Oct. 21, 1939. Refugee scientists urged haste for the good of America in developing practical national-defense aspects of the problem. Dr. Lyman J. Briggs, then director of the Bureau of Standards and a member of the original working committee on atomic research, recommended that American scientists "engage in a mental projection from the normal course of research-development to the impact of a mere scientific possibility upon the national defense."

The working committee on Nov. 1, 1939, submitted to President Roosevelt a report entitled "Possible Use of Uranium for Submarine Power and High Destructive Bombs." The report recommended the production of 4 metric tons of pure graphite for immediate experiments, followed by procurement of 50 tons of uranium oxide.

At a meeting of the committee on Apr. 27, 1940, further progress was made in considering large-scale expenditures. The first stage was scaled at $30,000 to $50,000; the second, at $250,000 to $500,000. Major General Leslie R. Groves, testifying before the Senate select committee on Nov. 28, 1945, reported the total cost of the atomic bomb project at $2,100,000,000. Future costs were estimated at $500,000,000 a year, requiring 35,000 employees, compared with a high total of 125,000 during the war years, including 1,500 scientific workers. On Dec. 2, 1942, a nuclear reactor functioned for the first time, at the University of Chicago—"a milestone in the advancement of science."

General Groves stated on Jan. 24, 1946, that plants for producing atomic power had "very little salvage value" and should be written off the books as a wartime investment. The atomic-bomb project at Oak Ridge, Tenn., had been made obsolete by techniques recently developed, it was reported by Dr. John R. Dunning. The Clinton Laboratories at Oak Ridge are operated by the Monsanto Chemical Company, of which Dr. Charles A. Thomas is technical director.

Uses. The release of atomic power had never been demonstrated until July 16, 1945, when the atomic-bomb project of the U.S. Army conducted

the first test at the atomic-bomb range, Los Alamos, N. M. Major General Leslie R. Groves, over-all director of the project, was assisted by Brigadier General Thomas F. Farrell. Professor Kenneth T. Bainbridge, of Harvard University, was in charge of the historic test explosion in New Mexico. Scientific research and development of the uranium bomb were in charge of Prof. J. R. Oppenheimer, assisted in the 5-year cooperative effort by more than 200 prominent scientists. Among these were the following: Dr. Victor R. Weisskopf, theoretical physicist; Prof. Robert F. Bacher, Dr. Richard W. Dodson, radiochemists; Dr. Louis H. Hempelmann, radiologist; Dr. J. G. Soffman; Maj. John Ferry, radiologist; and Dr. K. H. Kingdon and Dr. H. C. Pollock, of the research laboratory staff of General Electric Company.

The top-level committee charged with developing the atomic bomb consisted of Rear Adm. William R. Purnell, Lt. Gen. William D. Styer, Dr. Vannevar Bush, head of Carnegie Institute, and Dr. James B. Conant, president of Harvard University. Niels Bohr, Eugene Wigner, H. A. Bethe, and Dr. Leo Szillard were among the outstanding men engaged in this project. The first work under government auspices leading to the development of the atomic bomb was carried on at Columbia University under the direction of Dean George B. Pegram, Dr. Harold C. Urey, Dr. Enrico Fermie, and Dr. John R. Dunning. The universities of Chicago and California also shared in developing the great project.

Results of the uranium bomb explosion in New Mexico developed temperatures estimated at millions of degrees, which fused the earth for a radius of 1,200 ft. into a green, glasslike coating resembling fine jade. The earth below the explosion was compressed over an area of 400 sq. yd. into a giant bowl that reached a depth of 25 ft. Detonation of this bomb was from a steel tower 100 ft. above the ground near the great laboratory at Los Alamos.

Bombs dropped on Hiroshima and Nagasaki, on Aug. 6 and 9, 1945, exploded in the air from much greater heights, the detonation greatly reducing the absorption of gamma rays in the ground. Fewer radiations remained in the ground at those cities than in New Mexico, owing to release of the bomb at a higher altitude. Casualties in Japan were reported to be the result of the blast of the two bombs, the consequent collapse of buildings and flying debris, and burns from radiant heat and subsequent fires. Any deaths from gamma rays were stated to be due to those rays emitted during the explosion, not to the radiations present afterward. Most of the radioactivity went up with the big mushroom of smoke that followed the explosion; and within a few days, all radiation had disappeared. Supreme Allied Headquarters at Tokio reported on Feb. 2, 1946, that total casualties of the atomic bomb dropped on Hiroshima numbered 306,545, including 78,150 deaths, 9,428

seriously injured, and the remainder minor injuries and missing persons. The Nagasaki bomb accounted for about 45,000 deaths.

After his first-hand studies at Hiroshima and Nagasaki, Maj. Alexander P. deSeversky reported to Secretary of War Paterson on Feb. 18, 1946, that although he did not challenge the significance of the atomic bomb to future warfare, he considered destruction at both cities to be "entirely incendiary in character." New York could not be destroyed by eight "Hiroshima-type" atomic bombs, in his opinion, but would require hundreds.

The atomic-bomb project was organized under the auspices of the Army Corps of Engineers as the Manhattan Engineer District, covering activity in nuclear physics in various parts of the country. Raw materials for the atomic bomb were produced in mammoth plants, including the Clinton Engineer Works in the Tennessee Valley, near Knoxville. Before it was taken over by Manhattan Engineer District, research work on the gaseous diffusion, thermal diffusion, and electromagnetic separation processes for recovering U-235 was carried on by Dr. Dunning under a contract between Columbia University and the Office of Scientific Research and Development.

Postwar development of useful atomic power was discussed by S. C. Lind, Dean of the University of Minnesota's Institute of Technology, on Jan. 21, 1946. A system of producing atomic energy is known, although extensive research remains to be done. The system consists of large blocks of pure graphite with cylindrical pockets into which cylinders of metallic uranium are inserted. The system was described as an atomic pile, or primary reactor, which was placed in deep trenches in the earth and surrounded by very thick cement walls to protect against neutron and gamma radiation, all materials being handled by distant control. Cadmium shielding was automatically inserted or withdrawn to regulate longer or shorter paths for the passage of neutrons into the uranium.

Three "piles" simultaneously operated produce 36 to 108 million kilowatt hours per day, most of the energy being lost in the form of heat. The pile creates large quantities of U-235, Pu-239, and U-233, liberating vast amounts of atomic energy. The atomic pile is constructed of U-238 and U-235, embedded in graphite and arranged in a geometrical lattice. New elements are produced as by-products of the splitting of U-235. Each neutron generated must, in turn, generate at least one new neutron in order that the pile be self-operative by means of a "chain" mechanism. The multiplying factor, however, must not be too great; otherwise the pile would get out of control, leading to an explosion, as described by Dr. Lind. The same materials may be burned explosively in an atomic bomb.

At Oak Ridge, Tenn., about 5 lb. of uranium had been used by the

chain-reacting pile in almost three years of operation, it was reported on Sept. 5, 1946, by Dr. W. G. Pollard, University of Tennessee physicist. The pile produced about the same amount of heat as the coal-burning university power plant. Within the next two years it was expected to have a pilot plant operating at Oak Ridge to test the production of atomic power for industrial purposes. Before 1970, this was expected to be "a big growing industry," it was reported on Aug. 27, 1946, to the American Institute of Electrical Engineers by Bruce R. Prentice of the General Electric Company.

Six features will be required of nuclear fission plants of the future, as discussed on Jan. 31, 1946, by Dr. John A. Wheeler of Princeton University, as follows: (1) The reaction must be fission; (2) there must be a basic material to undergo fission; (3) the pile must produce new fissionable material; (4) uranium and thorium are the only fissionable materials available; (5) a chemical separation plant is required for nuclear fission; (6) heavy shielding is necessary, a unit that generates as little as 100 kw. requiring shielding several feet in thickness and weighing about 50 tons. Shielding walls at the Hanford Engineer Works required a large part of the 780,000 cu. yd. of concrete poured. Safety plans and regulations for nuclear fission plants should be under government control, as well as all fissionable material, whereas industry should be free to develop nuclear energy, in the opinion of Dr. Wheeler. Nuclear fuels may be burned at a controlled rate in a reactor, or in a runaway explosion, as in a bomb.

Several postwar uses of nuclear energy were expected to become technically possible, but whether or not such uses would be economic is not yet known. The most probable application appears to be in medicine and as a source of heat to produce steam or hot gases for use in conventional types of power-generating equipment, particularly as installations for heat and motive power in the Arctic or Antarctic regions far removed from ordinary sources of water power. It appeared to be a remote possibility that nuclear energy would be converted directly to electric power in usable form. In converting from conventional power sources to atomic energy, it has been estimated that only about 6 per cent of big power-plant equipment would need replacement. In the opinion of A. C. Klein, engineering manager of Stone & Webster who supervised construction of Oak Ridge, Tenn., superpower plants utilizing atomic energy will be developed gradually "in our lifetime" without dislocating the power industry. Special industrial uses might be developed, such as supplementing radium and X-ray inspections of castings, welds, and forgings.

Within less than five years, large cities might be heated with atomic energy, Dr. J. Robert Oppenheimer stated in November, 1945. Power units

capable of distributing very low-cost power would make possible the development of many achievements in such fields as agriculture and electronics. The production of electric power from atomic energy, while still in the experimental stage, may be possible at the rate of 2 million kilowatts a year or greater, using raw materials that now are readily available. The greatest immediate use of atomic power is believed to be as a means of providing low-cost radioactive elements for biological and medical research. "Atomic energy opens up the doors to the Golden Age without revolution or war," in the opinion of Boris Pregel, president of the Canadian Radium and Uranium Corporation.

Challenging possibilities are offered for the use of atomic energy for the large-scale generation of electric power and for industrial heating, comparatively small quantities of nuclear fuels being required for the release of enormous quantities of energy. Power and light for a city of about 1 million could be supplied by the consumption of a kilogram (about 2.2 lb.) of U-235, which could be converted into about 100,000 kw. of electric power. Costs may be competitive with electric power from coal.

Progress in the discovery of the nature of cancer and its treatment was expected to be a major application of the chain reaction of the uranium atomic pile. Work on cancer is expected to exceed the importance of any industrial use of atomic fission in the near future. The use of the uranium pile has made available a great increase of commoner radioactive materials. Irradiated substances such as carbon and hydrogen have made possible observations that trace the development of malignant or normal cell tissue and procedures that may lead to developing combinations of irradiated substances to destroy cancer cells.

Vice-Admiral W. H. P. Blandy, task force commander, was in charge of plans for historic tests on the atomic bomb first set for May 15 and postponed to July 1, 1946. The great project was prepared by some 30,000 men of the U.S. Navy, aided by scientists. The first of two experiments took place at 6 P.M. New York time on July 1, testing the atomic bomb on naval vessels. About 100 warships of the United States, German, and Japanese fleets were used, for the purpose of indicating the pattern of American defense rather than merely determining if navies have become obsolete. The site of this test was Bikini atoll, of the Marshall Islands group, an isolated Pacific area which was heavily patrolled. Dugouts and concrete emplacements were built on the islands surrounding the Bikini lagoon. A "Nagasaki-type" bomb was dropped from a height of 30,000 ft. and timed to explode several hundred feet above the ships. Observers were stationed on ships located 5 to 10 miles from the lagoon. Experimental stations to determine the effect of seismic

waves were installed at Wake and Midway Islands, 500 and 1,600 miles distant from Bikini.

Uranium or lead spun-glass garments and helmets lined with uranium-bearing glasses in plate form were reported to be "probably the best protection we have against harmful radiations from atomic bombing." Rescue squads equipped with oxygen respirators having glass-insulating high-frequency precipitators to keep radioactive dust out of the lungs were discussed by Prof. Alexander Silverman, of the University of Pittsburgh, before the American Chemical Society on Mar. 15, 1946.

Prior to development of the atomic bomb, about 85 per cent of world uranium production was used for medicinal purposes; 10 per cent for luminous materials, including paint used for instrument dials of aircraft and other war equipment; and 5 per cent for miscellaneous purposes, including the inspection of metal castings and forgings to find possible inner flaws. The principal prewar application of oxides and uranate was as a colorant in ceramics. A combination of iron and antimony was substituted for uranium in pottery making. Salts of uranium are used in photography, in analytical chemistry, and in dyeing and printing cloth. Uranium-vanadium bromide compounds in powder form were not affected by adverse climatic conditions and were shipped to the armed forces. War use was made of uranium emulsions for images that would disappear and reappear under many conditions, in conveying secret photographs and maps. Uranium nitrates formerly had been employed in coating photographic paper. Postwar research has resulted in the discovery of more than 150 radioactive substances that are now expected to find great usefulness in many fields. These substances were isolated and identified as fission fragments of U-235.

In high-speed tool steels, uranium is reported to show from 20 to 50 per cent higher general efficiency than other high-speed steels. Uranium metal has the hardness of soft steel and can be cold-rolled, hammered, or drawn. It has been used in making electrodes for gas-discharge devices, where a low initial-breakdown voltage is desired. Ferrouranium (39 per cent of uranium) has been produced.

Uranium has been widely employed since 1943 in physics laboratories for research on uranium isotopes as a source of energy. Thorium was reported, although not proved, in December, 1945, as a "probable second basic material" as a source of atomic power. Prewar use of thorium had been in the manufacture of illuminating-gas mantles. Only the elements uranium and thorium are known to have the two characteristics essential for atomic bombs: (1) Both are fissionable; (2) both have isotopes that are capable of a powerfully explosive chain reaction. U-233 can be produced by nuclear reactions from thorium.

Domestic Sources of Supply and Production. An order was issued by the War Production Board on Jan. 26, 1943, prohibiting the use of uranium in the manufacture of glass, glassware, pottery, tile, and other ceramic products. The order also gave the uranium industry materials priority over all other military procurement. The use was stopped on Aug. 15, 1944, for processing photographic plates, films, and papers. The sale of more than 10 lb. by any person in any calendar month required WPB authority after Sept. 1, 1944, and all sales of uranium compounds, alloys, or mixtures for certain uses were forbidden by amendments to Conservation Order M-285.

More than 100 small atomic bombs were in existence in the United States, and about 1,000 bombs of a larger size were to be made within a year, Dr. Linus Pauling, of California Institute of Technology, announced on Dec. 4, 1945.

Uranium was specified by the WPB on Aug. 22, 1945, as remaining subject to restrictions on special sales and export special sales. Uranium, tin, lead, and antimony were the only strategic metals retained under government control for use and distribution after August, 1945. An executive order on Sept. 13, 1945, banned the sale or other disposal of public lands containing deposits of radioactive substances. The order, relating to the development of the atomic-energy program, follows in part.

So far as not in conflict with existing law, all lands in the United States, its territories or possessions, heretofore acquired by the United States which contain deposits of radioactive mineral substances owned by the United States, are hereby reserved from sale, and all leases, licenses, or other authorization of whatever kind hereafter granted to occupy or use such lands, shall reserve to the United States the right, at any and all times, to enter upon such lands hereafter acquired by the United States and shall become subject to the provisions of this paragraph upon their acquisition; provided, that no reservation under this paragraph shall interfere with the use of the lands established or indicated by any act of Congress.

Placing in the public domain all government-owned land on which uranium ores occur was regarded as a forerunner both of legislation to be enacted by Congress and of an international agreement to control the mining of uranium ores.

Said President Truman in his message to Congress on the atomic bomb on Oct. 4, 1945:

The discovery of the means of releasing atomic energy began a new era in the history of civilization. The scientific and industrial knowledge on which this discovery rests does not relate merely to another weapon. It may some day prove to be more revolutionary in the development of human society than the inven-

tion of the wheel, the use of metals, or the steam or internal-combustion engines. . . . We should take immediate action to provide for the future use of this huge investment in brains and plant [which] will go a long way toward keeping a strong organization intact and to guard against the hazards of misuse.

Legislation was required to fix a policy with respect to existing plants in the United States and to control all sources of atomic energy and all activities connected with its development and use within the United States. For these purposes, it was proposed to appoint an atomic-energy commission with the advice and consent of the Senate. The supervision and control of the commission was to be extended to all United States-owned lands and mineral deposits that are sources of atomic energy and to all stockpiles of radioactive materials and all plants or other property of the government connected with atomic development.

The commission, to be authorized to buy any materials, either foreign or domestic, that are potential sources of atomic energy, would also hold authority to establish security regulations governing the handling of information, material, and equipment under its jurisdiction. The release of atomic energy represents a force too revolutionary to consider by old ideas; it requires strict control as an influence toward maintaining world peace. The use of atomic bombs should be renounced, and all future scientific information directed toward peaceful ends. The international problems can be treated only by the United Nations Organization, with international exchange of scientific information.

While the May-Johnson and the McMahon bills, proposing to establish a commission to control research and manufacturing connected with atomic energy, were being debated by Congress, Dr. Harold C. Urey, one of the scientists who helped develop the atomic bomb, said that the world's most important problem was to stop the production of atomic bombs by any government. A system of policing the laboratories of all nations, he stated, should be adopted to prevent production. The use of 1,000 atomic bombs could destroy 33 cities the size of New York.

Legislation was pending in January, 1946, to set up a Federal Atomic Committee under authority to the Congress, giving powers unprecedented in the life of the United States through control over uses of atomic energy for domestic purposes. It was proposed to transfer controls from the Army to a civilian commission consisting of five full-time officials. The atomic age required this strong control in dealing with both the fabulous opportunity and the immense perils. "Other nations are not likely to catch up with the United States on the atomic bomb for from five to twenty-five years, due to relative industrial weakness," Gen. Groves testified before the House

Military Affairs Committee on Oct. 9, 1945. Atomic energy was not likely to be of any considerable commercial value for perhaps a generation, although medical by-products might reasonably be expected in the near future, as predicted by Dr. Conant.

The problems of effective international control of atomic energy were studied in November, 1945, at a Washington conference of American, British, and Canadian experts attended by President Truman, Prime Minister Attlee, and Prime Minister Mackenzie King. It was proposed to establish within the framework of the UNO an Atomic Energy Commission empowered to prohibit, outlaw, and prevent the use of atomic energy for destructive purposes. Safeguards for the secrets of atomic bomb production were the main concern of the commission when it was established Jan. 18, 1946. The commission was to make specific proposals on four problems: for extending among all nations an exchange of basic scientific information for peaceful ends, for control of atomic energy to the extent necessary to assure its use only for peaceful purposes, for the elimination from national armaments of atomic weapons and of all other major weapons adaptable to mass destruction, and for effective safeguards by way of inspection and other means to protect the complying states against the hazards of violations and divisions. The United States, British, and Russian foreign ministers issued a communiqué on Dec. 27, 1945, inviting France and China, the other permanent members of the Security Council, to join them in recommending to the Assembly the creation of a commission. The purpose of this commission was to "deal with the problems raised by the discovery of atomic energy and other related matters."

The UN Assembly in London on Jan. 24, 1946, unanimously ordered the establishment of an atomic-energy commission, as drafted in Moscow by the Big Three foreign ministers, for the purpose of devising controls. Technical difficulties involved by the control include (1) strict regulation of traffic in uranium; (2) the inspection of factories and laboratories in which atomic energy is used or studied; (3) the creation of a state or international monopoly of pure graphite, heavy water, beryllium, and other rare materials required in making atomic explosives; and (4) a check on the production of various apparatus required in separating the isotopes of uranium. The atomic-energy commission, which included a representative of Canada, was empowered only to make recommendations, which were to require the approval of the UN Security Council.

The fourth of these steps, each initiated by the United States and leading to "encouraging the use of atomic energy . . . toward peaceful and humanitarian ends," was an inquiry by the State Department, the results of which

were discussed in the Acheson-Lilienthal report. This recommended the appointment, under the United Nations, of an Atomic Development Authority which would take complete control of world supplies of uranium and thorium. Extraction plants would be owned and controlled by this ADA, which would license "nondangerous" operations involving atomic energy and would have the right of inspection in order to locate any "dangerous" plants controlled by the leading countries. An Atomic Charter to be ratified by each participating nation would empower the ADA to devise "effective enforceable safeguards against the use of atomic energy for destructive purposes. . . . No nation could prepare for atomic war without bringing itself to the world judgment bar." This report "may become the Magna Charta of the future world," stated William L. Lawrence on Sept. 19, 1946. The alternative to adopting this plan "would be an atomic armaments race that may engulf the world in a third world war—which may well prove to be the last world war."

The Board of Scientific Consultants to the Secretary of State's committee on atomic energy proposed several control measures for uranium. One of these provides for denaturing fissionable materials to slow down for one to three years their conversion for use in making atomic bombs. The possibility of denaturing is believed to be an important factor facilitating international control of atomic energy.

International and political significance was attached to the four volumes of the report entitled "Scientific Information Transmitted to the United Nations Atomic Energy Commission by the United States Representative," made public between June 14 and Sept. 7, 1946. This report discussed the possible future uses of atomic energy for the production of industrial power.

Bernard M. Baruch, American member of the UN Commission for the Control of Atomic Energy, presented an international control plan on June 14, 1946, at the first session of the commission held at Hunter College, New York. Through November, 1946, no definite action had been taken to put into effect the proposals, which were as follows: (1) Create an International Atomic Development Authority; (2) place under its control all world supplies of uranium and thorium, and all production of fissionable materials; (3) it should have the exclusive right to conduct research in the field of atomic explosives; (4) it should try to distinguish between dangerous and nondangerous atomic activities and encourage peacetime uses of atomic energy. Practical problems of control led to withdrawal of support by Russia, which favored ownership and control of uranium determined by the economic system of each country, and reliance on treaties to outlaw destructive uses of atomic energy. It is clear that control on such a basis would leave the commission powerless to remove the danger of atomic war.

Atomic energy under state control will greatly increase the power of government over the individual, even though peaceful application is the only use made of this new force. In dealing with this major issue, decisions reached by the UNO are anticipated as a criterion of success in preserving world peace.

Dr. James T. Shotwell on Feb. 19, 1946, presented the first report of the committee on atomic energy of the Carnegie Endowment for International Peace. The committee included geologists, mining engineers, and other experts. It was recommended that uranium and thorium should be controlled by inspectors designated by the UNO, with all sales made only to an international organization responsible for control.

The Atomic Energy Commission headed by David E. Lilienthal was appointed by President Truman on Oct. 28, 1946. This commission, on behalf of the government, owns all fissionable materials, the production and refining of which it will manage. Research will be conducted and encouraged. Any system of international control that is decided by the United Nations will receive the cooperation of this commission.

Dr. Richard C. Tolman, special adviser to Gen. Groves and chairman of the committee of scientists appointed in 1943, announced on Feb. 4, 1946, that secret information was to be released dealing with discoveries made during the development of the atomic bomb. The data to be made public were discussed in the first report since the release by the War Department of the report by Dr. H. D. Smyth, of Princeton University, as covered by the following classifications: (1) information of a broad scientific nature which "could be released without danger to security"; (2) information about whose publication there is still some debate; (3) "topics which are for the most part of a military nature in the broadest sense—for example, the design and availability of atomic weapons."

The atomic information ready for release would lead to founding at least one new industry, Dr. Tolman stated. Improvements had already resulted from research that had led to developing pumps that operate at velocities higher than the speed of sound. It was estimated that industrial applications of this equipment would result over a period of years in savings exceeding the total cost of the great atomic bomb project. Information to be released was expected to benefit the national welfare, increase rather than threaten the security of the United States, and stimulate the development of science and industry.

The Brookhaven National Laboratory, on the site of Camp Upton, Long Island, N.Y., was to be in operation late in 1947 under the Manhattan District of the War Department as a great experimental laboratory where scientists will study the effects of atomic energy for power, metallurgy,

biology, and medicine. The director, Dr. Philip M. Morse, stated that research will be carried on by a staff of possibly 1,000 technical and non-technical workers. The project is to be financed by a Federal appropriation of $5,000,000. The general aims will be to study "in the field of atomic and related sciences" but to conduct no experiments of a military nature.

The War Department in November, 1946, announced the setting up three additional laboratories to study atomic power for peaceful purposes. These were the Clinton Laboratory at Oak Ridge, the Argonne National Laboratory at Chicago, the Knolls Laboratory near Schenectady, N. Y., all affiliated with the Manhattan District.

The Surplus Property Administration took action on Nov. 19, 1945, to protect workers from the effect of radium or radioactive salts. By revising Regulation 9, the SPA required disposal agencies to channel all scrap or salvage containing radium into the hands of refining organizations or to eliminate it from the civilian economy by destruction as "a menace to health and industry."

Uranium was the main objective in the war years in mining the carnotite ores of Arizona, Colorado, and Utah, although it was reported, prior to disclosure of the atomic bomb, that vanadium was the chief purpose of these operations. Domestic carnotite deposits were successfully exploited from 1912 to 1923, when radium production was controlled by the United States. Minor deposits of thorium are known in North and South Carolina and Idaho. About 100 tons of pitchblende had been produced in Colorado up to 1899, prior to the discovery of carnotite.

United States Vanadium Corporation operates a plant having daily capacity of 260 tons at Uraven, Colo., and a second plant in the same state, at Rifle. Another plant at Durango was operated on behalf of the Defense Plant Corporation.

Vanadium Corporation of America operates plants at Naturita, Colo., and Monticello, Utah. A number of small mines and plants are controlled by individuals and small groups in the vicinity of Gateway, Colo. The main operator in the latter area is Gateway Alloys, Inc. Domestic production has not been reported since 1941.

World Production, Imports and Exports. Prewar uranium production amounted to about 1,000 tons a year. The Belgian Congo is the major source of uranium. High-grade pitchblende ore developed in Canada first entered the market in 1936. Very rich uranium ores and alteration products occur in deposits near Elizabethville, Katanga, owned by Union Miniere du Haut Katanga. The ore minerals are uranite and curite, tobernite, and other oxidation minerals, discovered in connection with exploration of large

copper deposits. Congo pitchblende averaged 50 per cent of U_3O_8 compared with 1 to 5 per cent for the American carnotite ores. Uranium ore amounting to 944 metric tons was shipped in 1929; in 1930, 1,296. Austria first controlled the production of uranium and radium; later, from 1913 to 1923, the United States became the foremost producer. Belgium is reported to have the world's largest radium refinery.

Canada, in 1943–1945, ranked as the second producer of uranium, radium, and various derivatives. The Eldorado mine, Great Bear Lake, Northwest Territories, and the refinery at Port Hope, Ontario, were expropriated for war purposes and taken under government control in February, 1943. A Crown company was established to carry on the production of uranium and radium. No reports have been issued on the scale of operation, although it has been unofficially stated that capacity output was secured from the 100-ton mill. Development of the Eldorado deposits ultimately proved to be an important factor in the development of the atomic bomb.

The Canadian government took over control of all production and sales of uranium and radium, reserving to the Crown all future discoveries of radioactive substances in the Northwest Territories and Yukon, as well as in Quebec, Ontario, and four other provinces. Norman B. Davis was appointed controller of radioactive substances on Dec. 10, 1945, when C. D. Howe, Minister of the Department of Reconstruction, announced that controls over uranium and radium would continue as they were formerly administered by the Metals Controller of the Department of Munitions and Supply. With private prospecting for radioactive minerals in Canada forbidden by an Order-in-council, 20 government survey parties were active in the Northwest Territories in 1945 prospecting for uranium.

General A. G. L. McNaughton, Canadian representative on the United Nations Atomic Energy Commission and chairman of the Canadian-American Joint Board on Defense, was on Sept. 28, 1946, appointed president of the board established by Parliament under the Atomic Energy Control Act. General McNaughton was quoted on the use of atomic bombs as follows: The atomic bomb is something over and above and apart from other methods of warfare. It adds to the machinery of war but does not replace any other method. If the atomic bomb is used in war, it will be directed against great cities, capitals, and industrial areas. It will not be used against military formations or fleets. It will be directed against the civilian workers and the people who direct governments.

Canada's atomic-project plant, near Chalk River, Ontario, had an essential part in the great enterprise involved in producing the atomic bomb. The plant was built at an estimated cost of $15,000,000. The townsite at Deep

River had facilities for a population of 1,500. It was proposed in November, 1945, to maintain that plant as a laboratory where scientists could be trained in the field of atomic research. One line of study being followed in December, 1945, was the possibility of using thorium as a source of atomic energy. Early in 1947 the Chalk River plant was to be placed under direction of the Atomic Energy Board. Future operation will cost an estimated $3,500,000 yearly, following the $30,000,000 spent in the war period.

At the Chalk River plant, the basic process is producing fission in U-235 by a slow neutron. A slow-neutron chain reaction is set up resulting in setting free large numbers of neutrons. Some of these neutrons are absorbed in U-238 atoms to produce plutonium, the uranium being removed from the plant and the plutonium extracted by chemical means. New radioactive materials can be produced in large quantities and are absorbed in materials placed around the reacting uranium. Either the Chalk River plant is being supplied with thorium from imported ore, or a thorium deposit has been discovered in Canada of which no public announcement has been made. It was reported that Canadian radium ranked first in world markets because of its freedom from thorium impurities. Exports to the United States in 1944 amounted to 4,675 lb. of uranium oxide and salts and 101,290 gm. of radium salts.

The control of uranium and uranium ores has been discussed in many countries as a major international problem. Efforts are reported to locate domestic radioactive minerals in all parts of the world, and no other metal appears to be so jealously guarded or searched for as uranium. It has become "the Cinderella of all the natural elements, more valuable than radium."

In Europe, various deposits of uranium have been reported. France may be self-sufficient in the mineral. It is stated that pitchblende occurs in Britanny, the Pyrenees, and central France. In Bohemia and Saxony, pitchblende occurs in cobalt-nickel-silver veins. The Bohemian mines were the principal source of supply up to 1912. Other known sources are Urgeiriea, Portugal; Kvarantorn, Sweden; and Cornwall, England.

Czechoslovakia produced 23,347 kg. of uranium colors in 1929; in 1930, 20,267, the ore being picked to about 42 per cent of U_3O_8. Production is from government-owned pitchblende mines and laboratories at Jachymov. Jachymov deposits follow those of Canada and the Belgian Congo in importance. The mine was reported in January, 1946, to be under Russian operation, all work being conducted in great secrecy. Ore was being shipped to Dresden for treatment. "No Czechoslovak uranium will be used for destructive purposes," the UN General Assembly was told on Jan. 17, 1946, by Jan Masaryk, Foreign Minister of Czechoslovakia.

Nazi awareness of atomic energy was based on research work carried out by the Kaiser Wilhelm Institute. Research was stated to be only a step behind the work done in America by Prof. Enrico Fermi, a fugitive from fascism, and the American physicist Dr. Leo Szilard. After German armies had overrun Czechoslovakia in 1939, Hitler had forbidden the export of uranium ore. Intensified research with uranium was being carried on in Germany, it was reported by Dr. Einstein in April, 1940.

A heavy-water plant built by the Nazis in Norway for atomic-bomb research work was destroyed in a raid by British and Norwegian commandos. Heavy water is not an effective radioactive substance but is used as an auxiliary for the splitting of uranium atoms.

In Sweden, it was announced on Oct. 26, 1945, by the Foreign Office that a bill was to be introduced in Parliament for state control of all domestic sources and supplies of uranium. Exports were prohibited, and the extraction of uranium permitted only under license in order to prevent private speculation and for reasons of foreign policy. The discovery and development of the atomic bomb led the Swedish High Command to plan revisions of the armed forces organization program for the next 5 years. It was planned to recover uranium from residues of the Swedish state-owned shale-oil plant at Kvarntorp.

In an order issued on Sept. 21, 1945, Britain's Board of Trade added uranium and other radioactive materials to the list of products under export license control. Prime Minister Attlee stated on Oct. 23, 1945, that all necessary steps had been taken to search for new deposits and to open and explore known uranium occurrences in Britain. It was intended to take advantage of any future development for the industrial use of uranium. Attlee reported on Feb. 21, 1946, that British and Commonwealth governments were making continuous surveys of supplies and prospective deposits of uranium and thorium. The government of India had been asked for information on the extensive thorium deposits in that country.

In New Zealand, a bill was introduced in Parliament on Dec. 4, 1945, providing for government control of the mining and treatment of ore containing uranium and other elements usable for the production of atomic energy. The bill prohibited importing, possessing, or controlling any fissionable substance from which atomic energy can be produced, and restricted apparatus and machinery capable of producing atomic energy and materials, such as heavy water. In by-product recovery of uranium in gold mining, the government must be notified of methods and treatment employed. Uranium deposits are reported at Mount Pointer, Australia, and in Madagascar.

In Central Asia, large supplies of uranium were under Soviet control, in Kirgizia, as reported by Raymond A. Davies on Nov. 16, 1945. Fergana, Russian Turkestan, Kirovsk, and the Caucasus Mountains are also believed to be sources of uranium.

In September, 1945, Mexico declared the occurrence of uranium and other radioactive minerals to be national mining reserves. Uranium is reported to occur at Placer de Guadalupe, state of Chihuahua.

In Venezuela, President Isais Media published a decree on Oct. 15, 1945, declaring deposits of radioactive minerals a national reserve. Exploration and development could be carried out only by the government. Pitchblende is reported in the state of Merida.

In Brazil, uranium deposits were reported on Oct. 2, 1946, in Minas Geraes. Following four months of preparatory work, the Ministry of War recommended "cosmic energy" tests which were being carried out in secrecy at a small town in the state of São Paulo. Brazilian scientists had been mobilized to carry on the laboratory work.

Thorium is produced chiefly from monazite sands of Travancore, India. Other deposits of minor importance occur in Brazil, Australia, and Malaya. Canada prohibited the export of thorium by an Order-in-council dated Feb. 12, 1946.

Prices. The price of uranium increased to $20 a pound in 1946 from $7 in 1943. Formerly it had been worth about $1 a pound after extraction of radium. One milligram of radium is contained in about 6.5 lb. of uranium element in minerals. Radium was quoted at $25 to $30 per milligram, as to quantity, by *E & M J Metal and Mineral Markets* on May 10, 1945. The prices for uranium wire and sheet in 1930 were based on $900 a pound for the sintered metal. Black uranium oxide was quoted in 1944 at $2.55 a pound; sodium uranate (orange salt), $1.65, by *Oil, Paint and Drug Reporter.*

The price of radium was maintained at about $170,000 per gram by United States producers in 1912–1918. Following the First World War, the price was $105,000 to $120,000 per gram. The price of radium was forced down from $70,000 to $25,000 per gram by the discovery, in 1931, of pitchblende at Great Bear Lake and the operation of the Eldorado refinery at Port Hope, Ontario. The production cost in the United States was about $70,000. The price declined further to $20,000 to $25,000 per gram in 1938.

The Bureau of Mines at Ottawa reported in March, 1940, that Eldorado and Belgian companies had reached an agreement for sharing the world radium market on a basis of 40 per cent by the Canadian and 60 per cent by the Belgian interests. The agreement was to be in effect for 5 years at an undisclosed price. Uranium oxide and salts are on the free list. The tariff act

of 1930 provides a duty of 25 per cent ad valorem on ferrouranium and uranium in alloys.

No open market is established for radium; sales are usually based on individual tender and contract. Monopoly control of prices has been dominant for the past 50 years, as reported by F. A. McGregor, Commissioner of the Combines Investigation Act, to the Canadian Parliament in November, 1945. Wartime developments were secretly guarded. Atomic-bomb production makes it necessary to keep close government control over uranium and radium production, preventing any return to controls by a private cartel.

Uranium deposits at Krzysatka, Lower Silesia, Poland, were reported on Nov. 27, 1946, as being the second largest in Europe.

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VANADIUM ORE

Properties. A silver-white metallic element, vanadium has been produced as a pure metal for more than a century but remains as one of the rarest metals. It is one of 16 industrial nonferrous metals used essentially as alloying constituents. In steelmaking, vanadium serves to increase the strength, elastic limit, hardness, and shock. Vanadium is plastic when in pure form and is not affected by air or water at ordinary temperatures. It unites so readily with oxygen that it is difficult to produce the pure metal, which is sufficiently malleable to be rolled and drawn into wire. (V, atomic number, 23; atomic weight, 50.95; melting point, 1720°C.)

Patronite (VS_4) is the chief source of vanadium, which also occurs in vanadinite and descloizite (oxidation minerals of patronite). Lead vanadates are found in oxidized parts of deposits of lead, lead-copper, and lead-zinc. Carnotite, roscoelite, ilmenite, asphaltite, and some iron ores are also sources of by-product vanadium. A vanadium content of 5.5 per cent, higher than any crude ore now being worked in a vanadium mine, is found in ilmenite associated with magnetite in the United States. Recovery of the vanadium in this ore was under consideration in 1945.

Sodium vanadate, recovered by roasting vanadium sulfide and fusing the product with sodium salt, is smelted with iron in an electric furnace to ferrovanadium containing 35 to 40 per cent of vanadium. Extraction of radium from carnotite gives by-product iron vanadate (vanadium oxide), which is reduced in the electric furnace to ferrovanadium. In smelting minette ores, vanadium is carried off into the slag, to be extracted later. Asphaltite in Peru is burned, and the ash shipped to the United States for recovery of the vanadium. Vanadium minerals are prepared for the steel industry usually by first converting them to a simple oxide by roasting or some chemical process. The first stage of recovery of vanadium from ores and concentrates is in the form of vanadium pentoxide (85 to 90 per cent pure), which is a raw material in the manufacture of ferrovanadium. It is also used by the chemical industries.

Vanadium may be reduced in the presence of other metals, such as iron, copper, silicon, aluminum, manganese, chromium, and nickel; these alloys serve as addition mixtures for the preparation of compositions containing low percentages of vanadium. As a steel alloy, vanadium adds

strength and ductility, produces a finer and more uniform grain size, and forms very stable carbides that add to the hardness of the steel. Vanadium steels show less creep than other steels up to a temperature of 550°C. In high-speed tool steels, vanadium is the most powerful element for increasing cutting ability, due to finer grain structure and greater degree of stability of the carbides.

Uses. Vanadium is one of the 23 strategic metals and minerals most vital in war. Military equipment dependent on vanadium steel includes guns, armor plate, axles, springs, and various other items. The important function of the metal is in the manufacture of special alloy steels and irons, to which very small amounts add strength and resistance to shock and fatigue. War demand led to a sevenfold increase in the production of cutting and high-speed tools and dies, which represent the major requirement for vanadium, followed by the automotive and railway-equipment industries.

The metal is added to steel either in the form of ferrovanadium or as vanadium oxide, for introduction into the steel through the slag. More than 60 per cent of the total vanadium consumption in 1942 was in tool steel, with 2 per cent or less used outside the metallurgical industry. In making steels and irons, it is also combined with other metals, particularly chromium, molybdenum, titanium, and aluminum. Chromium-vanadium steel is widely used in ordnance as well as in railway, bus, and truck parts because of its resistance to failure from fatigue. A vanadium-titanium-ferroalloy recently developed produces a steel having remarkably uniform grain size which is retained through many successive heats, greatly increasing the hardening capacity.

The steel industry was the major consumer in 1943, using about 3,000 tons as a ferroalloying metal. A higher vanadium content is being used in modern high-speed tool steels, particularly when all or part of the tungsten has been replaced by molybdenum. A wide variety of purposes, from large forgings to small springs, requires various steel alloys containing vanadium, including the following: carbon-vanadium, manganese-vanadium, chromium-molybdenum-vanadium, nickel-vanadium, and nickel-chromium-molybdenum-vanadium. Vanadium-steel axles for automobiles and trucks are superior in resisting vibration and shock. Manganese-vanadium steels are easily welded, have a high strength, and are readily worked. Vanadium catalysts were reported in use to an increasing extent, particularly in sulfuric acid plants.

Copper-vanadium alloy was reported to be used for aircraft bushings, propellers for ships, and various parts where high strength and resistance to corrosion were required. Similar properties are also present in vanadium-

aluminum alloys. Variable amounts of vanadium in chromium-cobalt-tungsten alloys contribute wear-resisting qualities for drills, excavating machinery, and various tools, as well as for surgical instruments.

Vanadium-aluminum ferroalloys form a new group under the trade name "grainal," which increases hardening capacity and reduces the variability of given composition in successive heats. These alloys include the following:

	Ti	Al	V	Mn	B	F
Vanadium grainal No. 1.....	15	10	25	..	0.2	Bal.
Vanadium grainal No. 6.....	20	12	13	..	0.2	Bal.
Vanadium grainal No. 79.....	20	13	..	8	0.5	Bal.

In the form of ammonia metavandate, a minor quantity of vanadium is used as a catalyst in making certain organic chemicals. Other applications are in the glass, ceramic, and color industries.

Prewar uses of vanadium were about 95 per cent by the steel industry, which regarded the metal as a convenience rather than a necessity. As a deoxidizing agent in the manufacture of special steels, vanadium is superior to manganese and has been applied in this for a longer time than in other uses. Although price reductions have taken effect since 1930, vanadium remains relatively high cost; and for many alloys, it can be replaced with cheaper metals. A substantial postwar market for vanadium is expected to be maintained for railway and automobile equipment as well as for cutting and high-speed tools.

Domestic Sources of Supply and Production. Processes have been developed for recovering vanadium by chemical and metallurgical methods from low-grade domestic lead vanadates and from vanadium-bearing iron ores, particularly the magnetite concentrate of the MacIntyre mine, Tahawus, N. Y., and in Idaho, where very extensive beds are associated with phosphate deposits. Anaconda Copper Mining Company has developed a process for producing a minimum of 50 tons a year of vanadium. Production prior to the First World War was secured mainly as a by-product in the production of radium from carnotite ores in Colorado, where the main source is roscoelite (vanadium-bearing mica) containing 1 to 2 per cent of vanadium. Increased output was secured from Colorado in the Second World War.

Restrictions on the delivery and sale of vanadium were in effect from Dec. 20, 1941 (Order M-23-a). This order was amended on June 23, 1942, making the melting of vanadium subject to approval of the melter's schedule. Ferrovanadium producers were exempt from melting restrictions. Unrestricted deliveries were reduced from 50 to 10 lb. per month.

The government ore-buying program was terminated by the Metals Reserve Company in January, 1944, the processing plants at Durango, Gateway, and Monticello being held in stand-by condition. Allocation control of vanadium was removed on Dec. 30, 1943, by the War Production Board in an amendment to General Preference Order M-23-a, but vendors of more than 500 lb. of vanadium in any one month were required to report all sales. Vanadium imports continued under the control of General Imports Order M-63. General Limitation Order L-223 was revoked in January, 1944, removing restrictions on the distribution, sale, and use of hard-facing alloys containing vanadium and certain other metals. Revoking Order M-21-h allowed producers of alloy steels to use any alloy content but stipulated the use of 50 to 60 per cent of alloy scrap in all melts. The WPB removed restrictions on Dec. 31, 1943, after a stockpile of 1,500 tons of ferrovanadium and 1,717 tons of vanadium in unstated form had accumulated. The Office of Price Administration suspended price controls on June 12, 1946 from all products subject to vanadium and certain other alloys and metals regulation.

The ferrovanadium stockpile was reduced to 644 tons, as reported on July 17, 1944, by *The Wall Street Journal*, which stated that government stocks included 1,698 tons of vanadium concentrate and 1,121 tons of lead vanadate ore. At the end of 1943, the WPB reported 1,716 tons of vanadium (not including ore) available.

The MRC made a first commitment in 1941 for the purchase of vanadium for stockpiling. Ranking twentieth in cost of deliveries to the government stockpile ($6,503,284), vanadium having market value of $3,542,565 was shown in the inventory of Oct. 31, 1944. Government stocks held by the Reconstruction Finance Corporation through the Office of Metals Reserve, as of Aug. 31, 1945, were 700 short tons (ferro basis); on Oct. 31, 1945, 903 tons. The government-designated agents U.S. Vanadium Corporation started the purchase and treatment of domestic ore. Domestic vanadium was not purchased for the government stockpile after Feb. 29, 1944. Vanadium in adequate supply for industrial needs was reported by the Civilian Production Administration on Nov. 30, 1945.

We have less than a 35-year peacetime commercial supply of vanadium and twenty other minerals and metals . . . which we shall have to import in larger and larger quantities.

This was stated by Harold L. Ickes, Secretary of the Interior, in December, 1945.

The United States, leading producer of vanadium since 1941, with production greater than Peru, achieved record output (mine shipments) of

2,793 tons in 1943, estimated at 60 per cent of the world total. Consumption was 2,590 tons of domestic ore, about the same as in 1942. Domestic output was supplemented with phosphate rock and imported flue dust. Vanadium became relatively plentiful, 1943–1945, following the severe shortages in 1941–1942.

DOMESTIC VANADIUM ORE RECEIVED AT MILLS AND GOVERNMENT STOCKPILES, IN SHORT TONS
(After U.S. Bureau of Mines)

1941	1942	1943	1944	1945*
1,257	2,220	2,793	1,764	1,039

* First 7 months.

Limited reserves were indicated when lend-lease shipments were resumed. Mills producing fused oxide operated for the MRC at Monticello, Utah, and Durango and Gateway, Colo., were closed. U.S. Vanadium Corporation, in October, 1944, purchased the Durango mill and resumed operations as a custom plant. Ore produced by U.S. Vanadium Corporation (subsidiary of Electro Metallurgical Company) and purchased on its own account was treated at its own mills at Rifle and Uraven, Colo. Vanadium Corporation of America has conducted its milling operations at Naturita, Colo. (since 1939) and Bridgeville, Pa. A fused vanadium oxide containing 86 to 90 per cent of V_2O_5 is made and shipped East for reduction to ferrovanadium.

Domestic vanadium ores were also treated by Blanding Mines Company, Blanding, Utah, until the mill was closed on July 1, 1944, when recovery of sodium vanadate was also suspended at Tiger, Ariz., by Mammoth-St. Anthony Mines. Production was maintained through 1944 by North Continent Mines, Cedar, Colo., and S. W. Shattuck Chemical Company, Denver, Colo., and "red cake" was produced from phosphate rock mined at Conda, Idaho, by Anaconda Copper Mining Company. More than 200 small producers in the Colorado-Utah field contributed to the 1943 record output. Colorado was the major producer of vanadium ore and concentrates, followed by Utah, Arizona, Idaho, Nevada, and New Mexico.

Vanadium Corporation of America designed and built a plant at Monticello, Utah, for the Defense Plant Corporation. This was operated for the MRC, which ordered suspension of work at the end of February, 1944. Crude ore stockpiled at the plant then amounted to about 30,000 tons. The stockpile was purchased by Vanadium Corporation of America, which resumed operations at this plant on Mar. 1, 1945. The plant, having annual capacity of 36,000 tons, was financed by the government at about $1,251,000.

Vanadium and salts were obtained in 1940 as a by-product of complex ores produced in Arizona, Colorado, New Mexico, and Utah. Ore reserves adequate for many years were indicated in 1943 by Homestake Mining Company which, on behalf of the RFC, explored bedded deposits located in Utah, Idaho, and Wyoming.

Four exploration projects on showings of vanadium were carried out in 1940–1944 by the U.S. Buraeu of Mines. In southwest Colorado and southeast Utah, extensive diamond drilling was undertaken to indicate mineralization rather than to block out tonnage. This work showed 40,000 tons of ore averaging 1.25 per cent of vanadium. In Wyoming, about 20 million tons averaging about 1 per cent of V_2O_5 were indicated in trenches and tunnels along 20 miles of outcrops in the Phosphoria formation. Phosphorus may also be recovered when this ore is treated.

A 7-year reserve of commercial ore was reported in April 1945, by Elmer W. Pehrson, U.S. Bureau of Mines, to be available in the United States based on the annual rate of use in 1935–1939. Submarginal and highly speculative resources were assumed to be adequate for 100 to 500 years, although availability was stated to be highly speculative or remote because of uncertainties in basic estimates, high costs of recovery, or technologic problems involved in utilization. Less than 35 per cent of domestic vanadium ore is still unmined. Although large submarginal domestic rseources of vanadium, a deficient mineral, are available in terms of prewar consumption under emergency conditions and at a high price, greater dependence on foreign sources has been indicated for the postwar period.

Vanadium Corporation of America and Union Carbide and Carbon Corporation, with its four subsidiaries (United States Vanadium Corporation, Electro Metallurgical Company, Electro Metallurgical Sales Corporation, and Electro Metallurgical Company of Canada, Ltd.) were indicted on June 27, 1946, on charges of conspiracy to fix prices and monopolize the vanadium industry, as announced by Attorney General Tom C. Clark. Vanadium Corporation and Union Carbide were charged as a result of their alleged complete control of the industry. About 95 per cent of the commercially available ore deposits were held, 99 per cent of all vanadium oxide produced, sold, and consumed in the United States and 100 per cent of the entire ferrovanadium, according to the charges. Under the Sherman Anti-trust Act, the government was preparing an antimonopoly suit against these companies and five company officials, following an investigation of price-fixing and monopolization in vanadium ore, vanadium oxide, and ferrovanadium. The defendents were charged with fixing prices below independent mining costs so that independent vanadium miners in Colorado, Utah, New Mexico, and Arizona, were forced either to sell out or to operate at a loss.

World Production, Imports and Exports. World production of vanadium in ores and concentrates in 1940 was as follows: Mexico, 57 metric tons; Northern Rhodesia (1939), 384; South-West Africa, 428; United States (shipments), 948; Peru, 1,254. Imports from Peru in 1940 are not reported but amounted to 1,287 tons in 1939. Peru was the source of 31 per cent of world output in 1938, when the United States supplied 27.4 per cent of the total.

The British Empire holds national self-sufficiency in vanadium; the United States produces the metal in volume adequate to meet domestic demands without excess or deficiency. Other world powers are dependent almost entirely on foreign sources. Vanadium Corporation of America controls production in Peru and owns half the stock of the South-West Africa Company, Ltd., which owns the Abenab deposit, one of the largest known. British capital controls production in Rhodesia and part of the operations in South-West Africa, German capital formerly controlling production at Tsumeb. American capital was reported to hold at least 80 per cent of world vanadium output in 1942.

VANADIUM ORE IMPORTED BY THE UNITED STATES, IN SHORT TONS OF CONTAINED VANADIUM
(After U.S. Bureau of Mines)

1939	1940	1941	1942	1943	1944
15,694	22,551	1,069	1,211	1,026	642

WORLD PRODUCTION OF VANADIUM, CONTAINED IN ORE AND CONCENTRATE, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943	1944
Northern Rhodesia	384	368	342	350	375	*
South-West Africa	514	428	269	316	396	*
Peru	996	1,214	1,017	1,008	855	*
Mexico	80	32	†	*	*	*
United States (shipments)	900	981	1,140	2,014	2,534	1,750

* Data not available.
† Less than 1 ton.

Ore from the great deposit at the Minaragra mine of Vanadium Corporation of America is treated, and the concentrate shipped to the plant at Bridgeville, Pa., for conversion to ferrovanadium. A leaching plant located at a high elevation in the Peruvian Andes was completed in 1945, financed by the DPC. The imported concentrates average about 12 per cent of vana-

dium. Ore reserves were reported in 1930 at 35 million pounds of probable vanadium and the same volume of possible metal. Prewar production in Peru was about two-thirds of the world total. At Minaragra, the ore is mined in two pits separated by a porphyry dike. Ore is crushed and dried at the mine mouth and shipped 6 miles to the leaching plant at Jumasha; from there, the concentrates go by rail to Lima.

In Northern Rhodesia, oxidized metallic minerals from a large zinc deposit at Broken Hill have been a principal world source. Since 1930, a plant for the production of ferrovanadium has been in operation, with annual capacity of 570 tons containing 34 per cent of vanadium. The ferrovanadium is smelted from vanadium oxide. Ore reserves were reported in 1926 to contain 34,000 tons averaging 2 per cent of vanadium and 848,000 tons averaging about 0.5 per cent.

In South-West Africa, vanadium has been secured from the vicinity of Otavi, where the Abenab deposit was reported in 1931 to be probably the world's principal producer of vanadium. Concentrates averaging 15 to 20 per cent of V_2O_5 were shipped to Germany and to the ferrovanadium works at Lausitz.

Vast deposits of vanadium have been reported in U.S.S.R., which is stated to be "paramount" in the production of this metal. World superiority in minerals, as reported in January, 1946, by the Office of Strategic Services, was made possible in Russia as the result of a policy of importing minerals rather than using domestic deposits, leaving untouched vast reserves of essential materials.

Vanadium was one of the 25 minerals included in agreements negotiated by the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus from Peru and Mexico, as part of the foreign procurement program initiated late in 1940. In the United States, no concern is felt for postwar supplies of this material. In 1944, the Foreign Economic Administration followed the policy of withdrawing from public purchase of vanadium when possible, returning the trade to former private channels if no impairment to the war effort resulted.

Germany and Italy were reported to have become independent of foreign sources of vanadium in 1940, utilizing recoveries from blast-furnace slags and as a by-product in reducing bauxite. In December, 1944, the FEA reported 1943 production in Germany at about 1,000 tons secured from Lorraine ores. This source came under Allied control after D-Day in 1944. Batelle Memorial Institute reported in February, 1945, that Germany was cramped for vanadium whereas Japan was considered to have substantial stockpiles. In Italy, vanadium is recovered from the smokestacks of ships

and industrial plants. Europe is entirely dependent on vanadium imported from foreign sources.

Total exports from the United States in 1942 went to Canada, 22,140 lb. of contained vanadium valued at $86,218. Imports of vanadium-bearing flue dust amounted to 624,423 lb., from Canada, Curaçao, and Peru. Ore and concentrates imported from Peru and South-West Africa amounted to 36,492,268 lb.

Prices. The price of vanadium ore, f.o.b. mines was quoted at 27½ cents a pound of contained V_2O_5, from early in 1925 to Sept. 30, 1946. The average value of shipments in 1942, as reported by the U.S. Bureau of Mines, was 31 cents per pound. The MRC made purchases as high as 50 cents a pound. Vanadium pentoxide (technical grade) was $1.10 per pound of contained V_2O_5. Prices were frozen by General Maximum Price Regulation of Apr. 28, 1942, and prices of ferrovanadium and various other vanadium products were fixed by Maximum Regulation 489, effective Nov. 8, 1943.

Ferrovanadium, per pound of contained vanadium, was quoted at $2.70 to $2.90, delivered. Prices in 1930 were $3.15 to $3.50.

The tariff act of 1930, as revised to Feb. 1, 1943, set a 25 per cent duty for ferrovanadium; vanadium chemical compounds, mixtures, and salts, wholly or in chief part vanadium, 40 per cent; vanadium carbide, chromium vanadium, and other vanadium alloys, 25 per cent; ore, duty free.

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ZINC

(Concentrates and Refined)

Properties. One of the most widely applied of the common metals, zinc first found important use in the alloy brass before the earliest records of civilization. It is one of 16 industrial nonferrous metals used in substantial quantities in the pure state or serving as the base metal for alloys. Increased consumption is of comparatively recent development. Commercially known as spelter, zinc is easily fusible but somewhat brittle. Although only moderately resistant to corrosion, it surpasses iron in resistance to oxidation. Its density is 7.14. (Zn, atomic number, 30; atomic weight, 65.38; melting point, 419.43°C.; boiling point, 918°C.)

Zinc ranks lower than magnesium in the scale of volume electrical conductivity at 29.7; its mass conductivity is 37.2 compared with 100 for copper. Brass (copper-zinc) is classified at 24.6 and 25.5, respectively, in conductivity. Chemical rather than mechanical properties of zinc generally govern the uses of this metal. Its value in zinc-coated (galvanized) metals lies in its resistance to atmospheric corrosion. Zinc and iron have an affinity for each other that is exceeded by scarcely any other pair of metals. Brass requires from 15 to over 50 per cent of zinc, this being the second largest use of the metal, following galvanized steel or iron. Electrochemical properties make zinc essential in dry batteries and wet cells, and chemical properties are important in photoengravers' sheets. Close control of purity, up to 99.9+ per cent, is required in certain uses.

Zinc occurs generally in the sulfide (sphalerite) and the natural oxide (zincite) minerals, which vary from 3.5 to 4.5 in hardness; from 3.9 to 5.7 in specific gravity. At Franklin Furnace, N. J., 147 different zinc minerals are reported, including 11 oxidized compounds, but the important ore minerals there are zincite, willemite, and franklinite. The Franklin ore is so much lower than other ores in impurities that unusual properties were found in the resulting metal that greatly affected the growth of certain domestic industries. Zinc of similar purity was not available in other countries. Modern metallurgy has made possible the production of purer metal than could be secured by the old methods from the Franklin ores. Cadmium, indium, and vanadium are found associated with zinc ores, which are generally combined with

arsenic, copper, silver, and gold. The value of zinc ore may depend on the recoverable by-products.

Zinc ores occur in true veins or fissures, as metasomatic replacements of limestone and dolomite, in residual deposits consisting chiefly of lead minerals with which the zinc is associated, and in disseminated deposits confined to limestone and dolomites. The association of sphalerite and galena is very general in most ore bodies, one or the other predominating. Zinc and lead do not have similar chemical or physical properties. Zinc minerals of commercial importance, in addition to zinc blende (sphalerite) and zincite, are smithsonite ($ZnCO_3$) and calamine (hemimorphite), the zinc silicate. Zinc is recovered by the electrolytic process from complex ores that cannot be successfully treated by ordinary smelting processes. Sulfide ore, representing probably more than 95 per cent of all the zinc mined, requires concentration before smelting.

Primary or virgin slab-zinc specifications (A.S.T.M. designation B6-37) provide that metal be recovered from ore either by distillation or by electrolysis, not by sweating or remelting of secondary zinc. Specifications provide that the first five grades shall be free from aluminum and have combined lead, iron, and cadmium not over 0.01 per cent for Special High Grade (one of the purest commercial metals available), not over 0.1 per cent for High Grade, 0.5 per cent for Intermediate, 1 per cent for Brass Special, 1.25 per cent for Selected. The Prime Western grade shall have lead not exceeding 1.6 per cent and a maximum of 0.08 per cent of iron.

Uses. Essential industry made exceptionally heavy demand for zinc in the war years, when the great bulk of zinc output was for war purposes. Zinc is one of 23 metals and minerals most vital in war. Strategic uses included the coating of steel, manufacture of brass, zinc-alloy die castings, and rolled zinc. Major war applications were in making brass and bronze products for galvanizing and die casting, in zinc oxide, and in dry batteries for radios and flashlights.

The substitution of steel for brass in shell casings, in 1943, held demand for high-grade zinc at a lower level than had been anticipated; but in November, 1943, the War Department announced that brass would be used for some casings as a result of increased brass-mill capacity and larger stocks of brass. No new types of zinc alloy appeared in 1943; capacity production was maintained on materials that had proved most useful. Germany was reported to have substituted for brass cartridges a soft steel, possibly coated with a thin layer of copper or brass. The standard brass shell has the advantage of expanding with the heat of detonation and sealing the gun breech. On cool-

ing, the shell quickly shrinks and allows easy ejection. An advantage of copper-plated steel shells is that they may be used many times.

In the use of zinc for die casting, prewar increases were due to low price combined with favorable physical characteristics. Low-cost production of a great variety of shapes for metal parts is made possible by the die-casting industry, which increased requirements for zinc from 84,000 tons in 1939 to more than 125,000 tons in 1943. Die casting requires zinc of the purest grade.

Rolled zinc is used in dry batteries, in lithography and photoengraving, as roofing material, for weather strip, and for many articles of wearing apparel. Rolled zinc plates are used as "hull plates" in shipbuilding to protect the steel of the hull, propeller-shaft bushings, and other brass and bronze work.

Galvanized metals are produced as sheets, tubes, wire and wire cloth, pipes, and structural steel. Zinc used in galvanized sheets dropped off in 1943 to less than half the 1941 rate; efforts were made to encourage increased galvanizing for civilian purposes. The galvanizing industry in prewar years was the major consumer of zinc. About 35 per cent of the zinc used for all galvanizing in 1942 was applied in sheet galvanizing, amounting to 69,327 tons. This marked a decline from previous years, due to the reduction in the amount of zinc used from 9.1 to 7 per cent of the total from 1938 to 1943. The Zinc Institute planned to promote the use of galvanized products as soon as postwar material was available for civilian requirements. The quantity of slab zinc consumed for galvanizing gained 7 per cent in 1945 over 1944, when the use for brass products declined 32 per cent and for zinc-base alloys increased 55 per cent.

The second largest consumption normally is for brass and castings, followed by uses of rolled zinc. Brass is essential to many industries. Brass-mill requirements were smaller than expected in the war period, but demands of new brass mills in the latter part of 1943 took all the increase in high-grade production.

Improved metallurgical control has developed new types of wire and electrolytic zinc-coated sheets, which rival in quality those produced by the hot-dip method. Uses were chiefly in brass products in 1943, followed in order of importance by galvanizing, zinc-base alloy, rolled zinc, and zinc oxide. Increased requirements for ammunition, brass, and zinc-coated products for military needs were reported in January, 1945.

Zinc oxide is indispensable as a filler in compounding rubber and in the manufacture of glass. Zinc paint is one of the most durable surface finishes. Zinc white has uniform quality, whiteness, and covering ability. Both lead

and titanium oxides are satisfactory substitutes. Lithopone, one of the most widely used white pigments, contains about 30 per cent of zinc sulfide, the balance being barium sulfate. Increased application of zinc oxide has been indicated as a pigment in the manufacture of paint, floor coverings, ceramics, and other materials. Zinc oxide is also an important pharmaceutical compound.

Postwar markets threaten competition from aluminum, although special properties assure the wide application of brass for new construction, in the electrical industry, for transportation, and for household appliances. Although other metals may be substituted for zinc, this usually involves a price increase. Special characteristics are expected to sustain zinc in die casting, in spite of some competition from aluminum. Substitutes for zinc are available in nearly all uses except the indispensable brass. In protecting iron, many substitutes for galvanizing are available.

Domestic Sources of Supply and Production. The Metals Reserve Company, making the first commitment to purchase zinc in 1941, gave considerable assistance in financing zinc mines and smelters. Long-term MRC contracts with American Smelting & Refining Company, Anaconda, American Zinc Company, and U.S. Zinc Mining & Smelting Company increased domestic smelting capacity by about 200,000 tons of zinc metal annually. Zinc production dropped 19 per cent in the period 1929–1939, according to the American Bureau of Metal Statistics.

The supply of slab zinc was taken under control of the War Production Board early in 1942 under General Preference Order M-11, and complete allocation became effective on June 1. Zinc controls were tightened by an amendment to the order on Feb. 9, 1943, when remelt zinc and refined metal were placed under allocation. Zinc dust was also placed under complete allocation by General Preference Order M-11-1, on Dec. 22, 1942, owing to shortages for war uses. Conservation Order M-11-6 was issued July 24, 1942, for the purpose of restricting certain uses and prohibiting others. Further restrictions on uses in batteries and engravers' plates were made in amendments to the order and by General Limitation Order M-71 and General Conservation Order M-99.

Restrictions on deliveries of slab zinc to the MRC were removed on June 7, 1943, by an amendment to Order M-11. Many amendments were made to Conservation Order M-11-b referring to gradual tightening and subsequent easing of use restrictions for zinc.

The WPB designated zinc on Mar. 1, 1944, as a metal sufficient for war uses plus essential industrial demands. After September, 1944, the WPB

dispensed with monthly allocation certificates and required consumers to file regular reports. Purchases were limited to requirements for one month. General Preference Order M-11, relating to slab zinc, was amended on Sept. 15, 1944, to discontinue the system of allocation. Order M-11-l, covering deliveries of zinc dust, became effective on Jan. 1, 1944.

Effective on Apr. 1, 1945, slab zinc was again placed under allocation controls by the tin-lead-zinc division of the WPB, owing to increasing requirements for ammunition and other war purposes; exporters were included on the same basis as domestic consumers under this amended ruling. In May, 1945, Myron Trilsch, deputy-director of the tin-lead-zinc division, estimated zinc available for all 1945 at 916,000 tons compared with estimated requirements of 1,116,000 tons. This was an increase from the 1,078,000 tons estimated earlier in the year when production, including imports, was placed at 870,000 tons. A deficit of upward of 200,000 tons was threatened by the end of 1945, in spite of the expected greater purchases of spelter (concentrate) from foreign sources. The rubber industry was expected to require larger supplies of both zinc and oxide in 1945.

The use of zinc for plating purposes was increased 20 per cent in June, 1945, by WPB Direction No. 1 to Conservation Order M-11-b. The increase was granted to apply in the second and third quarters of 1945, following temporary increases in zinc supplies as a result of increased imports of Canadian metal. Additional increases in zinc uses were stated by the WPB to depend on improvement at smelters of available man power. The WPB removed all war restrictions on zinc when Orders M-11 and M-11-b were rescinded on Aug. 20, 1945.

The Zinc Industry Advisory Committee was advised by the WPB in September, 1945, that no lack of zinc supplies would be allowed to hamper reconversion needs of industry, for which the government-owned zinc stockpile would be made available. The stockpile amounted to 187,000 tons on Aug. 31, 1945, the first report on stockpile tonnage since 1941. On Dec. 31, 1945, the zinc stockpile amounted to 260,967 tons, as reported by the Office of Metals Reserve; on June 1, 1946, 581,517 short tons plus 44,635 tons of foreign-stored zinc ore. No further purchases of unsold zinc and concentrates for stockpiling were made after Oct. 31, 1945, and at the end of the year subsidies were terminated for smelters treating Tri-State concentrates.

Special high-grade and prime Western-grade zinc were included with several materials important to the emergency-housing program and industrial reconversion over which inventory controls were tightened on June 14, 1946, by the Civilian Production Administration. The ruling was contained in an

amendment to Priorities Regulation 32, limiting inventories to a 30 days' supply because of a tendency by the die cast alloy industry to accumulate excessive inventories of zinc.

Release of government-held high-grade zinc to zinc-consuming plants (steel and brass mills, zinc-rolling mills, ingot makers, and job galvanizers) was recommended on Aug. 26, 1946, by the CPA in an attempt to guard against shutdowns that were threatened by the severe metal shortage. The zinc stockpile policy was liberalized on Oct. 22, 1946, as reported by the Office of Price Administration. All six grades of the metal, to be released to help manufacturers requiring the metal for continued operation, would provide more material for the production of galvanized sheet, brass-mill products, and for die castings. Government supplies were so limited that zinc would be made available only when consumers were in urgent need of the metal.

Additional zinc stocks were being held by the procurement division of the U.S. Treasury and the War and Navy Departments. Large zinc supplies were also recoverable from battlefield scrap. Legislation was being considered by Congress to establish a stockpile policy that would provide for the permanent stockpiling of surplus zinc acquired by government agencies in the war years. The market value of inventories for zinc held in the government stockpile was $66,941,952 out of total deliveries of $157,936,523 (excluding payments under the premium-price plan) as of Oct. 31, 1944. Zinc ranked fourth among stockpile items purchased by the MRC.

"We cannot afford another prolonged war in 20 or 30 years," said Harold L. Ickes, Secretary of the Interior, in December, 1945. "We just haven't got the zinc [and other minerals and metals]. The prodigal harvest that we have reaped to win this war [3,642,000 tons of zinc mined between January, 1940, and January, 1945] has bankrupted some of our most vital resources."

Consumption of slab zinc in 1945 at 690 domestic plants, according to products made by industry, amounted to 852,311 short tons, including 5,111 tons of remelt spelter, as reported by the U.S. Bureau of Mines. This compares with the record 1944 total of 897,299 tons. Brass products dropped from first to second place in 1945 zinc consumption, as a result of lower application for munitions, and galvanizing again became the major classification for uses of this metal. Rolled zinc increased 28 per cent in 1945.

Zinc dust produced in 1945 amounted to 23,892 short tons, 585 tons higher than in 1944. At the same time, secondary, or redistilled, slab zinc produced was 49,242 short tons, 205 tons above 1944. Producers' stocks of zinc oxide were increased from 19,761 short tons on Jan. 1, 1945, to 29,611 at the end of October. Stocks of raw materials (zinc ore, slab zinc, and ore

residues) used in the production of zinc oxide amounted to 31,509 tons at the end of October, 1945.

Larger tonnages of low-grade zinc ore were milled in 1943; zinc chemically locked in slag was recovered; operating reduction plants were enlarged; output of high-purity metal by direct production and by refining was increased to a level that may stand as an all-time record; recovery of by-products was increased. New production was secured from old ore dumps in the Leadville, Coeur d'Alene, and Tri-State districts.

Secondary zinc recovery from scrap in 1943 was reported by the U.S. Bureau of Mines at 368,488 tons valued at $63,379,936 compared with 330,526 tons valued at $57,511,524 recovered in 1942; in 1944, 345,469 short tons; in 1945, 360,444. Sources of scrap also include engravers' plates.

1945 CONSUMPTION OF ZINC SCRAP, IN SHORT TONS
(After U.S. Bureau of Mines)

Rod and die scrap	Die castings	Flue Dust and residues	Dross	Sal skimmings	New clippings	Sheet and strip
5,969	11,300	41,663	53,595	73,575	9,592	5,273

Domestic production of primary zinc was 901,332 tons valued at $97,696,000 in 1944, of which mine production in the United States and Alaska (including zinc made into pigments and chemicals direct from the ore) was 715,806 tons. Total domestic output was reported at 799,462 tons in 1945; in 1943, 942,309 short tons were reported of which 744,196 tons came from mine output in the United States; 768,025 tons in 1942. Production of slab zinc and spelter in 1944 was reported at 913,663 tons by the American Bureau of Metal Statistics. Shipments in 1944 were 842,735 tons; in 1943, 887,638.

Mine production of recoverable zinc was reported by the U.S. Bureau of Mines as follows: in the first 6 months of 1946 the monthly average was 48,308 short tons compared with 51,195 in 1945, when output amounted to 614,344 short tons; in 1944, 718,642 tons; in 1943, 744,196; in 1942, 768,025; in 1941, 749,125. Smelters and other industries using zinc ore required 930,000 tons in 1941, leaving a deficit of 277,401 tons to be drawn from foreign sources. The uncertainty of adequate shipping made it necessary in 1943 to expand domestic production to the maximum.

Production of natural zinc and lead pigments (sublimed blue lead, sublimed white lead, leaded zinc oxide, and zinc oxide) was reported as follows: in 1943, 192,827 short tons valued at $26,340,947; in 1942, 156,215; in 1941, 228,123. Production of zinc oxide in 1945 was 201,842 tons.

Shipments of slab zinc for munitions manufacture in January, 1945,

reached the record figure of 92,804 tons compared with total shipments by smelters of 92,453 tons; deliveries in March were 94,494 tons; in April, 90,000; in May, 80,000, as reported by the American Zinc Institute. Zinc concentrate was being produced by 56 mills, including 17 tailings plants, on Aug. 5, 1944.

Smelter stocks, excluding large tonnages of government-held stockpiled ore and concentrate, were reduced in March, 1945, to 174,672 tons compared with 246,172 tons reported at the end of November, 1944, by the American Zinc Institute. Continued withdrawals were expected in 1945, but stocks had reached a new peak of 259,333 tons at the end of 1945.

Consumption of slab zinc for producing rolled zinc was 59 per cent higher in 1944 than in 1943 and gained another 50 per cent in 1945.

PRODUCTION OF ROLLED ZINC IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Product	1944	1943	1945
Sheet zinc (0.1 in. thick or less)	10,902	9,099	16,746
Boiler plate and sheets (over 0.1 in. thick)	5,998	3,628	3,057
Strip and ribbon zinc*	58,230	33,979	77,175
Foil, rod, and wire	1,359	1,420	1,406
Total rolled zinc	76,489	48,126	98,384
Imports	15	†	†
Exports	3,403	2,281	5,418
Available for consumption‡	72,749	46,113	98,199

* Not including zinc rerolled from scrap.
† Less than 1 ton.
‡ Includes import-export data.

DOMESTIC PRODUCTION OF PRIMARY SLAB ZINC, IN SHORT TONS
(After U.S. Bureau of Mines)

	1939	1940	1941	1942	1943	1944
From domestic ore	491,058	589,988	652,599	629,957	594,250	574,453
From foreign ore	16,178	85,287	169,421	261,915	348,059	294,849
Total	507,236	675,275	822,020	891,872	942,309	869,302

Of the four lead-blast-furnace-slag fuming plants in North America, treating slag and some oxide ore averaging over 60 per cent of zinc and about 10 per cent of lead, only one (St. Joseph Lead Company, Herculaneum, Mo.) produces metal directly. There are 10 Waelz furnaces in the United States operating mostly on zinc retort residues to obtain zinc oxide fume (including the 75,000-ton annual capacity plant built at Fort Smith, Ark., by the Defense Plant Corporation at a cost of $471,000 and operated by the Athletic Mining

GOVERNMENT-OWNED PLANTS BUILT BY DEFENSE PLANT CORPORATION

Operator	Location	Type of plant	Annual capacity, tons	Approximate cost
American Zinc Co. of Illinois	Monsanto, Ill.	Electrolytic zinc plant	17,000	$6,299,000
American Zinc Co. of Illinois	Fairmont City, Ill.	Zinc, lead, and cadmium smelter	7,200	
American Zinc Co. of Illinois	Dumas, Tex.	Retort zinc plant	17,000	894,000
United Mining & Milling Co	Platteville, Wis.	Zinc-lead mill	450,000	256,000
Panaminas, Inc	Paytes, Va.	Zinc, lead, copper mill	36,000	115,000
Corod Minerals Corp	Marion, Ky.	Zinc, lead, fluorspar mill	35,000	252,000
Hegeler Zinc Co	Hegeler, Ill.	Zinc and cadmium plant	12,880	848,000
Eagle-Picher Mining & Smelting Co	Henryetta, Okla.	Zinc retort and Waelz plant	13,000	583,000

DOMESTIC ZINC-SMELTING CAPACITY
(After American Metal Market)

	1939	1940	1941	1942	1943
Horizontal retorts:					
American Metal Co					10,656
American Smelting & Refining Co					6,400
American Steel & Wire Co					6,080
American Zinc Co. of Illinois					10,656
Athletic Mining & Smelting Co					4,160
Eagle-Picher Mining & Smelting Co					8,896
Hegeler Zinc Co					4,500
Matthiessen & Hegeler Zinc Co					3,696
National Zinc Co					5,504
New Jersey Zinc Co					6,480
United Zinc Smelting Corp					2,368
Total operating‖	48,159	55,328	65,969	65,508	69,396
Vertical retorts:					
Grasselli Chemical Co.*					16
St. Joseph Lead Co.†					6‡
New Jersey Zinc Co.§					50

* 22,000-ton capacity.
† 38,000-ton capacity.
‡ Electrothermic units.
§ Tonnage not reported.
‖ On Dec. 31.

and Smelting Co.). Zinc mining is carried on in ten Western states, seven Central states and four Eastern states. Zinc is smelted or refined in 14 states. Domestic reserves of both zinc and lead ore have been considerably increased by adapting differential flotation to the recovery of complex refractory minerals of the Rocky Mountain region and the Illinois fluorspar district.

In large vertical retorts, briquetted coal ore is charged continuously rather than in batches, as in the horizontal Belgian retorts, and metal of greater purity is recovered.

DOMESTIC ELECTROLYTIC ZINC PLANTS, CAPACITY IN SHORT TONS

Anaconda Copper Mining Co	240,000
Sullivan Mining Co	42,000
American Zinc Co. of Illinois	36,000
American Smelting & Refining Co	29,000

These companies operate five plants and had a total of 3,210 cells at the end of 1945 compared with 2,526 cells in 1941, before construction of a new plant at Corpus Christi, Tex., by American Smelting & Refining Company, in 1942.

The plant of Weirton Steel Company uses the same electrolytic lines that have revolutionized the production of tin plate. Brass output has broken all previous records and is expected to result in a large war surplus. Primary zinc smelters in 1945 had a capacity of 1,054,000 tons; electrolytic plants, 338,000; secondary smelters, 44,000; horizontal- and vertical-retort plants, 672,000.

Of domestic mine output in 1944, the Western states supplied 43 per cent (36 per cent in 1940) and 47 per cent of the United States total recoverable zinc in April, 1945; Eastern states, 25 (in 1940, 28); Central states, 32 per cent, of which the Tri-State region supplied 27 per cent (in 1942, 36 per cent). Oklahoma, the principal zinc-producing state, was followed by New Jersey, which moved into first place in 1945; Oklahoma, holding leadership since 1933, dropped into third place, following Idaho.

The United States has been the leading producer of zinc since 1909. In prewar years, important new deposits were developed in New York and Virginia.

The Tri-State district in 1943 produced only 27 per cent of the total domestic zinc (200,000 tons) compared with 55 per cent (400,000 tons) in 1926. War production was sustained by premium prices; and when these were withdrawn, a sharp slump followed. The depleted state of domestic reserves of zinc ore in 1944 shows tonnage reduced to a 19-year supply, as reported by Elmer W. Pehrson, U.S. Bureau of Mines. Less than 35 per cent of domestic ore remains unmined. Submarginal and highly speculative

resources of zinc are stated to be inadequate for more than 25 years, not including commercial reserves. Reserves of recoverable metal available at the 6-cent price were estimated in 1944 by McKnight and Fitzhugh, U.S. Bureau of Mines, at 11,200,000 tons, more than half of this being inferred ore. Emergency prices would increase reserves to about 17 million tons.

The availability of this low-grade material is stated to be highly speculative or remote because of uncertainties in basic estimates, high costs of recovery, or technologic problems involved in utilization. Although substantial submarginal domestic resources of zinc, a deficient mineral, are available in terms of prewar consumption under emergency conditions and at a high price, greater dependence on foreign sources, nevertheless, has been indicated for the postwar period.

The Office of Economic Stabilization by a directive on Sept. 13, 1946, increased the subsidies on zinc, copper, and lead to encourage exploration where there was reasonable expectation of production by the end of 1947. Mines producing less than 600 tons a month prior to June 30, 1946, were to be paid an exploration premium of 1 cent a pound of metal produced, up to $1,000 a month per mine.

Future zinc demands by domestic industry, including manufactures for export, are expected to amount to about 800,000 tons a year. Only 40 per cent of that amount was available in November, 1944, from unsubsidized domestic mine output, according to a statement by Philip D. Wilson, WPB. The short supply of low-grade zinc and all types of mill scrap, as well as lead and copper, would result in curtailing American basic industries, particularly housing, automotive, and electrical output, it was stated in September, 1946, by T. E. Veltfort, manager of the Copper & Brass Research Association.

World Production, Imports and Exports. Shortages of metals and minerals in Europe in prewar years made it necessary to import 20 per cent of the consumption of zinc. Control of the zinc industry is based on control of reduction plants rather than on ownership of ore deposits. Ore-buying, metal-selling organizations, smelters, and mines were decentralized in the years following the First World War. Britain, France, Norway, and Belgium have inadequate mining operations to supply the ore for smelter output of zinc metal. The Netherlands produces no ore but has substantial smelter capacity. World capacity for the production of ingot zinc in 1940 was estimated at 2,360,000 metric tons, about one-third being in electrolytic plants.

World smelter output of zinc in 1939 was as follows: United States, 460,154 metric tons; Germany and Czechoslovakia, 212,285; Belgium,

185,700; Canada, 159,338; Poland, 117,936; Australia, 72,363; France, 60,262; smaller amounts were reported by 10 other countries. Ore production was secured in 1938 from 35 countries. World mine production of 2,044,000 short tons in 1942 was reported by the U.S. Bureau of Mines. Major prewar zinc-producing countries, in order of importance, were the United States, Canada, Australia, Germany, Poland, Mexico, and U.S.S.R. The United States in 1938 led in production of zinc ore and in smelter capacity; Australia ranked second both as a producer and exporter of ore; and Belgium ranked second in smelter output. Mexico, the largest exporter, held fifth place as a producer.

Only the British Empire and Spain hold national self-sufficiency in zinc. The United States and U.S.S.R. have zinc adequate to meet domestic demands; Germany, Italy, and Japan have zinc resources inadequate for domestic needs; whereas France, Belgium, the Netherlands, and China are dependent almost entirely on foreign sources. Belgium ranked first as an exporter of refined zinc in 1938, accounting for 27 per cent of the combined world exports of this metal. Canada follows Belgium in exports of refined zinc. Britain in 1938 imported more refined zinc than Germany, France, and Japan together. Japan was supplied chiefly from Canada and Australia. Zinc demonstrates, perhaps more effectively than other metals, the interdependence of nations for mineral resources.

Imports of zinc ore and concentrate in 1940 increased 400 per cent, made up largely of ore from Canada, Newfoundland, and Mexico which formerly had been treated in Europe; smaller amounts were secured from Peru, Argentina, Chile, and Australia. Imported ore and concentrates were 10 per cent lower in 1945 than the previous year at 382,500 tons, distributed as follows: Mexico, 48 per cent, Canada, 24; Bolivia, 9; Peru, 8; Newfoundland, 6; Australia, 4. Slab-zinc imports in 1945 were estimated by the U.S. Bureau of Mines at 48 per cent higher than 1944 and the largest tonnage since 1919. Imports from Mexico were unchanged, but double the 1944 tonnage was received from Canada. All import controls on slab zinc were removed by the WPB on Sept. 5, 1945. Slab zinc imported in 1944 from Canada was 111 per cent higher than in 1943. The total imported in ore and as slab zinc in 1944 was 18 per cent lower than the 1943 record volume and included 422,700 tons of ore, 42 per cent coming from Mexico, 27 per cent from Canada, and 10 per cent each from Peru and Australia; in 1945, 379,473.

Exports of zinc ore and manufactured articles containing zinc of foreign and domestic origin (excluding galvanized products, alloys, and pigments) reached a total value of $11,302,228 in 1940, more than five times the 1939 volume. Exports were 76 per cent lower in 1945 than in 1944.

EXPORT SHIPMENTS OF SLAB ZINC FROM THE UNITED STATES, IN SHORT TONS
(After American Zinc Institute)

1940	1941	1942	1943	1944	1945*
88,165	106,195	151,650	56,208	6,988	7,780

* U.S. Bureau of Mines.

Output of zinc concentrate available for import to the United States or elsewhere from North America in 1944 was estimated at more than 200,000 tons of recoverable metal; from South America, 65,000; Australia, 50,000. Government foreign procurement, combined with private purchases, was at the rate of roughly 400,000 tons a year of zinc metal and metal in concentrate in February, 1945. Practically all imported zinc was delivered at ceiling prices or less.

Canada, holding second place among zinc-producing countries, reported an estimated 142,894 short tons in the first 7 months of 1946 and for all 1945, 183,317 tons of refined metal; in 1944, 275,412; in 1943, 305,377 valued at $24,430,174; in 1942, 290,129; in 1941, 256,191; in 1940, 185,722 short tons. Over-all zinc production in Canada, Sept. 1, 1939, to Sept. 1, 1945, amounted to 1,585,200 short tons valued at $120,117,800.

The Sullivan mine, at Kimberley, British Columbia, operated since 1909 by Consolidated Mining and Smelting Company, is the zinc producer accounting for about 55 per cent of Canada's total. The concentrates are hauled 185 miles from the 8,000-ton concentrator at Kimberley to the smelter and refinery at Trail. Recovery in British Columbia is reported by several small-scale operators. Zinc is mined in Quebec, Ontario, Manitoba, and Saskatchewan. Hudson Bay Mining and Smelting Company and Sherritt-Gordon, both in northern Manitoba, are major zinc producers. In Quebec, Normetal, Waite Amulet, and New Calumet are important producers. Canada exports about 77 per cent of its zinc chiefly in refined form. Canada depends on the British market as an outlet for refined zinc. It was regarded as a serious threat to Canadian economy that British contracts for zinc expired in September, 1945. The Metals Controller on May 11, 1942, prohibited the buying or selling of zinc without a permit; only an inventory control was required after June 7, 1945, and all restrictions were removed in August.

In Newfoundland, the Buchans mine, developed in the early 1930's, exported 130,200 tons in 1938. Newfoundland held third place, following Mexico and Australia, as an ore shipper, chiefly to Britain and Belgium. In the war years, the ore was exported to the United States. Mine production of zinc in 1943 was 66,418 short tons contained in zinc concentrate and in lead-copper concentrate; in 1944, 59,472.

Zinc valued at $127,000,000 was included in the total of $1,952,000,000 spent abroad for metals and minerals by the Department of Commerce in foreign financial and supply transactions, from July 1, 1940, through June 30, 1945. Inventories held abroad included a total of $87,000,000 in metals and minerals, of which $72,000,000 was held in Canada, including MRC stocks of zinc valued at $6,000,000.

Mexico, the largest zinc producer in Latin America, averaged 200,000 tons a year in 1941–1943. Production in 1941 was 170,495 metric tons, chiefly in concentrates and semirefined form, of which all but 3.8 per cent was exported. In prewar years, the zinc exported averaged about $18,000,000 in value. Zinc-mining activity has been closely linked with economic and political growth, about 70 per cent of total exports being accounted for in mineral products. Industry is being developed for the manufacturing of zinc into finished products to replace imports, although at present, exports for reduction in the United States account for all but about 55,000 tons of concentrate (in 1941, 6,517 tons), which is shipped to the Rosita retort plant.

In Mexico more than 100 zinc-lead mines produce complex ores at a monthly rate of from 5 to 150 tons, the ores or concentrate being sold to large American operators. A growing interest was reported in February, 1945, in reopening certain older mines having known reserves of zinc-lead ores, located in the Topia, Durango, Chihuahua, and Michoacan districts. Mexico gives promise of lesser potential output, dependent on a higher zinc price and improved transportation facilities.

Peru, an important producer of zinc concentrate from mines of Cerro de Pasco Corporation, has reserves of lead-zinc-silver ore estimated in millions of tons. Other known deposits of lead-zinc ore have not yet been developed. One medium-sized property rated a potential producer had not reached the stage of shipping ore in February, 1945. Peru faces the prospect of reduced potential production unless the zinc price is increased. Better transportation facilities are also required. Pilot electrolytic zinc-plant operations were reported in 1944.

In Bolivia, annual zinc production averages about 8,000 tons from the Huanchaca mine of Hochschild Company. A medium-sized property was reported in February, 1945, as a potential producer but had not reached the stage of shipping ore. Production was reported at 6,065 tons in 1941; in 1942, 10,099; in 1943, 21,074; in 1944, 16,319 (zinc content in ore and concentrates). Mexico, Peru, and Bolivia negotiated agreements with the Federal Loan Agency, through the MRC, for purchase of the entire exportable surplus of zinc, one of 25 minerals included under the procurement program initiated with Latin-American countries late in 1940.

In Argentina, the Aguilar mine of St. Joseph Lead Company is the only large producer, zinc concentrates being shipped to the United States. A plant for the reduction of zinc concentrate was reported under construction in 1945. Large-scale industrialization of the mineral industries in Argentina has been appraised as impractical, because of dependence on imported coal and coke and about one-third of petroleum requirements. Pilot electrolytic zinc-plant operations were reported in 1944 in both Argentina and Brazil.

With capital available from raw materials exports and from loans through the Export-Import Bank for making machinery and equipment purchases in the United States, certain Latin-American countries are attempting to utilize raw-material products locally by erecting processing plants for zinc ores.

In Alaska, zinc has not been brought into widespread commercial production, as reported on May 7, 1945, by U.S. Geological Survey, but favorable possibilities have been indicated for important advances in the postwar period.

The Board of Trade reported on Dec. 28, 1945, that Britain's position, as far as raw materials were concerned, did not give rise to anxiety. Economy in the import of materials was required, particularly where these were of little aid to the export position. Zinc was in adequate supply, with consumption of 128,810 tons in the first 9 months of 1945 reported by the Directorate of Nonferrous Metals in December, 1945; consumption in all 1944 was 184,341 tons. Cutting down the output of heavy munitions resulted in stopping all shipments to Britain, under lend-lease, of high-grade and intermediate zinc from the United States on Oct. 1, 1945. Metallic zinc from concentrates produced within the British Empire was estimated at 100,000 tons in 1944 compared with 68,000 tons in 1940. British-government running contracts on Empire zinc for war uses were in effect from September, 1939, to Aug. 16, 1945, when they expired. These contracts, plus England's sales to India, South Africa, and the United States, absorbed the total Empire zinc output.

In Australia, the 1944 zinc output was estimated at a rate lower than in 1942. Roaster- and acid-plant operations at Electrolytic Zinc Company of Australia, Risdon, Tasmania, were increased in 1944. The Broken Hill district, major zinc producer in the British Empire, contains the world's richest known ores. Broken Hill mines were under lease to German interests prior to the First World War, when the lease was terminated. Zinc ores, concentrates, and metals of Australia will continue to be marketed until 1986 by Zinc Producers Association Proprietary, Ltd., of England. The Mount Isa mine in north Queensland is an important new producer that has been

described as a dependable world source of both zinc and lead. Ore reserves were reported at 8 million long tons containing 8 per cent zinc and 8.6 per cent lead.

Britain took action in 1918 to control Empire supplies of zinc concentrates which, before the First World War, came under German control of world nonferrous metal markets. The German cartel held long-term contracts for smelting zinc ores from most of the large producing countries outside the United States.

The Waelz revolving furnace was developed in Germany in 1926 and made possible more efficient and profitable smelting of the calamine and smithsonite ores in Poland and Germany. Smelters in Poland became increasingly dependent on zinc ores from German Silesia near Beuthen. Poland, under the Versailles Treaty, acquired the greater part of the zinc-ore deposits and mines of German Silesia, together with zinc oxide works, smelters, lead and silver plants, and most of the rolling mills. Poland has been one of the largest producers of zinc, having the advantage of coal fields located close to the mines.

The German zinc industry in prewar years was divided into companies smelting ores produced by their own mines and those smelting foreign ores and selling the metal in domestic markets. The industry was expanded to high efficiency with government aid. New smelters were built at Madgeburg, Saxony; Oker, Brunswick; and Duisburg, Rhine province.

Japan was known to have increased its purchasing of metals and minerals in prewar years, in spite of the military-secrets law adopted in 1937. Smelting capacity was enlarged and adequate foreign supplies of zinc, lead, and tin were secured by the invasion of the Netherlands East Indies and Burma. Edwin C. Pauley, United States reparations representative, on Nov. 16, 1946, submitted recommendations to President Truman on the exaction of reparations from Japan. Refining of zinc, lead, tin, sulfur, and pyrites was to be immune from reparations; substantial removal of facilities was proposed in the categories of iron and steel, iron ore and ferroalloy minerals, copper, chemicals, and industrial explosives.

Latest figures for Poland show an annual output of 130,000 to 180,000 metric tons; Germany, 40,000 to 55,000. The greatest zinc-lead mining areas of Europe are located in Silesia, the principal mines being along the southeast boundary of German and Polish Silesia. This area has produced an estimated 75 per cent of the zinc-lead supplies of Germany since 1940. Zinc-lead mining and refining in Silesia are principally at Katowice, Poland, and Beuthen, in German Upper Silesia, and at Gleiwitz and Hindenberg, in Germany. German zinc consumption increased from 132,000 metric tons in

1932 to about 320,000 tons in 1940. The capture of Poland in 1939 made available mine production adequate to supply all war needs.

German reparations to U.S.S.R. and Poland were to be taken out of the eastern zone, it was reported by Edwin C. Pauley on Oct. 11, 1945. Poland and U.S.S.R. were also to receive 25 per cent of the industrial equipment of the western zone, which was controlled by the United States, Britain, and France. In exchange for this equipment, U.S.S.R. and Poland were to deliver various commodities, including clay products, potash, and zinc, equal in value to three-fifths of the amount received from the western zone. The United States limited reparations claims to patents, samples of specialized machinery, "know how," and German foreign-exchange assets.

In Belgium, zinc smelters were not seriously damaged by the German occupation. Inactivity up to the time of the German retreat late in 1944 caused some deterioration.

The Trepca lead-zinc mines in Yugoslavia were to be expropriated without compensation to the British company, it was announced by Marshall Tito's Socialist government on Nov. 11, 1946. The owners of Trepca were declared to have been collaborators with Mikhailovitch and Germany. The French-owned Bor copper mines were similarly expropriated as sequestered property that had been sold to Germany in 1939. Trepca concentrates were exported for treatment. Other European producers are Sweden, Spain, Italy, Greece, and other areas in the Balkans.

U.S.S.R. has major zinc-lead deposits in south Kazakstan, in west Siberia, and in the Caucasus and Altai regions. A zinc-lead smelter reported to be the third largest in the world was under construction in 1937 in Kazakstan. A potential producing district of major importance was reported in Central Asia near Tashkent. Refinery capacity adequate for domestic requirements was completed in 1936. The two largest refineries are electrolytic plants having annual capacity of 90,000 tons, located in the central Urals and west Siberia.

Economic and political factors were expected to determine postwar zinc supplies from Canada, Mexico, Peru, and Australia, where greatly expanded ore supplies have been made available. Although adequate domestic zinc was formerly available, postwar needs of the United States are expected to involve importing about 40 per cent of requirements. In the war years, construction of four large zinc refineries was completed; these increased refining capacity over domestic ore supply and will be available for treating foreign concentrate. However, postwar foreign output may be shipped as slab zinc rather than as concentrate.

WORLD SMELTER PRODUCTION OF ZINC, IN METRIC TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943	1944
Australia	72,363	76,736	80,840	78,180	73,506	79,398
Canada	159,338	168,486	193,784	195,769	187,342	153,934
France	61,019	37,843	25,918	22,829	17,770	8,367
Mexico	35,369	33,388	38,678	51,743	54,449	46,630
Spain	13,396	12,322	19,143	19,150	19,200	18,048
United States	460,154	612,596	745,720	809,088	854,844	788,613

Prices. The price of Prime zinc ore, 60 per cent concentrate, at Joplin, Mo., was quoted, 1942–1945, at $55.28 a ton; $50 on Sept. 30, 1946. Subsidy payments of $5 per ton to smelters treating Tri-State concentrates were terminated at the end of December, 1945, and smelters reduced the price for all grades to $50 a ton.

The East St. Louis ceiling price of 8.25 cents a pound for Prime Western zinc was in effect from 1942 through Sept. 30, 1946. The price in 1941 was 7.474 cents; in 1940, 6.335 cents. Average prices of Prime Western slab zinc at East St. Louis (after *American Metal Market*) were as follows: 1915–1924, 8.29 cents; 1925–1934, 5.31 cents; 1935–1944, 6.40 cents. Prices for Prime Western at New York were as follows: 1915–1924, 8.61 cents; 1925–1934, 5.66 cents; 1935–1944, 6.79 cents. Zinc blende, 60 per cent concentrate, in the Joplin district averaged $51.59 per ton, 1915–1924; $35.09, 1925–1934; $42.01, 1935–1944.

On Oct. 30, 1946, the OPA increased producers' ceiling prices 1 cent per pound of zinc contained in zinc anodes and special shapes, primary and secondary zinc-base alloys, zinc dust, wire and battery cans, and battery sides and bottoms.

When ceiling prices were established on Nov. 9 by the OPA, both zinc and lead prices advanced to 10.5 cents a pound, as announced by the American Smelting & Refining Company. Kennecott Copper Corporation increased the price of domestic copper to 17.5 cents a pound. Government imports of copper and lead continued to be permitted, but this did not apply to zinc. These metals could be exported or imported by individuals and corporations under license only, until the law expired Mar. 31, 1947. Subsidy payments to domestic zinc, copper, and lead producers were to continue through June 30, 1947, if metal prices did not rise above the old ceiling levels. Grade A tin recovered from scrap advanced 18 cents to 70 cents a pound at New York, on Nov. 14, 1946.

The average cost of domestic zinc under the premium-price plan was 11

cents a pound, as announced in November, 1944, by P. D. Wilson. The average weighted price for all grades, including bonus payments by the MRC to marginal producers, was as follows (after *American Metal Market*): 1942, 9.3 cents; 1943, 10.8 cents; 1944, 11.4 cents; in 1945, 11.5 cents (figures for 1944–1945 from the U.S. Bureau of Mines). Price stability of zinc has been a notable achievement since 1941, in contrast to the First World War increase of about 100 per cent.

The premium-quota plan, effective Feb. 1, 1942, provided for payment by the MRC of a premium on all domestic production of zinc, copper, and lead in excess of monthly quotas as established by the WPB and the OPA and approved by the MRC. This premium reflected the difference between the ceiling price and the equivalent of 11 cents a pound for zinc, at East St. Louis, subject to prior termination of the national emergency before July 31, 1944.

During the life of the WPB, since Feb. 1, 1942, quotas including one or more of the three metals zinc, copper, and lead were issued to 3,700 mines. Total payments were as follows: $25,900,000 in 1942; in 1943, $72,600,000; in 1944, $83,400,000. In 1945, payments of $36,205,177 were made by the Office of Metals Reserve for overquota mine production and special mine contracts, as reported by the OPA. Premiums on zinc increased from 29 per cent in 1942 to 64 per cent in the first 6 months of 1945. The general policy of the quota committee relating to the premium-price plan for overquota production of domestic zinc continued through 1945. On Nov. 9, 1946, President Truman took sweeping action to decontrol prices. The only metals to continue under production controls, in order to maintain supplies, were zinc, copper, and lead. These were allowed subsidies under the premium-price plan amounting to $25,000,000 during the period July 1 to Nov. 9, under the Price Control Extension Act.

There has been no subsequent change in the ceiling price, with the basic A premium remaining at 2¼ cents a pound. Congress extended the effective period of the premium-price plan for zinc, copper, and lead, in force since Feb. 1, 1942, until July 31, 1945, and again to June 30, 1946, by Public Law 88, under the Hayden-McFarland bill, S-502. The quota committee continued to function under the Civilian Production Administration after Nov. 3, 1945, when the WPB was terminated.

The "world price" amendment to the Price Control Extension Act, adopted Oct. 14, 1946, forced the OPA to increase the legal ceiling of slab zinc 1 cent a pound. This applied to all grades of zinc, raising prices to the following levels: prime Western, 9.25 cents; selected, 9.35; brass special, 9.5; intermediate, 9.75; high grade and special high grade, 10.25.

The OPA declined to suspend price controls on zinc due to "present and

prospective demand for the metal, compared with supply, to avert price fluctuations . . . and to avoid the difficulties of controlling prices of products made of zinc." Domestic prices were to be held at a high level to enable importers to compete for world supplies. The ceiling price of zinc had been exceeded since April, 1946, after adjusting the average zinc price in foreign markets for freight and duty. This had resulted in a substantial decrease in imports.

The premium-price plan was broadened in February, 1943, to cope with changing conditions in the zinc industry. The B and C premiums were added, on joint recommendations of the WPB and the OPA, to increase the maximum premium to 8¼ cents a pound. This premium, over the basic A premium, was payable on quotas made available only in those special cases where the basic A premium would not provide revenue adequate to secure the necessary maximum production. In order to assist zinc smelters operating on concentrate from the Tri-State district, a subsidy of $5.28 per ton was paid on zinc concentrates that averaged about 400,000 tons a year.

Premium rates in November, 1945, were as follows: 2¾ cents on production in excess of basic A, B, and C quotas; as specified, on production in excess of special quota.

Secondary slab zinc classified as high grade was given a base ceiling price of 9.25 cents a pound, delivered at buyer's receiving point in carload lots, by the OPA, effective Mar. 20, 1946. Sheet zinc, f.o.b. works, was 13.15 cents a pound; ribbon, 12½ cents (discount on 18 tons or more).

Congressional action was started in May, 1945, to modify the Reciprocal Trade Agreements Act in order to reduce tariffs another 50 per cent. Before the war, zinc products felt the adverse effects of imports, and domestic producers feared that serious problems for the industry would be raised under the proposed lower tariff rates when normal trade conditions were restored.

Purchases of foreign zinc by the Foreign Economic Administration in 1945 were made on the basis of East St. Louis, the price rolled back to the foreign delivery point by reductions for charges against smelting, penalties, handling, transportation, insurance, and other similar costs, but with import duties for the buyer's account.

Under the Mexican agreement, tariff on zinc ore and slab zinc was reduced to 50 per cent below the 1930 rates. The Mexican agreement substantially reduced the tariff on zinc oxide and zinc sulfate. No restoration of duties at the end of the war had been indicated. A 20 per cent reduction was made in the Canadian agreement, which had been effective since Jan. 1, 1939.

The Metals Control in London quoted zinc at £31 5*s.* per long ton on June 11, 1945, compared with the official maximum price of £25 15*s.* in effect

from Sept. 1, 1939, for foreign zinc delivered to consumers, duty paid. The average London price of G.O.B. spelter was £44 18*s.* 10*d.*, 1915–1924; £22 1*s.* 10*d.*, 1925–1934. The London price ceiling on zinc was increased by the British Ministry of Supply on Apr. 8, 1946, £8 to £39¼ ($157 U.S.) a ton. The British had been buying zinc at prices in excess of the United States ceiling of 8.25 cents a pound, the action being in contrast with the policy announced on Mar. 30, 1946, by Economic Stabilizer Chester Bowles that increased subsidies would be made to zinc producers in order to offset increasing labor and other costs. Quotations of the London Metal Exchange were discontinued in September, 1939, and had not been resumed up to the end of 1945.

In Canada, the average price of zinc in 1944 was 4.3 cents a pound (Canadian funds, based on London quotations); in 1943, 4 cents. The Wartime Prices and Trade Board, on Nov. 14, 1946, issued an order giving primary producers a share in the profits on manufactured metal articles containing zinc, copper, and lead, when these articles were sold in export markets. This arrangement was made to apply to 42 companies using zinc, copper, and lead in their manufactures. Price controls continued in Canada.

Zinc duties set by the tariff act of 1930 and the revenue bill, effective on June 21, 1932, as corrected to Feb. 1, 1943, embracing revisions resulting from reciprocal trade agreements, were as follows: zinc-bearing ores, except pyrite containing not over 3 per cent of zinc, ¾ cent a pound; slabs, blocks, pigs, and zinc dust, ⅞ cent; sheets, 1 cent; sheets coated with other (not precious) metals, 1⅛ cents; old zinc, for manufacture only, ¾ cent; oxide (dry powder), 1.1 cents; oxide (with oil or water), 1½ cents.

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ZIRCONIUM ORE AND BADDELEYITE

Properties. Ranking nineteenth among the elements in primary abundance, zirconium is one of 19 industrial nonferrous metals used essentially as alloying constituents. Extensive study of the metal shows it to be stable in the presence of moisture even in finely divided form; when heated, it reacts energetically with all elements except the gases, a property leading to its extensive use as a "getter" in vacuum tubes. The metal has strong affinity for oxygen and burns brilliantly when heated in air. It is reported to be the most explosive metal powder. The pure metal is as soft as copper, with a strength of approximately 135,000 lb. per sq. in. Zirconium has a blackish gray color similar to titanium. It has density of about 6.5, not represented by other metals. Zirconium oxide (ZrO_2) has density of 5.73. (Zr, atomic number, 40; atomic weight, 91.22; melting point, 1700°C.)

Baddeleyite (zirconium oxide) is colorless to yellow, brown, and black; its hardness is 6.5; its specific gravity, 5.5 to 6. The silicate group includes zircon ($ZrSiO_4$), having a hardness of 7.5 and a specific gravity of 4.68 to 4.86. A complex zirconium silicate (lavenite) occurs in yellow to brown prismatic crystals. Zirconium-bearing minerals are commonly concentrated in local faces of nepheline syenite rocks.

Zircon, essentially a silicate of zirconium, occurs in square prisms and in irregular forms and grains. Large crystals weighing up to 10 lb. have been found in contact rocks, particularly granite, syenite, and pegmatite. Black sands are, in many cases, rich in minute zircon crystals, Australian monazite sand from ocean beaches being the principal world source. Zircon and baddeleyite are the only commercial ores of zirconium.

Zirconium is a constant and almost inseparable companion of hafnium, the two elements having similar chemical properties, as is the case with tantalum-columbium and the rare earths. Ferrozirconium can be made in the electric furnace by reduction of zircon and iron ore or by reduction of the mixed oxides with aluminum. Alloys of zirconium with iron, magnesium, aluminum, cobalt, and silver have been prepared. Steels treated with zirconium show increased ductility and greater resistance to shock and fatigue failure. Zirconium hydride is used in powder metallurgy.

Uses. Zirconium was widely used in steel for war materials. Early in the 1930's, no commercial application had been established, although prior

to that time, zirconium filaments in electric lamps were being used. In the war years, the metal increased in importance for fabricating wire used in the manufacture of radio tubes, for zirconium-silicon and zirconium-ferrosilicon in the steel industry, and as sheet metal for the manufacture of spinneret cups for rayon. Ductile zirconium is produced for use under certain corrosive conditions, in electronic tubes, in lamp filaments and welding rods in spot welding. In electrical heating units, zirconia is an important metal due to its properties both as a conductor and as an insulator of electricity.

The strength of copper is doubled through the addition of 7 per cent of zirconium, which has been found to improve the high-temperature conductivity and tensile strength of cast nickel-copper alloys. Metal anodes are sometimes sprayed with zirconium powder to improve their performance. Metallic zirconium is employed in the manufacture of ammunition primers, electrodes, and radio-transmitter tubes. The metal powder is used in photoflash bulbs, flares, and blasting caps. Nickel containing up to 10 per cent of zirconium produces a hard alloy that requires no tempering, which is of use in high-speed machine tools. In steelmaking, ferrozirconium acts as a deoxidizer and scavenger to remove oxygen, nitrogen, and nonmetallic inclusions. In certain steels, small additions of zirconium improve hot-working properties, surface characteristics, and impact strength. In armor-piercing bullets and in cutting tools, zirconium-nickel alloy may be substituted for tungsten.

Used increasingly in refractories, in specialized porcelains, and in certain types of glaze or heat-resisting glass, zircon (zirconium ore) is the raw material employed in the manufacture of opacifiers and other compounds. The zirconium supply was reported in 1942–1943 as being used chiefly as an opacifier in porcelain enamels and pottery glazes and a constituent of refractories, electrical and chemical porcelains, grinding balls, and heat- and chemical-resistant glasses. Zircon refractories are used as linings in aluminum remelt furnaces. One of the major uses of zircon is as a foundry sand. Valuable properties of zirconium oxide as a refractory include its very high melting point, resistance to corrosion, low coefficient of expansion, low heat conductivity, and long service. As a refractory, the oxide is used in the form of brick, crucibles, muffles, and laboratory utensils. Fused silica is given improved properties by the addition of up to 1 per cent of zirconia. In porcelain, the strength, electrical resistance, and resistance to temperature changes are improved by the addition of 15 per cent of ZrO_2, which is also a constituent of polishing and toilet powders. Applications of zirconium oxide and other compounds are added to rubber, white leather, and resins; they replace tin compounds in weighting silk; are satisfactory pigments in white paint; and are used as dye extenders, water repellents, and

catalysts. As a white tanning agent, zirconyl sulfate is reported to be possibly superior to chrome.

Zircon stones, hard and tough, are used in addition to the diamond and sapphire as bearings for meters and various scientific instruments and for timing instruments, such as mechanical fuses for bombs, switches, and microgears. Baddeleyite was formerly a source of zirconium oxide for the manufacture of incandescent gas mantles.

In vitreous enamels and ceramic glazes, zirconium is replacing both antimony and tin oxide to an increasing extent, owing to its nonpoisonous property and the opacity secured with 2 per cent of zirconium. This is the equivalent of 6 per cent of antimony oxide. Zirconium may become a postwar substitute for stainless steels; various other applications also have been indicated. As a substitute for platinum in the preparation of noncorroding chemical apparatus, an alloy has been used consisting of 6.8 per cent of zirconium, 53.5 per cent of columbium, and 39.7 per cent of tantalum. Zirconium-nickel alloys have been employed as a substitute both in armor-piercing bullets and in cutting tools. Various uses for zirconium were developed in Germany in the war years. It served in alloyed form as a substitute for platinum and the metal for flash bulbs, in vacuum tubes, and for time fuses in bombs.

A postwar use of zirconium oxide for a new kind of electric lamp was announced in March, 1946, by the Long Island laboratory of Western Union. In this lamp, the oxide is employed on one of two electrodes within a small glass bulb filled with argon gas. Electric current causes the zirconium to melt, glowing ten times as brightly for its area as the brightest tungsten filament. This point source of light is produced by a concentrated arc in which the speck of molten oxide is 3/1,000 in. in diameter. Applications were proposed for microscopes, motion-picture projectors, and various optical instruments.

Domestic Sources of Supply and Production. A method for obtaining zirconium on a commercial scale was perfected in the early 1930's. In 1927, domestic output amounted to 3,646 short tons, but no production was secured in 1929–1939. Output increased in the period 1940–1943 amounting to several hundred tons. In the war years, production and use studies were carried on by Dr. W. J. Kroll at the Electrodevelopment Laboratory of the U.S. Bureau of Mines, Albany, Oreg. Adequate reserves are available both in domestic deposits and in American-controlled sources in Peru for strategic war requirements.

Zircon is abundant in gold-bearing sands in North Carolina and California. In Henderson County, North Carolina, production has been secured

from decomposed granite and pegmatite. It also occurs in beach sands on the Florida coast. Near Pensacola, zircon, rutile, and kyanite were reported in 1945 by the U.S. Bureau of Mines, in commercial quantity in the beach concentrate. These beach deposits have an estimated content of 750,000 tons of material averaging 0.4 per cent of zircon plus 1.2 per cent of kyanite, 1 per cent of ilmenite, and 0.1 per cent of rutile. No production has been reported.

The only producer up to 1943 was Riz Mineral Company, zircon being recovered from beach sands near Melbourne, Fla., worked mainly for rutile and ilmenite. Ore feed for the concentrator is black sand recovered from dunes 3 miles inland from the coast. Crude zircon concentrates were produced in 1943 by two other companies: Rutile Mining Company, subsidiary of Titanium Alloy Manufacturing Company, as a by-product of rutile-ilmenite sands near Jacksonville, Fla., and Southwestern Engineering Company, as agent for the Metals Reserve Company, as a by-product of chromite from beach sands in Coos County, Oregon. Production in Oregon amounted to 2,143 short tons averaging 27 per cent of ZrO_2. Preliminary tests were made in 1942 by the U.S. Bureau of Mines on concentrating zircon from Oregon beach sands.

Domestic buyers of zircon include the following: Westinghouse Electric Company, Titanium Alloy Manufacturing Company, Zirconium Products Company, and E. J. Wiggans, Pittsburgh, Pa.

The MRC made a first commitment for the purchase of zircon for stockpiling in 1941; at the end of 1942, MRC stocks held 4,590 short tons of zircon and 4,156 tons of baddeleyite. Ranking thirty-second among stockpile items in cost of delivery, zirconium was purchased at a total cost of $1,044,582. No sales were reported, but the value of stockpiled zirconium declined to $825,960, as shown by the inventory of Oct. 31, 1944. Zircon amounting to 2,581 short tons and baddeleyite amounting to 15,829 tons were in government stocks held by the RFC, through the Office of Metals Reserve, on Oct. 31, 1945, as reported by the Civilian Production Administration.

Zircon concentrates were placed under import control by the War Production Board on Dec. 27, 1942, in Order M-63, and freed Oct. 1, 1944.

By a proclamation and an executive order, President Truman on Sept. 28, 1945, took jurisdiction over the natural resources of the continental shelf contiguous to the coasts of the United States. Although no minerals have ever been discovered in the subsurface lands of the continental shelf, evidence indicating their presence has been found in the inland sands around Jacksonville, Fla., and along the Gulf coast of Texas and Louisiana. Zircon was one of five minerals, in addition to petroleum, that have been indicated in offshore

areas. "The rapid development of technical knowledge and equipment occasioned by the war now makes possible the determination of the resources of the submerged lands outside of the three-mile limit." The proclamation was for the purpose of carrying on orderly development of these resources. Prior to the Second World War, advanced technology had made possible the exploitation of a limited amount of minerals from submerged lands within the 3-mile limit.

World Production, Imports and Exports. World consumption of zirconium in the early 1930's did not exceed 300 tons a year, compared with consumption in the United States alone, in 1940, of about 6,000 tons.

The United States, in 1940, imported 16,845 short tons of zirconium concentrates, of which about half was mixed zircon-rutile concentrate from Australia. Of the 1941 imports, zircon dioxide from British India and Ceylon accounted for 3 per cent. Government purchases of zircon in Australia were stated to be for the purpose only of stimulating an increased production of rutile from concentrates containing zircon and rutile. Exports of zirconium concentrates amounted to 94 short tons in 1943, with 90 tons of alloys and metal and 211 tons of compounds. No zirconium ferroalloys were imported in the war years. Imports in 1942 were 33,906 tons; in 1944, 24,033.

In Canada, zircon is widely distributed in pegmatites both north and south of the Ottawa River. The silicate (lavenite) occurs in southern Norway.

Brazil has been an important producer of baddeleyite since 1919 (24 per cent of the 1941 imports). Brazil, if required, could supply the total United States consumption. In the Caldas district, rolled pebbles in the diamond sands are nearly pure ZrO_2. In the state of Rio Grande do Norte, near Santa Cruz, crystalline zirconium ore occurs in a deposit 17 m. thick. Beach deposits of Espiritu Santo have produced considerable tonnage of zircon, of which regular deliveries are made to consumers, as reported in May, 1945, by James S. Baker, Foreign Economic Administration.

Zircon was one of 10 minerals included in the agreements negotiated by the Federal Loan Agency, through the MRC, the entire exportable surplus from Brazil being part of the foreign procurement progam initiated late in 1940.

Zircon stones are by-products of sapphire mining in Ceylon, occurring in stream gravels derived from crystalline limestone, gneiss, and schist. Indo-China has been a source of gem-quality zircon.

In 1944, the FEA followed the policy of withdrawing from public purchase of foreign zirconium compounds when possible, returning the trade to former private channels if no impairment to the war effort resulted.

ZIRCON CONCENTRATES IMPORTED FOR CONSUMPTION IN THE UNITED STATES, IN SHORT TONS
(After U.S. Bureau of Mines)

Country	1939	1940	1941	1942	1943
Australia	1,526	7,387	14,689	11,145	11,472
India	241	3,609	963	196	
Brazil	.....	.....	.....	.....	110
Brazil (baddeleyite)	706	1,591*	5,002*	15,283	8,821

* Zircon included with baddeleyite.

Prices. The price of zircon ore, 55 per cent of ZrO_2, f.o.b. Atlantic seaboard, was quoted on May 10, 1945, by *E & M J Metal and Mineral Markets*, at $65 to $75 a short ton ($60 to $70, 1940–1942). Commercially pure zirconium metal, powdered, was $7 a pound in 1940–1945. Pure ductile zirconium is sold as sheets, wire, and rods. Zirconium metal, 98 per cent, was $15 a pound in 1927. Zirconium ferrosilicon was quoted at $102.50 to $107.50 a long ton for 12 to 15 per cent zirconium content; 35 to 40 per cent, 14 to 16 cents a pound. Powdered zirconium metal is $7 a pound.

Alloys were quoted as follows: 12 to 15 per cent zircon, 39 to 43 per cent silica, $102.50 to $107.50 a gross ton; 35 to 40 per cent zircon, 47 to 52 per cent silica, 14 to 16 cents a pound.

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INDEX[1]

A

Acres, Henry G., 44
Adkerson, J. C., 301
Afghanistan, ruby and sapphire production, 420, 426
Africa, 9, 12, 14
  copper, 149, 155
  manganese, 300
  East, soda-ash production, 451
  French, nickel, 365–366
    phosphate rock, 59
  South (*see* Union of South Africa)
  South-West (*see* South-West Africa)
African Manganese Mines Company, Ltd., 309
Agriculture, Department of, 375, 377
Aircraft Resources Control Board, 291
Alabama, mineral production, bauxite, 79
    graphite, 203
    iodine, 210
    iron ore, 222
Alabama Flake Graphite Company, 203
Alaska, minerals produced and indicated, antimony, 8, 54
    asbestos, 70
    barite, 74–76
    bismuth, 95
    chrome, 8, 121–122, 125
    copper, 159
    graphite, 206
    iron ore, 233
    lead, 8, 265
    mercury, 8, 318, 323
    molybdenite, 346
    nickel, 363
    platinum metals, 8, 383, 389, 401
    ruthenium, 422
    silver, 8, 443
    sulfur, 466
    tin, 8, 496
    tungsten, 522
    zinc, 567
Alcoa, Tennessee, aluminum reduction works, 35, 38
Alcoa Mining Company, 80
Algeria, mineral production, antimony, 52
    iron ore, 236, 242
    phosphate, 60
    potash, 406
    pyrites, 465
Alien Property Custodian, 405
Allied Chemical & Dye Corporation, 375–376
Allied Control Council, 234
Allocation tickets, aluminum, 34
Alloying elements, 20, 24
Alloys, new, 24
Alumina, 30, 33
Alumina hydrate, 30, 173
Aluminium, Ltd., 44
Aluminosilicate in superrefractories, 245
Aluminum (*b*), 4, 8–10, 16, 18, 30–48
  AA-1 priorities, 40
  alloy sheet, 31, 41
  alloys, R-301, 75-S, 31, 32
  bauxite, 31
  Bayer process, 31
  carbothermic process, 31
  casting alloys, 30
  casting processes, 31
  competition in industry, 42
  continuous casting process, 32
  duralumin, 30–31
  duty, 46–48
  experimental processes, 31
  Hall-Héroult process, 30
  laboratories, Canada, England, 34
  plant capacity, 35
  portable landing mats, 32
  prices, 21, 46–48
  production costs, 35
  production processes, 30–31
  properties, 30
  "red mud," 31
  refined and reclaimed, 30

[1] The Army and Navy Munitions Board designates certain materials as follows: (*a*) 34 stockpile items for essential production; (*b*) 16 supplementary items to be stockpiled, if available, under the Surplus Property Act; (*c*) 2 strategic and critical materials not now recommended for stockpiling, due to storage limitations.

Aluminum (*b*), scrap-metal supplies, sources, 41
secondary supplies, consumption, 41
troop shelters, 32
"window," 32
world capacity, 45
uses, 32
in postwar competition with copper, 33
in war, 32
Aluminum alloys, heat-treated, 31
Aluminum carbide, 33
Aluminum chloride, 33
Aluminum Company of America, 35–40, 42–43, 81
Aluminum Company of Canada, 43–45
Arvida, Kingston, plants, 43–45
brucite production, 278
Aluminum Ore Company, alumina production, 81
artificial cryolite, 174
Aluminum oxide, 33
Aluminum paint, 33
Aluminum salts, 40
Aluminum sulfate, 33
Aluminum therapy, 33
Aluminum-foil clips, 32
Aluminum-zinc alloys, 31
Alunite, 78, 80, 84, 403, 405
Amblygonite (*see* Lithium)
Amco Magnesium Corporation, 287–288, 292, 294
American Abrasive Company, 171
American Agricultural Chemical Company, 59
American Bureau of Metal Statistics, 444
aluminum, 36–37
copper, 141, 147, 153–154
lead, 253, 261
magnesium, 286
nickel, 360
steel, 226
zinc, 556, 559
American Ceramic Society, 109
American Cyanamid Company, 59
calcium cyanamide production, 378
Calco Division, 505
American Gem Mines, 420, 425
American Iron and Steel Institute, 224–226, 229, 230, 232–233, 235, 239
American Lava Corporation, 472
American Manganese Producers Association, 301
American Metal Company, 561
indium, 209
Rhodesian copper, 159
American Metal Market, 21, 242, 400
manganese, 304
mercury, 324
tin, 498
tungsten, 523
zinc, 570
American Nepheline Corporation, 189
American Potash & Chemical Company, 273–274, 405, 450
American Rutile Corporation, 504
American Smelting & Refining Company, arsenic, 63
bismuth-lead alloys, 94
indium, 209
nickel in Brazil, 365
smelters, Washington, N. J., 142
zinc smelter capacity, 556, 561–562, 570
American Steel & Wire Company, 561
American Zinc Company of Illinois, 556, 561–562
American Zinc Institute, 555, 559–560, 564
Anaconda Copper Mining Company, arsenic, 63
bismuth-lead, 94
chrome, 121
indium, 209
magnesium, 286–287
pyrites, 463
smelter, Montana, 142
vanadium, 546, 548
zinc, 556, 562
Ancor Corporation, 80–81
Andalusite, 245–246, 431–433
production and properties, 248
Andes Copper Company, 155
Angaur Island, phosphates, 60
Anglesite, 250
Angola, diamonds, 180
mica, 333, 335
Antimony (*a*), 4, 14, 18
antimonial lead, 49, 250
antimonial scrap, 49
battery plates, 49, 51
domestic requirements, 52
electrolytic, 50
flameproof cotton, 51
flame-retarding paints, 51
lead smelters, 50
mildewproof compounds, 52

Antimony (*a*), military applications, 49
opacifiers, 49, 51
ore and concentrates, 50
prices, 55
production, 52
properties, 49
secondary, 50
storage-battery plates, 49, 51–52
substitutes, 49–50
white pigments, 49, 51
Antimony oxide, 49–50
Antimony salts, 49
Antimony sulfide, 49
Antimony trichloride, 49
Antimony trioxide, 49
Antimony trisulfide, 49
Apatite, calcium metaphosphate, 57
defluorinated phosphate, 57
imports, 59
monocalcium phosphate, 57
occurrence, 56
properties, 56
uses, war, 57
Argentina, 9–10
antimony, 54
beryl, 89–90
bismuth, 95
columbite, 136
copper-fabricating plant, 158
feldspar, 189
fluorspar, 199
graphite, 206
lead, 265
mica, 334–335
palladium consumption, 391
platinum metals, market for, 215
sulfur, 465–466
talc, 474
tantalite, 479–480
tin, 490, 492, 494
tungsten, 519–520, 522
zinc, 563, 566–567
Argonne National Laboratory, 538
Arizona, mineral and metal production, copper, 141
indium, 209
iron-ore deposits, 222
manganese, 304
mercury, 318
molybdenite, 342
potash feldspar, 188
silver, 441
Arizona, mineral and metal production, strontium ore, 455–456
tungsten, 517
uranium, 526, 540
vanadium, 550–551
Arizona Chemical Company, 450
Arkansas, mineral production, bauxite, 78–81
manganese, 304
mercury, 318
nitrogen, 376
quartz crystal, 413
rutile, 505
tripoli, 413
Armament cutbacks, 16
Army Air Forces, 193, 371
Army Corps of Engineers, 531
Army Industrial College, 285
Army Quartermaster Corps, 187
Arsenate, calcium, 62, 63
lead, 62
Arsenic, artificial arsenic sulfide (red, yellow), 63
flue dust as source, 63
loellingite, 62
London purple, 65
metallic arsenic, 63
metallurgy, 62
orpiment, 62
Paris green, 65
prices, 64–65
properties, 62
realgar, 62
speiss, 63
uses, war, 62
Arsenious oxide, 62, 64
Arsenopyrite, mispickel, 62–63
Arvida, Quebec, 44
Asbestos (*a*), (*c*), 10, 13
actinolite, 66
amosite, 66
anthophyllite, 66
chrysotile, 66
common forms, 66
crocidolite (blue asbestos), 66
imports, 67
paligorskite, 66, 70
production, domestic, 67
properties, 66
tremolite, fibrous, 66
uses, 66–67
war, 66–67

Asia, 14, 25
Asphaltite, vanadium source, 544
Athletic Mining and Smelting Company, 560–561
Atkins, T. W., 284
Atlantic Charter, 25
Atomic bomb, 27, 202, 523, 525–532
Atomic Energy Commission, 204
Attlee, Prime Minister, 537, 543
Australia, mineral and metal production, aluminum, 47
antimony, 52
barite, 75
beryl, 90
bismuth, 95–96
cadmium, 101
china clay, 114
columbite, 135–136
copper, 151, 153, 155
crocidolite, 69
diamonds, 181
emery, 184
feldspar, 189
fluorspar, 199
graphite, 206
iridium, 215
iron ore, 235, 238–239, 242
lead, 260–263, 265
lithium ore, 274
magnesite, 279
magnesium, 296
mercury, 323
molybdenite, 347
monazite sand, 353
nickel, 366
osmium, 383, 385
platinum metals, 215
ruby and sapphire, 420, 426
rutile, 507–509
sillimanite, 433
silver, 443–444
steel industry, 241
sulfur and pyrites, 465
talc, 474
tantalite, 479–480
thorium and uranium, 526, 541–542
tin, 490, 492
tungsten, 519, 522
zinc, 563, 567, 569
zircon, 573, 577–578
Austria, mineral and metal production, copper, 153
Austria, mineral and metal production, iron ore, 236, 238, 242
langbeinite, salt deposits, 403
magnesite, 278
magnesium, 296
mercury, 321
radium and uranium, 541
Autonite, 526
Azurite, 138

B

Bacher, Prof. Robert F., 529
Baddeleyite, 577, 580–582
Badin, N. C., 35, 38
Bainbridge, Prof. Kenneth T., 529
Baker, James S., 353, 507, 581
bauxite, molybdenite, and tungsten in Brazil, 83, 346, 520
Baker & Company, 388, 417
Ball clay, domestic production, 112
English clay, 109
prices, 115
uses, 111–112
Bank for Reconstruction and Development, 26
Barite (*b*), 4, 6, 10, 14, 19
alkaline earth, 72
crude, sources, 73
crude ore, chemical grade, tariff, 76
domestic production, 74
exports, imports, 74–75
ground and crushed, uses, 73
lithopone, prices, 73–74, 76
military uses, 72
nickel-barium alloys, uses, 73
prices, 76
properties, 72
synthetic carbonate, sulfate, 72
Barium, strontium alloyed with aluminum, magnesium, 72
Barium carbonate, 76
Barium chlorate, 76
Barium chloride, 76
Barium dioxide, 76
Barium hydrate, 76
Barium metal, in special alloys, 72
Barium nitrate, 76
Barium oxide, 72
Basic Magnesium, Inc., 286–288, 292, 294
Basic Refractories, 288

Batelle Memorial Institute, 310
chrome ore in Germany, Japan, 125
molybdenum, 347
nickel, 365–366
tungsten, 521
vanadium, 553
Bateman, Dr. Alan M., 14–15, 161
Bateman, George C., 263
Baton Rouge, La., alumina plant, 35, 38
Batt, William L., 23, 489
Bausch & Lomb Optical Company, fluorspar, 192
Bauxite (*a*), 6–7
acid and alkali processes, 80
alunite, clay, leucite substitutes, 78, 80
ammonium bisulfate process, 80
artificial corundum, 166
Bayer process, 80
boehmite, 78
combined with kyanite, 245
diaspore, 78
domestic ore reserves, 82
duty, 85
gibbsite, 78
grades of bauxite, 78
high-silica, 4, 6
laterite, 78
lime-sintering process, 80
low-grade, processes for treating, 80
low-silica, 4, 6
nepheline as substitute, 187
origin, 78
postwar requirements, 83
prices, 85
production, domestic, 79
foreign, 82
uses, 78
Belgium, research in, 20
mineral and metal production, antimony, 54
arsenic, 63–64
bismuth, 95
chalk, crude, 108
cobalt, 131
copper, alloys, 152–154, 157
diamond cutting and polishing, 178
indium, 209
iron, steel, 231, 235–236
platinum metals, 385, 400
refined lead, stocks, 262, 266
soda ash, 451
tin, exports, 491–492, 496
Belgium, mineral and metal production, zinc, 565–566, 571
Ministry of Economic Affairs, 157
Bell Telephone Laboratories, apparatus testing mica, 329
Bennett-Clark Company, Inc., 456
Bentonite, 4
domestic production, 112–113
foundries and steelworks, 110
metabentonite, 109–110
new uses, 112
northern (true) type, 109–110
prices, 115
properties, origin, 109
substitute for mica, "alsifilm," 329
uses, 110–111
Beryl crystals, 86
Beryl ore, 86
Beryllium (beryl) (*a*), 4, 15, 19
alloys with iron, silver, 87
atomic bombs, 89
domestic production, 88–89
imports, 90
international controls, 537
metallurgy, 86
occurrence, 86
phosphorescent lamps, 88
prices, 91
properties, 86–87
uses, war, 87–88
world production, 89–90
Beryllium Corporation of Pennsylvania, 89
Beryllium metal, 86
Beryllium-aluminum, 87, 91
Beryllium-copper, 86–88, 91
Beryllium-nickel, 86–87, 91
Bethe, H. A., 530
Bethlehem Steel Company, cobalt production, 130
iron-ore imports, Venezuela, Chile, 240–241
pyrites production, 463
Beutel, Dr. A. P., 287
Big Five, 27
Big Three, 27, 537
Bikini Atoll, 533
Biotite scrap mica, 327, 330
Bismite, 92
Bismuth (*a*), 4
domestic production, 94
duties, 96

Bismuth (*a*), exports, imports, 93
metal, 96
metallurgical applications, 93
occurrence, 92
prices, 96
properties, 92
salts, compounds in drug manufacture, 93, 96
sources, 92
uses, war, 95
Bismuth alloys, 92
Bismuth carbonates, nitrates, 93
Bismuth compounds, mixtures, salts, 93, 96
Bismuthinite, 92, 95
Bismuth-lead bullion, 93
Bismutite, 92
Bismutosphalerite, 92
Black Hills Keystone Corporation, 273
Black Hills Tin Company, 273
Blanding Mines Company, 548
Blandy, Vice-Adm. W. H. P., 533
Bohr, Niels, 530
Bolivia, 9
mineral and metal production, antimony, 52–54
bismuth, 95
cobalt, 131
copper, 150, 158
lead, 259–261, 264, 267
mica, 335
silver, 443
sulfur, 466
tin, 483, 485, 489, 491, 493–494, 497, 499
tungsten, 519, 522
zinc, 566, 568
Borneo, osmiridium occurrences, 386
Bornite, 138
Boron, 9, 15, 219
Borosilicate glass, 425, 511
Bowles, Chester, 163, 268, 292, 319, 575
Boyd, Col. James, 234
Braden Copper Company, El Teniente mine, 155
molybdenite production, 346
Bradley Mining Company, 517
Braunite, 298
Brazil, 9, 23
American Technical Commission to, 9
market for platinum metals, 215
metal and mineral production, aluminum, 46
Brazil, metal and mineral production, arsenic, 64
baddeleyite, 581–582
bauxite, 83
beryl, 89–90
chromite, 124, 126
cobalt, 132
columbite, 136
corundum, 170
diamond cutting, 178–179
diamonds, 179–180
graphite, 205–206
iron ore, 222, 231, 237, 239
kaolin, 113
manganese, 15, 306–308, 311
mica, 331, 333–335, 337
molybdenite, 346
monazite sand, 353
nickel, 365–366
palladium-platinum, 392
quartz crystal, 413–414
rutile, ilmenite, 507–509
spodumene, 274
steel plant at Volta Redonda, 239–240
tantalite, 479–480
thorium, 526, 543–544
topaz, 512
tungsten, 519–520, 522
uranium, 544
zinc, 569
U.S. Purchasing Commission, 180
Bretton Woods agreement, 14, 25, 26
Briggs, Dr. Lyman J., 529
British Iron and Steel Foundation, 233
British Iron and Steel Research Association, 233
Brookhaven National Laboratory, 539–540
Bronze hardeners, 32
Brookite, 501, 503
Brown Instrument Company, 396
Brucite, 277
magnesium production, 281, 283, 290, 295
Brunnerite, 276
Brush Beryllium Company, 89
Bulgaria, 27
chrome deposits, 125
Bulova Watch Company, manufactured ruby, sapphire, 420, 425
Bunker Hill & Sullivan Mining Company, 254
Burlington, N. J., aluminum-reduction works, 38

Burma, metal and mineral production, antimony, 54
arsenic-bearing cobalt-nickel speiss, 64
cobalt, 131
lead, 260, 262
nickel, 366
ruby, sapphire, 420, 426
silver, 443
tin ore, 492
tungsten, 519, 521
Burma Ruby Mines, 420
Burton Mines Corporation, garnet production, 184
Bush, Dr. Vannevar, 530

C

Caddle, B. B., 149
Cadmium (*a*), 4, 6, 555–556
anodes, patented shapes, 101
associated with zinc, 97
commercial sticks, 101
consumption, exports, imports, 99–100
duty, 101–102
luminescent paint, 98
paint colors (red, maroon, yellow), 98
prices, 101
properties, 97
protective coating on steel, 98
shielding for atomic pile, 531
use, military, 97
in pure state, as alloys, 97
Cadmium alloys with nickel, silver, 97
Cadmium blende (greenockite), 97
Cadmium bromide, 101
Cadmium compounds, 97–98, 101
Cadmium plating, 98
Cadmium ray in lens grinding, 98
Cadmium-zinc sulfide, 98
Cairo Conference, 25
Calamine, 556, 570
Calcite, optical, crystals for optical uses, 103
domestic production, 105
foreign production, 105
Iceland spar, calcite spar, 103
prices, 106
nicol prism, 103
uses, military, 103
in standardizing solutions, 103
Calcium, 4, 20
alkaline earth, 103
magnesium-calcium, 104
metallic, prices, 103, 106
Calcium, properties, 103
welding rod coatings, 104
uses, war, 104
Calcium alloys used in steelmaking, 103
Calcium carbonate, 104
Calcium chloride, production, prices, 104–106
Calcium fluoride, 104
Calcium lead, production, 104–105
Calcium metal, calcium-silicon, 104, 106
imported, 105
Calcium-magnesium chloride, production, 104
California, mineral production, ammonium nitrate, 375
andalusite, kyanite, 432–433
chrome ore, 122
diatomite, 413
lithium, 273
magnesite, 277, 288
magnetite sands, 220
manganese, 304
mercury, 317–318
mineral earth pigments, 226
molybdenite, 342
optical calcite, 105
potash feldspar, 188
potassium, 405
quartz crystal, 413
rutile, 504
steatite, 472
strontium ore, 455
talc, 471–472
trona, burkeite, sodium carbonate, 447, 449
tungsten, 517
zircon, 579
California, University of, 436
Radiation Laboratory, 528, 530
California Institute of Technology, 535
Calomel, 314
Cambodia, ruby, sapphite production, 420, 426
Cameroons, French, rutile, 509
tin, 485, 495
Campbell, Thurlow J., 506
Canada, 10–11, 22, 26
Merchant Marine, 11
metal and mineral production, aluminum, controls, exports, prices, stocks, 37, 43–47
antimony, 53

Canada, metal and mineral production,
apatite, 59–61
arsenic, 63–64
asbestos, 68–70
barite, prices, tariff, 75–76
bentonite, structural clays, 113, 115
beryl, 90
bismuth, 95
brucite, magnesitic dolomite, 278
cadmium, 100–101
calcium-silicon, 105
cerium products, 354
chromium, 124–125
cobalt, 131–132
copper, exports, 149–150, 152–153, 155–157, 162
corundum, 170–172
diamond cutting, 181–182
feldspar, prices, 189–190
fluorspar, 198–199
graphite, natural, artificial, tariffs, 205–207
ilmenite, 507–508
indium, 209
iridium, 215
iron, steel, 231–232
lead, consumption, exports, 259, 260–264
lithium ore, 274
magnesium, 295–296, 310–311
magnesium sulfate, 295
mercury, 321–322
mica, prices, 330, 335, 337
molybdenite, prices, 344–345, 347
nickel, imports, exports, 356, 361–362
nitrogen production, synthetic, 378
osmium, exports, 384
palladium, consumption, 391
phosphate rock, 61
platinum, 398–400
potash, imports, 406
rhodium, ruthenium, 418, 422–423
selenium, 429–430
silver, 443–444
soda ash, 449, 451–452
sodium sulfate, carbonate, 451–452
talc, soapstone, 473–474
tin smelter production, exports, 490, 494–495
tungsten, 521–522, 524
uranium, radium, thorium, 541–542, 544–545
Canada, metal and mineral production, vanadium, 554
whiting substitute, 108
zinc, 566–567, 571, 575
zircon, 581
metals controller, 11, 45
metals exports, 10–11
Munitions and Supply, Department of, 215
Canadian Chemistry and Process Industries, soda-ash, sodium sulfate prices, 453
Canadian Copper Refiners, Montreal works, 142
Canadian Industrial Minerals, Ltd., barite, 75
Canadian Radium and Uranium Corporation, 533
Cananea Copper Company, 157
Carnegie Endowment for International Peace, 539
Carnotite, 281, 403, 526, 539
source of vanadium, 546, 548
Carolina Mineral Company, columbium ore, 135
Carpp, Charles H., 425
Cartel systems, 23, 25
German, 25
mercury, 323–324
nitrates, 377–378
phosphate, 59
platinum, 391–392, 401
potash trust, 405
zinc, 570
Cassiterite, 483
Celestite (*see* Strontium ore)
Census, Bureau of, 449
Cerium (*see* Monazite sand)
Cerium Products Corporation, 352
Cerro de Pasco Corporation, 264
bismuth refined in Peru, 94
copper production, 157–158
lead, lead-silver ores, 95
zinc production, 568
Cerusite, 250
Ceylon, mineral production, graphite, prices, 205–206
monazite sand, 353
ruby, sapphire, 420, 426
titanium, 507–508
topaz, 512
zircon, 581
Ceylon Graphite Company, 203

Chadwick, Sir James, 528
Chalcocite, 138
Chalcopyrite, 138
Chalk (English), production, (*b*), 108
  marl, 107
  prices, 108
  properties, 107
  uses of "Paris white," whiting, 107
    war, 107
  whiting, whiting substitute, 107
Chalk River, Ontario, atomic research, 45, 541–542
Champion Sillimanite, Inc., 433
Champion Spark Plug Company, 433
Chapultepec, Act of, 25
Chicago, University of, 530
Chile, 10
  mineral and metal production, antimony, 54
    copper, 149–151, 153–155
    iodine, 211
    iron ore and steel plants, 222, 236–237, 241
    manganese, exports, 12, 307, 309, 311
    mercury, 321
    molybdenite, 346
    nitrates, 368, 373, 376–378
    platinum metals, 215
    potash, exports, 406
    sulfur, 465–466
    zinc, 566
Chile Copper Company, 377
  Chuquicamata ore reserves, 155
Chilean Nitrate Sales Corporation, 211, 377
China, 23, 26
  metal and mineral production, antimony, 52–54
    bismuth, 95–96
    china clay, kaolin ("bone" clay), 113
    iron ore, 231, 235, 238
    mercury, 321
    soda ash, 451
    talc, 473
    tin smelter production, exports, 490, 492
    tungsten, 519, 522
    zinc, 566
China clay, domestic production, 112
  exports, imports, 113
  froth flotation, 112
  kaolin, kaolinite, 109
  origin, 109
  prices, 114–115
China clay, properties, 109
  uses, 109, 111
    strategic, 109
Chloanthite, 355
Chosen (*see* Korea)
Chrome metal, 4, 10, 118
Chrome-alloy steel, refractories, 122, 339
Chrome-nickel steels, 117
Chromite bricks, 118–119
Chromite ore, low-grade, milling, 121
Chromium (chrome) ore (*a*), (*b*), 7–9, 12–14, 23
  alloys, 118
  Chrom-X alloy, 121
  domestic production, 121–122
  duty, 126
  essential steel alloy, 118
  ferrochromium in metallurgy, 117
  high-speed tool steel, 118
  imports, exports, 125
  pigments (chromates), 119
  pilot-plant production, 121
  prices, 126–127
  properties, 117–118
  reduction of chrome ore, 117
  refractories, furnace linings, 118
  rustless steels, 118
  in steelmaking, 118
  stellite, 118
  superrefractories, 245
  superstainless steels, 118
  uses, war, 118
  world production, 122
Chromium chemicals, 119
Chromium salts, 118
Chrysocolla, 138
Cinnabar, 314
Civilian Production Administration, controls, aluminum, 35, 37
  antimony, 51
  celestite, 457
  copper, 149
  lead, 254–255, 257
  manganese, 301
  mercury, 319
  mica splittings, 333
  molybdenum, 344
  tin, 486–487
  titanium, 506
  tungsten, 518
  vanadium, 549–550
  zinc, 559–560, 572–573

Civilian Production Administration, controls, zircon, 580
stockpiled minerals and metals, arsenic, 64
barite, 74
bauxite, 79
bismuth, 94
cadmium, 99
calcite, optical, 105
corundum, 168–169
cryolite, 174
Indian kyanite, 247
lithium, 274
monazite sand, 352
osmium, 382
rhodium, 417
talc, 471
Civilian Requirements, Office of, allotments, carbon-steel, 228
copper and brass, 147
Clark, Attorney General Tom C., 551
Clay, 19
English china, 4
fire, 4
Clayton, William L., 23
Clifton Products, Inc., 89
Climax Molybdenum Company, production, 342, 344
Clinton Engineer Works, 436, 529–531
Clinton Laboratory, 538
Cobalt (*a*), 4, 10, 14
domestic production, 130
ferronickel-cobalt alloy, 128
imports, 129
iron-cobalt alloys, 129, 131
prices, 133
properties, 128–129
skutterudite, smaltite, 128
stellite, 128–129
uses, 128
Cobalt compounds, salts, 129
Cobalt metal, 128, 133
Cobalt oxide, 129, 133
Cobaltite group, 128
Cobalt-nickel alloys, 128
Colmer Committee on Postwar Economic Policy, 22
Colombia, Industrial Development Institute, 241
iron ore, 241
platinum metals, 214, 385, 391–392, 398–400
Colombia, quartz crystal, 414
Colonial Mica Corporation, 331–332, 336
Colorado, mineral and metal production, beryl ore, 89
columbite, 135
fluorspar, 193–194, 199
mica, 329
molybdenite, 342
optical calcite, 105
potash feldspar, prices, 188, 190
pyrites, 463
tungsten, 517
uranium, 526, 540
vanadium, 548, 550–551
Columbia Metals Corporation, alumina production, 80–81
Columbia University, 530–531
Columbite (niobate) (*a*), 4, 15
domestic production, 135
foreign production, 136
imports, exports, 136
intergranular corrosion in stainless steels, 134
prices, 136–137
uses, war, 134
Columbite-tantalite series, 134
Columbium (niobium), 134
Combined Copper Committee, functions of, 143
Combined Materials Plan, copper, aluminum, steel, 143
Combined Production Resources Board, 7, 263
copper production, 144
Combined Raw Materials Board, 256, 266
antimony, 50
asbestos, 68
copper, 143–144
nickel, 363
tin, 488, 493
Combined Tin Committee, tin allotments, 488, 490
Commerce, Department of, foreign financial and supply transactions, copper, 156–157
lead, 264
tin, 495
zinc, 568
Commercial Fertilizer Yearbook, nitrogen prices, 379
Conant, Dr. James B., 530, 537

Congo, Belgian, mineral and metal production, cadmium, 101
cobalt, 131–132
columbian ore, 136
diamonds, 180
Beceka diamond mines, 181
palladium-platinum, 391, 401
smelter copper, exports, 150, 152–153, 158
tantalite, 480
tin smelter production, exports, 485, 490–492, 495
Union Miniere de Haut Katanga, 158
uranium, 158, 540
Connally, Senator Tom, 26
Connecticut, mineral and metal production, magnesium, 288
mica, 329
potash and soda feldspar production, prices, 188, 190
Conservation of minerals, 19
Consolidated Feldspar Corporation, alaskite, 188
Consolidated Mining and Smelting Company, Ltd., 264, 443
zinc production, 567
Continental Machines, Inc., Alloy Metals Division, 194
Controlled Materials Plan, 18
aluminum, 34
Copper (*a*), 3–4, 6, 10, 12, 14–16, 18, 22, 24
alloys, 31–32
with aluminum, 32
with zinc, tin, 139
aluminum, zinc as substitutes, 140
atomic structure, 138
chalcopyrite, 138
copper, brass, bronze, special alloys, 139
domestic consumption, production, 140–161
domestic refining, fabrication, 141
electrical uses, 138
electrolytic refining, 138
essential war functions, 139
foreign procurement, 154, 161
grades, Chile, Britain, 139
imports, exports, 153–154, 161
incendiary bombs, 139
powder metallurgy, 140
prices, 21, 162–163
properties, 138
scrap, 140, 147
Copper (*a*), stocks, 142–143
tariffs, 156, 162–163
world areas, 139
world production, 149–161
Copper and Brass Research Association, 149, 565
Copper Institute, 147
Copper Mountain Company, 463
Copper sulfate, 156
Corning Glass Company, 274
Corod Minerals Corporation, 561
Coronet Phosphate Company, 59
Corundum (*a*), 4, 9, 14
artificial corundum, alundum, carborundum, 166, 168
coarse corundum grain, strategic uses, 166, 168
commercial grades, block, sand, 166
crystal corundum ore, 168
flotation, 169
foreign sources, production, 170–171, 248
gem stones, abrasive corundum, emery, 166
grinding-wheel manufacturers, 166
high-grade industrial abrasives, 166
high-precision lenses, grinding, polishing, 166
imports, 171
loose grain, optical lenses, 166
optical emery, 167
optical-lens makers, 166
opticians, 166
prices, 171
primary abrasive grain, preparation, 167
properties, 166, 248
quartz-crystal finishing, 167
reef corundum (plumasite), 170
snagging wheels, 167–168
strategic uses, 167
superfines, 167
wheel industry, 168
Covellite, 138
Crane, Clinton H., 260
Cristobalite, 410
Crowley, Leo T., 14, 45, 126, 159, 227, 496, 519
Crucible Flake Graphite Company, 203
Cryolite (*b*), 4
artificial, imports, 173–174
natural, imports, 174
prices, 175
properties, 173

Cryolite (*b*), source of aluminum metal, 173
substitutes, 174
three grades of refined, 174
uses, 173
Cuba, 9, 15
mineral and metal production, barite, 75
chromite, 12, 123–124
copper, 12, 150, 158
iron ore, 222, 238, 240–241
magnesite, 279
manganese, 12, 306–308, 311
nickel, 365–366
platinum metals, market for, 215
Cuprite, 138
Cuprous oxide, paint, 140, 145
Curaçao, phosphate-rock production, 59
Curite, 539
Cylindrite, 483
Cyprus, mineral and metal production, asbestos, 69
chrome ore, 124
copper, 150, 160
pyrites, 465
Czechoslovakia, mineral and metal production, antimony, 52–53
china clay, 114
copper, 154
graphite, 205
iron ore, 236, 238
magnesite, 279
mercury, 321, 323
soda ash, 451
uranium deposits, 542
zinc, 565

D

Davies, Raymond A., 544
Davis, Arthur V., 39
D-Day, 553
Deepwater Chemical Company, indium production, 210
Defense Plant Corporation, 10, 437–438
aluminum plants, rolling mills, 35, 38
fluorspar plants, 194
foreign assistance given, 15
magnesium plants, 286, 289
nickel production, 359, 363
steel industry, 224–225
tantalum production, 479
uranium production, 540
vanadium production, 550, 552
Defense Plant Corporation, zinc production, 562–563
Defense Supplies Corporation, 12, 377
Defense Transportation, Office of, steel use, 226
Delaware, kaolin production, price, 112, 115
nickel production, 363
DeLuca, Joe, emery production, 184
Descloizite, 546
Desert Chemical Company, 450
deSeversky, Maj. Alexander P., 531
Diamond, industrial (*a*), 4, 12
bonded diamond tools, 177
Borneo stones, 176
bort, shot, hailstone, carbonado, 176
domestic consumption, 178
drilling, 176
gem material for war purposes, 179
for glaziers and engravers, unset, miners, 178
grinding wheels, 177
imports, 178
natural carbon abrasives, 176
occurrences, 176
prices, 181–182
properties, 176
substitutes, 177
uses, war, 176–177
world production, 179–181
Diamond Alkali Company, 288
Diamond Corporation, 181–182
Diamond dust, 177
Diamond Magnesium Company, 288–289, 294
Diamond-impregnated wheels and tools, 176
Diaspore in refractories, 245
Diatomaceous earth, uses, prices, 412, 415
Diatomite, 4
Dilly, B. M., 273
DiRubbo & Ellis, emery production, 184
Dodson, Dr. Richard W., 530
Dolomite, 468
dead-burned, 277
magnesium production, 281, 295
refractory, 4
Dominion Bureau of Statistics, 95, 263, 443, 449
nickel production, 361
Dominion Magnesium Ltd., 278
Dow, Dr. W. H., 284
Dow Chemical Company, indium production, 210

Dow Chemical Company, magnesite production, 278
magnesium production, 281, 284, 286–288, 292, 294
Dow Magnesium Corporation, 287–289, 293, 294
Drimortierite, properties, 248
Dumbarton Oaks conference, 25–26
Dumortierite, 431–433
Dunning, Dr. John R., 528–531
du Pont, E. I. de Nemours & Co., Inc., 449, 527

E

Eagle-Picher Mining & Smelting Company, 209, 254, 563
Eastern Magnesia Talc Company, cobalt production, 130
talc production, 472
Economic Affairs, Office of, 24
Under Secretary of State for, 126
Economic Development, Committee for, 18, 23
Economic peace, 23
Economic Stabilization, Office of, 2, 48, 244, 297, 337
nickel controls, 367
zinc, copper, lead subsidies, 563
Economic warfare, 22, 26
Economic Warfare, Board of, 414
fluorspar from Mexico, 198
mica production, 334
molybdenum exports, 343
sillimanite supplies, 433
Economic warfare agencies, 11
Egypt, feldspar production, 189
manganese exports, 307
phosphate-rock production, 59
talc production, 474
Einstein, Dr. Albert, 528, 543
Electro Metallurgical Company, 104, 550–551
ferrocolumbium, 135
magnesium, 287–288, 294
Electro Metallurgical Company of Canada, 551
Electro Metallurgical Sales Corporation, 551
Electrodevelopment Laboratory, 20, 429, 504, 579
Electrolytic Zinc Company of Australia, 569
Emeny, Brooks, 320, 374, 388, 395–396
Emergency Price Control Act, 21
Emery ore, (*b*), 166–168
domestic, foreign production, 183–184
grinding wheels, 183
new applications, 183
prices, 184–185
properties, 183
Turkish and Naxos ore shipments, 167
uses, war, 183
Enargite, 138
Engineering and Mining Journal, prices, mercury, 324
mica, 336
molybdenum, ferromolybdenum, 347
E & M J Metal and Mineral Markets, price quotations, antimony, 55
celestite, 457–458
china clay, clays, bentonites, 114–115
chromium, chrome ore, ferrochrome, chrome brick, 126–127
cobalt metal, ore, oxide, 133
columbium ore, metal, ferrocolumbium, 136–137
corundum, 171
diatomite, 415
emery ore, 184
feldspar, 189–190
fuller's earth, 114–115
iridium, 215
iron ore, iron oxide, steel, 243–244
kyanite, domestic and Indian, 248–249
lead, 266–268
lithium metal, lepidolite, amblygonite, spodumene, 275
magnesite, 280
manganese ore, 311–313
monazite sand, 354
nickel, 366
osmium, 386
palladium, 392
platinum, 401
potash, 407
quartz crystal, 414
radium, uranium, 544
ruthenium, 423
selenium, tellurium, 430
sodium metal, 452
sulfur, pyrites, 467
tantalum metal, 480
titanium, rutile, ilmenite, 509
tripoli, 415
tungsten, 423

E & M J Metal and Mineral Markets, price quotations, vermiculite, 336
whiting, domestic, 108
zircon ore, 582
Englehard, Charles, 417
English Magnesium Electron, Ltd., 286
Essential minerals, 24
Ethiopia, osmium, palladium, platinum production, 385, 391, 400
silver under lend-lease, 444
Ethyl Gasoline Corporation, 449
Europe, neutral, 11
competition with, 12
trade agreements, 25
Export-Import Bank, 12, 25
functions of, 13–14
loans to Latin-American countries, 265, 569
for blast furnaces, 239, 241
for processing bauxite, 84
Export restrictions, 12
Export Trade Act, Webb-Pomerene, 59

F

Falconbridge Nickel Mines, Ltd., 362, 399
Fansteel Metallurgical Corporation, 479
Fansteel Products Company, 340
Farrell, Brig. Gen. Thomas F., 530
Federal Loan Administrator, 126
Federal Reserve Bank of Kansas City, 21
Federal Trade Commission, 59
Feldspar, 4
domestic production, 188–189
fiber glass, bat wool, textiles, 187
flotation, 188
glass spar grades, 186
glaze spar grades, 186
ground feldspar, 186
imports, 189
occurrences, 186, 410
potash spars, 186
pottery spar grades, 186
prices, 189–190
properties, 186
soda feldspar, 186
source of potash, 186
synthetic Cornwall and Carolina stone, 186
tariff, 190
uses, war, 186–187
world production, 189
Ferberite, 513
Fermi, Dr. Enrico, 530, 543
Ferro Enamel Supply Company, agents for MRC, nickel production, 359
purchasing arsenic, 64
Ferro Nickel Supply Company, cobalt oxide production, 130
Ferroalloy, 4, 218
Ferry, Maj. John, 530
Finland, 27
metal and mineral production, cobalt, 132
feldspar, 189
molybdenite exports, 347
nickel, 365–366
smelter copper, 153
Fire clay, domestic production, 112
exports, 113
Klingenberg clay, 111
prices, 115
properties, origin, 109
semifire clay, 112
substitutes for, 111
war uses, 111–112
Flint, 4
Flint glass, uses, 411–412
Florida, mineral production, kaolin, prices, 112, 115
fuller's earth prices, 115
monazite sand, 351
phosphate rock, 58
rutile, 505
thorium, 526
zircon, 580
Florida Hard Rock Phosphate Export Association, 59
terminal at Fernandina, 59
Fluorine, fluorocarbons, 193
new products, 193
production, properties, 191, 193
Fluorspar (*b*), 4, 6, 19
acid grade, 192–193
basic open-hearth process, 191
ceramic grade, 193
chemical industry, hydrofluoric acid, 192
domestic consumption, production, 193–197
duty, 198
electrolytic process, aluminum manufacture, 192
exports, imports, 197–198
flotation, 193
fluorides used in pottery, 193
fluorine salts, 192–193

Fluorspar (*b*), fluorite with barite, calcite, 197
fluxing-gravel fluorspar, 193, 195
gravel fluorspar, 191
gravel spar, 191
Illinois-Kentucky district, 191
lepidolite, source of fluorine, 192
lithium-fluoride crystals, 193
metallurgical grade, 193
occurrence, 191
optical fluorite, 191
"persistent minerals," 191
prices, 199–200
properties, fluorspar and optical fluorite, 191–192
sink-float process, 193
strategic uses in metallurgy, 191
substitutes, 192–193
uses, 173, 192
world production, 197–199
Fontana Steel Works, 225–226
Foote Mineral Company, 352
Ford Motor Company, 287–288, 294
Foreign Commerce, Department of, graphite imports, 205
iron deposits, 235
mica production, 336
molybdenum production, 346
tungsten supplies, 521
Foreign Economic Administration, 2, 9, 12, 14
advance payments, 15
Africa, contingency reserves in, 14
aluminum imports, 45
asbestos purchases, 70
Asia, contingency reserves in, 14
beryl purchases, 91
bismuth, potential output for Bolivia, 95
chrome ore, foreign procurement, 125–126
cobalt purchases, 132
columbite purchases, 136
contracts, 14
copper contracts, purchases, 159–161
diamond purchases, 181
exploration by, 14
function of, 12, 14–15
Germany, Japan, contingency reserves in, 14
graphite imports from Norway, 206
lead purchased from Mexico, Peru, 256
manganese, foreign purchases, 311
mercury purchasing, 323
Foreign Economic Administration, mica, imports, 333, 335
purchased in Brazil, 333
molybdenite procurement, 347
neutral countries, contingency reserves in, 14
pyrites shipments, 466
quartz crystal procurement, 414
rutile from Brazil, 507–508
steel use, 226
tantalite procurement, 479–480
tin purchases, prices, 496, 499
vanadium purchases, 553
zinc purchases, 574
zircon purchases, 581
Foreign investments in strategic minerals, 126
Foreign loans, 23
Foreign mineral supplies, 24
Foreign mineral trade, 15, 22
Foreign Policy, Executive Committee on, 24
Foreign Relations Committee, U.S. Senate, 26
Foreign trade, 26
Fortune, 360, 375
France, 26
metal and mineral production, aluminum, 46
antimony, 54
arsenic, 63
barite, 75
bauxite, 75
bismuth, 95
calcium, calcium-silicon, 105
chalk, 108
china clay, bentonite, 114
chrome ore, 122
copper, exports, 150, 153
iron ore, steel, 222, 231, 235–236, 242
lithium ores, 275
magnesium, 296
phosphates, 60
potash, exports, 406–407
soda ash, 451
talc, 473
uranium, 542
zinc, 565–566, 572
research in, 20
Frankeite, 483
Franklinite, 555
Frary metal, as substitute, 104
use of, for bearings, 73

Freeport Sulphur Company, 363
French Indo-China, high-grade phosphates, 60
Froth flotation, 19
Fuller's earth, domestic production, 112
  prices, 115
  strategic uses, 109

G

Gadolinium, 20
Galena, 250
Gallium, 20, 316
Garnet, 4, 167–168, 419
  electromagnetic separation, 246
  metallurgy, 184
  substitute for emery, corundum, 183
Garnierite, 365
Gateway Alloys, Inc., 540
General Chemical Company, 463
  aluminum chemicals plants, 40
General Electric Company, 274, 426, 472, 515
  incendiary bombs, 139
  plutonium production, 527, 530, 532
Geneva Steel Works, 224–225
Genthite, 355
Geological Survey, U.S., 7, 9, 11, 24
  antimony, asbestos, chrome in Alaska, 54, 70, 125
  barite sources, 75–76
  copper in Alaska, 160
  domestic graphite, 203
  fluorspar uses, 193
  iron ore in Alaska, 233
  lead resources, 265
  manganese in Mexico, 309
  mica surveys, 332
  molybdenite in Alaska, 346
  nickel, platinum, sulfur in Alaska, 363, 401, 466
  silver in Alaska, 443
  talc reserves, 472
  tungsten sources, 522
Georgia, metal and mineral production, bauxite, 79
  chrome reserves, low-grade, 122
  corundum, 169
  fuller's earth, prices, 115
  kaolin, prices, 112, 114
  kyanite, 247
  manganese, 304
  mineral earth pigments, 226
Georgia, metal and mineral production, muscovite mica, 327, 329, 332
  sillimanite, sources, 432
  talc, 471
German disarmament, 25
German industrial economy, 25
German industrialists, 24
German industry, military power of, 25
German metal and mineral production, 12, 23, 27
  aluminum, 37, 39, 45–46
  arsenic, 63
  barite, witherite, 74–75
  bauxite and clay, 83–84
  bentonite, china clay, 114
  bismuth, 93, 95
  cadmium, 101
  chromite purchases, 122, 125
  cobalt supplies, 132
  copper, 153, 159–160
  fluorspar, 194
  graphite, 205
  indium, 209
  iodine imports, 211
  iron and steel, 25, 233–234, 242
  langbeinite, salt deposits, 403
  lead, 263, 266
  lithium ore, 274–275
  magnesite, dead-burned, 278
  magnesium, 294, 296
  manganese, 310
  mercury, 323
  mica, imports, synthetic, 329, 334
  molybdenite, 347
  nickel, 365–366
  nitrogen, 25, 373
    synthetic, 379
  phosphate rock, 60
  potash monopoly, 407–408
  soda ash, 451
  strontium ore, 456–457
  talc, 473
  tin consumption, 490–491, 495
  tungsten, 521
  vanadium, 553
  zinc, 565–566, 570
  zirconium, 579
German radar detection, 32
German reparations to Poland, 114
  to U.S.S.R., 114
German research, 20
  strategic war materials, 12

Germanium, 20
Gersdorffite, 128
Glass Industry, barium selenite, sodium selenite, 430
Glass products, 19
Glauber's salt, 447
Gold Coast, bauxite production, 83–84
  diamond production, 180
  manganese production, exports, 306–307, 309–311
Golwynne Magnesite & Magnesia Corporation, 248
Graphite (*a*), (*b*), 19
  Alabama flake, special type retorts, 202
  amorphous, 4, 201–202
  artificial (manufactured), 201
  carbon, 201
  Ceylon lump, 203–204
  crucible grades, 201, 204
  domestic production, 203
  duty, 205
  flake, 7, 201, 203
  international controls for pure graphite, 537
  lump, 4
  Madagascar flake, 204–205
  natural (crystalline, amorphous), 201, 204
  plumbago, 201
  prices, 206
  properties, 201
  pure, atomic bombs, 202
  refining processes, 201
  shielding, for atomic pile, 531
  uses, of low-grade, high-grade, amorphous, 201–202
    of manufactured graphite, 202
  war requirements (carbon electrodes, lubricants), 203
Graphite fines, 204
Grasselli Chemical Company, 561
Great Britain, 26
  Board of Trade, 133, 157
  consumption of, antimony, cadmium, nickel, diamond, palladium, 54, 101, 178–179, 366, 391
  Directorate of Nonferrous Metals, 101, 157
  Iron and Steel Trades Confederation, 233
  metal and mineral production, aluminum, 45–47
    arsenic, 63
    barite, witherite, 75
Great Britain, metal and mineral production, chrome, cobalt imports, 122, 132
    copper, production, consumption, stocks, exports, 152–154, 157
    fluorspar, 198
    iron and steel, imports, 233, 242–243
    kaolin, clays, 113
    lead, consumption, 260, 263
    lithium ores, 275
    magnesium, prices, 295–297
    osmium exports, 383
    phosphate rock, 59–60
    rhodium, ruthenium, exports, 418
    ruthenium, 422
    silver under lend-lease, 444
    sodium carbonate, exports, 450–451
    strontium ore, 456–457
    sulfur, 466
    tin, consumption, exports, prices, 490, 492, 497, 499
    uranium deposits, 542
    zinc, 565–566
  Ministry of Supply, 157
  research in, 20
Greece, mineral and metal production, arsenic, 63
    barite, 75
    chromite, 124–125
    iron ore, 237
    magnesite, dead-burned, 278–279
    molybdenite, exports, 346–347
    nickel, 365–366
    zinc, 571
Green, A. P., Fire Brick Company, 247
Greene Act, 438, 440
Greene-Cananea Copper Corporation, 157
Gregory, Lt. Gen. Edmund B., 43
Groves, Maj. Gen. Leslie R., 529, 536, 539
Guatemala, 9
  chromite, quartz-crystal production, 124, 414
Guiana, British, bauxite, diamond production, 78, 80, 84, 181
  columbite occurrence, 136
Guiana, Dutch (*see* Surinam)
Gypsum, 4

H

Hafnium, 577
Haiti, bauxite deposits, 83
Halite, 403

Halloysite, 79
Hanawalt, Dr. J. D., 294
Handy & Harman, silver prices, 446
Hanford Engineer Works, 527, 532
Harshaw Chemical Company, 50
  lithium fluoride, 193
Hayden Mining Company, 273
Hayden-McFarland Bill, S-502, 267
Heavy-mediums separation (sink-float), 19
  fluorspar treatment, 193
Hegeler Zinc Company, 563
Hematite, 217
Hempelmann, Dr. Louis H., 530
Henderson, Charles B., 4, 489
Hochschild, Dr. Mauricio, 493
Hochschild Company, 264
  zinc production, 568
Homestake Mining Company, manganese production, 308
  vanadium exploration, 551
Honduras, antimony, mercury production, 54, 321
Horton, F. W., 330
Howe Sound Company, 442
Hübnerite, 513
Hudson Bay Mining and Smelting Company, Ltd., 443, 567
Hull, Cordell, 25–26
Hungary, 27
  bauxite production, 84
Hurricane Creek aluminum plant, 35, 38
  lease to Reynolds Metals, 40
  use of Bayer process, 80
Hydromagnesite, 281

I

Ickes, Harold L., 258
  shortages of minerals and metals, antimony, 51
    asbestos, 68
    bauxite, 81
    cadmium, 100
    chromite, 120
    copper, 141
    manganese, 205
    mercury, 320
    nickel, 361
    platinum, 398
    tin, 489
    tungsten, 516
Idaho, mineral and metal production, cobalt, 130
    lead, 254
    mercury, 318
    mica, 332
    monazite sand, 352
    sillimanite, 432
    silver, 441
    thorium, 526, 540
    tungsten, 517
    vanadium, 548, 550–551
Illinois, mineral production, fluorspar, prices, 194, 199
    fuller's earth, prices, 115
    sandstone, tripoli, 413
Ilmenite, 349–351, 501–504
  associated with osmiridium, platinum, 382, 393
  source of vanadium, 546
Imperial Chemical Industries, 507
Imported minerals, 15
India, mineral and metal production, lead, 263
    lithium ore, 274
    magnesite, 279
    sillimanite, 431, 433
    silver under lend-lease, 444
    tantalite, 479–480
    thorium, 526, 543–544
  British India, mineral and metal production, barite, 75
    beryl, 90
    china clay, 114
    chrome ore, prices, 124, 126
    columbium ore, 136
    corundum, 170
    diamond cutting, 181
    feldspar, 189
    graphite, 205
    iron ore, 237, 241
    kyanite, 248
    langbeinite, salt deposits, 403
    manganese, exports, 15, 306–307, 311
    mica, high-grade, prices, 327, 330–331, 333–335, 337
    monazite sand, 352–353
    nitrate earth, 378
    rutile, ilmenite, 507–509
    smelter copper, 153
    soda ash, 451
    strontium ore, 457
    talc, 473

India, British India, mineral and metal production, zircon, 581–582
Indium, 555
domestic production, 209
foreign production, 209
low-melting alloys, 208
prices, 209
properties, 208
in solders, 208
sources, 208
strategic, with steel, nickel, copper, 208
uses, 208
Indium Corporation of America, 209
Indium platings, 208
Indium-cadmium bearing metals, 97
Indo-China, iron-ore, tin, tungsten, zircon production, 238, 492, 521, 581
Industrial Diamond Association of America, research in use and manufacture of diamond tools, 178
Industry controls, 17
Ingalls, W. R., 147
Inspiration Consolidated Copper Company, Arizona smelter, 142
Inter-American Affairs, Coordinator of, 9
Inter-American Conference on Problems of War and Peace, 25, 443
Interior Department, 6
development and conservation program, asbestos, 69
bauxite, 82
beryllium, 89
bismuth, 94
cadmium, 100
chrome, 120
cobalt, 131
columbite, 135
copper, 145
diamond cutting and polishing centers, 178
potash, 406
International Alkali Cartel, 452
International bank, 26
International commerce, 24
International cooperation, 25–26
International Minerals and Chemical Corporation, 57, 287–288, 405
development at Bartow, Florida, 58
fluorspar for MRC, 199
magnesium plant, 294
to withdraw from cartel, 59
International Monetary Fund, 26
International Nickel Company of Canada, 357, 359, 361–362, 364, 389, 391, 399, 401
copper smelter, 142
precious metals refining, 422
rhodium production, 418
selenium production, 429
silver production, 443
sodium sulfate production, 451
International Smelting and Refining Company, Raritan copper works, 142
International Supply, Bureau of, 489
International Tin Committee, 497, 499
Inventory controls, 18
Iodine, domestic production, 210
prices, 211
properties, 210
sources in oil-well brines, 210
uses, 210
Iowa Soda Products Company, 450
Ireland, bauxite production, 84
Iridium (*a*), chemical uses, 212–213
dental uses, 213
domestic production, 213
electrical uses, 212–213
foreign production, 214–215
hardening alloy, 212
imports, 215
platinum-iridium meter bar on interferometer, 98
prices, 215
properties, 212
sources, 213–215
uses, war, 212
world production, 215
Iron, in aluminum alloys, 32
and steel, alloy, seamless tubing, (*c*), 219
alloy steels, 218–219
Birmingham district, 222
carbon steel, 227
cast iron, 4
composition of earth's crust, 217
domestic production, 223–231
ferroalloys, 218
flat-rolled steel, 221
foreign production, 231–243
future requirements, ore, pig iron, steel, 221
high-tensile steel, 220
imports, exports, 238
improved steels, 218

Iron and steel, "intensified" steels, 219
Lake Superior district, 222–223
low-alloy steels, 220
metallurgy, 221
military steel springs, landing mats, 219
mineral earth pigments, 226
nonferrous smelting, 218
ocher, 218, 220, 226
ore, ore grades, 3, 6, 10, 19, 217
origin of iron deposits, 217–218
pig iron, 4, 224
powder metallurgy, 221
prices, 243–244
properties, 217
sienna, 218
silvery iron, 4
stainless steels, 218
standard steels, 219
steel in tin plate, 219
substitutes, 221
"supercharger" steel, 219
technologic advances in steelmaking, 219
tin plating, electrolytic process, 219
umber, 218, 220
uses, war, 218
wire rope, military and naval uses, 220
Iron Age, 227
Iron oxides (mineral pigments), 218, 220, 226
Iron paint, 220
Iron and Steel Research Association, British, 20
Italy, 27
metal and mineral production, aluminum, 46
antimony, 52
barite, 75
bauxite, 84
china clay, bentonite, 114
copper, smelter, 153
iodine, 211
magnesite, 279
magnesium, 296
mercury, 321–323
soda ash, 451
sulfur, 464, 466
talc, 473
tin, 495
vanadium, 553–554
zinc, 566, 571

J

Jamaica, bauxite deposits, 83
Japan, 12, 23, 27
mineral and metal production, aluminum, 37, 39
arsenic, 63
asbestos, 69
bauxite, 84
bismuth, 93
chalk, crude, 108
china clay, bentonite, 114
chromite, 122
copper, smelter production, imports, 153, 159–160
fluorspar, 198
ilmenite, 509
indium, 209
iron ore, 235
lead, smelter production, imports, 259, 265–266
magnesite, dead-burned, 278
magnesium, 294, 296
manganese, 310–311
mercury, 321
mica, imports, 333–334
molybdenite, 344
nickel, 365–366
nitrate, 379
osmiridium, 386
phosphates, 60
platinum, 398
ruthenium, 422
silver, 443
soda ash, 451–452
sulfur, 464
talc, 473–474
tin, exports, 219, 490, 492
tungsten, 521
vanadium, 553
zinc, 566, 570
strategic war materials, 12
Jardine, F. M., 19
Jardine Mining Company, arsenic production, 64
Java, iodine production, 211
Johnson Act, 14
Jones, Jesse, 2, 10
Jones Mills aluminum-reduction works, 39, 42
lease to Reynolds Metals, 40
Judson, Lawrence, 273

K

Kainite, 403, 408
Kaiser, Henry J., 287
Kaiser Company, Fontana Steel Works, 225
magnesium production, 292
Kaiser-Frazer Corporation and Kaiser Cargo, Inc., aluminum production, 43
Kalunite, Inc., alumina production, 80–81
Kansas, nitrogen production, 376
Kaolin (kaolinite) (*see* China clay)
Kaolinite in manufacture of alum, aluminum sulfate, 79
Kemet Laboratories Company, barium metal production, 72
Kennecott Copper Company, copper, lead prices, 572
Kentucky, ball clay, fire clay, fire-clay brick, prices, 115
fluorspar production, prices, 194, 199
Kieserite, 403
Kilgore, Senator Harley, 234
Kilgore Committee, 24
King, Prime Minister Mackenzie, 537
King Laboratories, Inc., barium metal production, 72
Kingdon, Dr. K. H., 530
Kirchberger & Sons, 472
Klein, A. C., 532
Knolls Laboratory, 540
Koppers Coal & Coke Company, 229
Korea (Chosen), metal and mineral production, aluminum, 46
arsenic, 64
barite, 75
china clay, 114
copper, smelter, 153, 159
fluorspar, 198
graphite, 205
iron ore, 235
mica, low-grade, 336
molybdenum, 346
tungsten, 519, 522
Kröll, Dr. William J., 429, 504, 579
Krug, J. A., 2, 16, 18, 41, 147–148, 228, 258, 489
Kyanite (*a*), 4, 431–432
domestic production, 246–248
flotation, 246
glass-grade, 249
imports, 248
large-grained Indian, 246
Kyanite (*a*), mullite, 245
prices, 248–249
properties, 245
raw, calcined kyanite, 248–249
refractories at high temperatures, 245–246
source of alumina, 245
superrefractories, 245
uses, war, 245–246
Kyanite Mining Corporation, 246
prices, 248–249
Kyanite Products Corporation, 246

L

Labrador, iron-ore deposits, 222, 231
Lake Superior Iron Ore Association, 223
Langbeinite, 403, 405
Lanthanum, 20
(*See also* Monazite sand)
Lateritic nickel ore, 363
Latin America, 9–10
mineral missions to, 9, 12
Lavenite, 577
Lawrence, Prof. E. O., 436
Lead (*a*), 4, 6, 10, 14–16, 18–19, 22, 24
alloys with silver, 250
antimonial lead, 250
base bullion, 250
concentration, flotation, 250, 259
in copper cable, 251
domestic production, consumption, 252–259
foreign production, 260–266
imports, exports, 261, 263, 265
premium-quota plan, 266–267
prices, 21, 266–268
properties, 250
scrap, 252, 255, 257
secondary recovery, 252
small-arms production, 254
in storage batteries, 250
substitute for copper, iron, tin, zinc, 250, 252
tariff, 267–268
tetraethyl lead, 251
uses, war, 250
white lead, red lead, 251
Lead chemical compounds, 250, 251
Lead dyes, pigments, 251
Lead Industries Association, 253, 257
Lead solders, 250–251
Lead vanadates, 544, 546

Leith, Dr. C. K., 25, 262
industrial-diamond production, 179
Lend-lease, 12
copper, 159
functions of, 13
iron and steel, 227
in reverse, 13
zinc, 569
Lepidolite (lithia mica), 192, 327
(*See also* Lithium)
Lepidomelane scrap mica, 327
Lewin-Mathes Company, smelter, 142
Light metals, alloys, 8
Lime, 4
Limonite, 217
Lind, Dr. S. C., 531
Linde Air Products Company, manufactured ruby, sapphire, 420, 425
Listerhill aluminum-reduction works, 38
Litharge, 251, 259
Lithiophilite, 270
Lithium (amblygonite, lepidolite, spodumene), air-conditioning, 271
alkaline-earth metals, 270
Bahn metal, 272
bearing-metal alloys, 271
chain-reacting pile, 272
domestic production, 272–274
foreign production, 274–275
froth flotation, 273
glassmaking, 272
imports, 274
occurrence, 270
prices, 270
properties, 270
refining agent on molten metal, 270
scavenger, 271
scleron, 275
substitute for lead, 272
tin bronze, silicon bronze, 271
uses, in castings (copper, bronze, steel), 270–271
war, 271
Lithium amide, 271
Lithium carbonate, 272
Lithium chloride, 271–272
Lithium compounds, 271
Lithium fluoride, 272
Lithium hydride, hydroxide, 271–272
Lithium metal, 271
Lithium salts, 270–272
Lithium vapor process, 271
Lithium-mica, 270
Lithopone, domestic production, 74
prices, 76
reconversion problems, 74
titanated, 74
used as white pigment, filler, 73, 252
as war substitute, 73
Lochmund, B. J., 247
Lockwood, Maurice H., 408
Loellingite, 62
London, England, 11, 27
Metal Bulletin, 241
Metals Control price for antimony, 55
Longview aluminum-reduction works, 35, 38
Louisiana, ammonia-soda process, 450
magnesium production, 288
sulfur, prices, 459, 462
Low-grade ores, 24
Luxemburg, iron and steel production, 235, 242

M

McCook aluminum-sheet mill, lease to Reynolds Metals, 40
Macedonia, chromite, lead, zinc production, 346
molybdenite production, 346
McGrath, J. S., 10
McKinley Tariff, 264
McMahon Bill, 536
McNabb, B. G., 248
McNutt, Paul V., 258
Madagascar, beryl exports, 90
corundum production, 170
graphite, prices, 205–206
lithium ore, 274
mica production, 333, 335
uranium, 543
Magnesia, magnesitic dolomite, 277
plastic, 276
Magnesia refractories, 246
Magnesite (dead-burned), 4, 19
amorphous, 276
basic brick, 277
brick burning for metallurgy, 276
calcined brucite, 277
calcining process, 276
caustic magnesite, 276–277
crystalline magnesite, 276
domestic production, 277-278
Epsom salts, 277

Magnesite (dead-burned), foreign production, 278–280
imports, 278–279
insulating materials, 277
occurrence, 276
prices, 280
properties, 276
rammed magnesia grain bottom, 276
Sorel cement, 276–277
source of magnesium, 281, 295
substitutes, 276–277
Magnesite brick, 276
Magnesium (*b*), 4, 6, 18
aluminum alloys, 30–31
castings, forgings, 284
domestic production, 285–294
Dow electrolytic process, 288
electrolysis, 282
exports, 283
foreign production, 294–296
"Goop" bomb, 282–283, 289–290
Hansgirg carbothermic process, 282
natural brine, 288
oxide and chloride processes, 282
periclase oxychloride cement, 288
Pidgeon thermal-reduction process, 282, 286
prices, 297
properties, 281
secondary recovery, 286, 290
sources, 281
substitute for aluminum, 281
uses, war, 282–283
Magnesium Association, 284, 285
Magnesium chloride, 290
Magnesium hydroxide, 290
Magnesium oxide, 4, 287–288, 290
Magnesium Reduction Company, 288–289, 294
Magnesium sulfate, 283
Magnetite, 501
iron ore, 217
osmiridium associated with, 382
ship ballast, 220
source of vanadium, 544–546
Mahoney, Dr. J. R., 230
Maine, beryllium ore, shipments, 89
mica production, 329
potash, soda feldspar, prices, 188, 190
Malachite, 138
Malaya, British, china clay, 114
ilmenite, 507–508
Malaya, British, iron ore, 235–237
manganese exports, 307
monazite sand, 353
thorium, 526, 544
tin smelter production, exports, 485, 490–492, 498
tungsten, 519, 522
Mammoth-St. Anthony Mines, 548
Manchuria, mineral and metal production, iron ore, 235, 346
lead-zinc, 346
magnesite, dead-burned, 278
Manchuria Lead Mining Company, 346
molybdenite, 344, 346
talc, 473–474
Manganese (*a*), 7, 9–10, 14–16
in aluminum alloys, 30, 32
battery-grade, 300
chemical grade, 299
combat suits, 299
concentration, flotation, beneficiation, 300–301
domestic production, 300–303
ferro-grade ore, 298–299
ferromanganese, ferroalloys, 298–300
ferrosilicon, 299–300
ferruginous ore, 299
high-grade manganese nodules, 300
low-grade ore, 300
manganin, 299
molybdenum as substitute, 299–300
prices, 311–313
properties, 298–299
silicomanganese, 300
spiegeleisen, 298–299
uses, 300
war, 299–300
Manganese ore grades, 298–299
metallurgical, 299
Manganese oxide, carbonate ores, 300
Manganese steel, 299–300
Manganese sulfate, 300
Manganiferous iron ore, 299
Manganite, 298, 300
Manganosiderite, 300
Manhattan Engineer District, 531, 539
Marcasite, 459
Marginal production, 15, 22
Maritime Commission, copper and steel uses, 144, 226
Maryland, mineral production, ball clays, prices, 115

Maryland, mineral production, glaze spar, 188
kaolin, 112
quartz, ground, 413
soda, 450
steatite, 472
Maspeth aluminum-reduction works, 38
Massachusetts, ground quartz, andalusite production, 413, 433
Massena, aluminum-reduction works, 35, 38
Mathieson Alkali Works, 287–288, 294
Matthiessen & Hegeler Zinc Company, 563
May-Johnson Bill, 536
Maywood Chemical Company, 273, 352
Melaconite, 138
Mercuric nitrate, 315
Mercury (*a*), 4, 6–10, 14, 16, 18
chemical compounds, 315
chemical-warfare uses, 315
domestic production, 317–320
duty, 324
foreign production, 320–323
imports, 321
occurrence, 314
prices, 324
properties, 314–315
Ruben dry-battery cells, 315
smelting methods, furnace, retort, 314
substitutes, 315
uses, war, 314
Mercury ray, 98
Mercury sulfide, 315
Mercury-vapor lamp, 98
Metal prices, First and Second World Wars, 22
Metal Traders, Inc., 323
Metallurgical engineering, 19
Metallurgical research, 19
Metals Reserve Company (Office of Metals Reserve), 4, 9, 10, 12, 15
agents for, 21
contracts, for bauxite from Brazil, 83
for beryl from Brazil, 90
for bismuth from Mexico, 95
for cadmium from Mexico, 101
for Canadian aluminum, 44
for chromite from Brazil, 124
for cobalt from Mexico, 132
for copper from South America, 154
for fluorspar from Mexico, 198
for graphite from Mexico, 205
for industrial diamonds from Brazil, 180
for Latin-American antimony, 53
Metals Reserve Company (Office of Metals Reserve), contracts, for lead from South America, 264–265
for manganese from Mexico, Brazil, 309
for molybdenite, 345–346
for nickel, rutile, 362, 363, 506–507
for quartz crystal, 414
for tin, tungsten, 495, 520–521
stockpile purchases, aluminum, 37
antimony, 50–52
arsenic, 64
asbestos, 68
barite, 74
bauxite, 79
beryllium, 88–89
bismuth, 94
cadmium, 98–99
calcite, optical, 105
celestite, 456
chrome ore, 119, 126
in Alaska, 125
cobalt, 130
in Canada, 130
columbium, 135
copper, 145–146, 163
bonus payments, 145
in Canada, 156
corundum, 168
cryolite, 174
diamonds, 178
fluorspar, 195
graphite, 204
iridium, 213
iron ore, 228
kyanite, 247
lead, 256–258
bonus payments, 266–267
lithium, 274
magnesium, 291
manganese, 301
mercury, 318–319
mica, procurement, 331–332, 334
molybdenite, exports, 342–343, 345
monazite sand, 352
nickel, 360
osmium, 382
palladium, 390
platinum, 397
quartz crystal, 413–414
rhodium, 417
ruthenium, 422
silver, 439

Metals Reserve Company (Office of Metals Reserve), stockpile purchases, talc, block, 471
steatite, 470
tantalum, prices, 479, 481
tin, 485
tungsten, 523
vanadium, 549
zinc, 558–560
zirconium, 580
Meteorites, 355
Mexico, 9, 22–23
Mexican-American Commission for Economic Development, 9
mineral and metal production, aluminum, 46
antimony, 52–54
arsenic, 63–64
bismuth, 95
cadmium, 101
calcite, optical, 105
bentonite, 114
cobalt, 132
copper, smelter production, exports, 150, 152–153, 155, 157
fluorspar, 198–200
graphite, 205–206
indium, 210
iron ore, steel, 240
lead, exports, prices, 259–261, 264, 267
manganese, 308
mercury, 321–323
mica manufacturing, imports, 334
molybdenite, 342, 344–345
rutile, ilmenite, 508
selenium, 430
silver, 442, 444
strontium ore, 456–457
sulfur, 465
tin, 495
tungsten, 519–520, 522
uranium, 544
vanadium, 552–553
zinc, 566–568, 571–572
mining projects in, 12
Mica, block (*a*), (*b*), 6, 327
sheet, 328, 330
book splitting, 326
built-up mica board, 327–328, 330
cigarette, 328
circle grade, 330
dielectric, 328
Mica, domestic production, consumption, 331–333
duty, 337
foreign production, 333–336
grinding methods, 330
ground, nonstrategic, 328, 330
import controls, 333
landing mats, 328
mineral staining, 327
muscovite, 4, 9–10, 326–327
dark stained, 327, 331
specifications, 330
occurrence, 333
phlogopite, 4, 326–328
specifications, 330
prices, 336–337
properties, 326–327
punch, 327, 330–331
radio-condenser films, 327
sheet mica grades, 327, 330–331
ruby, 326–327
scrap, 329, 336
silver amber, 326
spark plugs, 326
splittings, 326–327, 330–331
substitutes, 328–329
uses, 326–328
war 326–328
waste grades, 330
Mica powder, 330
fine flake, 328
Mica splitting, 334
Michigan, mineral production, ammonia-soda process, 450
graphite, 203
iron ore, 221
magnesium from brines, 281, 288
manganiferous iron ore, 305
Microlite, 479
Midland Electric Coal Corporation, 463
Military Affairs Committee, 537
Military Government, Office of, 234
report on German munitions production, 379
Millerite, 355
Milwhite Company, Inc., 456
Mineral economics, 24
Mineral production of United States, 8
Mineral resources, 24
Mineral wool, 4
Minerals procurement program, 1
in foreign countries, 14

Minerva Oil Company, fluorspar production, 194
Mines, Bureau of, 7–9
aluminum-production statistics, 35–36
asbestos in Alaska, 70
chromite supplies, 119
cobalt exploration in Idaho, 130
corundum exploration in North and South Carolina and Montana, 169
diamond exploration in Arkansas, 178
exploration projects, mica, 332
molybdenite, 342
nickel, 359, 363
sillimanite, 432
talc, processing, 470–471
tungsten, 522
vanadium, 551
zircon, 580
fluorspar exploration, 196
Foreign Minerals Division, 10
graphite production, studies in, 203
iron ore in Alaska, 232, 233
iron-ore exploration, 222
kyanite in Florida, 247
magnesium techniques, 291
pig iron, steel production, 224
Minnesota, iron-ore production, 221
manganese ore, 300, 305
University of, 531
Mint, Bureau of the, 442
Missouri, fire clay, brick, production, prices, 113, 115
lead, nickel production, 254, 359
tripoli, prices, 413, 415
Mobile aluminum-reduction works, 35
Moctezuma Copper Company, 157
Molding sand, natural bonded, 109
strategic uses of, 109
Molybdenite (*b*), 4, 6, 16
ammonium molybdate, 341
calcium molybdate, 341
copper mining, by-product, 342
domestic production, 341–344
ferromolybdenum, 341, 343
foreign production, 344–347
metallurgy, 345
prices, 344, 347–348
properties, 339
substitute for tungsten, nickel, manganese, chromium, 340
thermit reaction, 341
uses, war, 339–341
Molybdenum, competition with nickel, 339
scrap, 343
Molybdenum salts, 341
Molybdenum steel, cast iron, 339, 343
Molybdenum sulfide, 344
Molybdenum trioxide, 341
Molybdenum wire, 344
Molybdenum Corporation of America, production, 342
Molybdic oxide, 341
Moment, Samuel, 230
Monazite sand (*a*), 573
Auer metal, 351
beach deposits, 349
cerium, 349
acetate, 350
electrolysis, 349
oxide, 349
"crude" sand, 350
domestic production, 351–352
ferrocerium, 350–351
foreign production, 352–354
imports, 353
Kunheim metal, 351
metallurgy, 350
mix metal, misch metal, 349, 351
prices, 354
properties, 349–350
rare earths, oxides, 349
silica, 349
tariff, 354
thorium, mesothorium, 349–351, 353, 526, 544
thorium-bearing minerals, 349
uranium minerals, 349
uses, war, 350–351
yttrium, 349
Monel metal, 4
Monolith Portland Mid-West Company, alumina from anorthosite, 81
Monopoly, aluminum, 44
diamonds, 181
graphite, pure, 204
iodine, 211
monazite, 354
phosphates, 59
sulphur, 467
tin, 489, 491, 493
uranium-radium, 545
vanadium, 551
Monsanto Chemical Company, 529

Montana, metal and mineral production, calcite, optical, 104–105
chrome ore, 121–122
copper, 141
corundum, Elk Creek mine, 169
graphite, 203
iron-ore deposits, 222
manganese, battery-grade, low-grade, 300, 304
nickel prospects, 359
phosphate-rock industry, 58
ruby, sapphire, natural, 420, 425
rutile, 504
silver, 441
steatite, 472
vermiculite, price, 336
Montana Phosphate Products Company, 57
Morocco, French, mineral production, cobalt, 131–132
manganese, 307
molybdenite, 344, 346
phosphates, high-grade, 60
potash, 406
lead exports, production, 260
Spanish, graphite, iron-ore production, 206, 236–237
Morse, Dr. Philip M., 540
Moscow conference, 25, 27
Mozambique, mica, tantalite production, 335, 479–480
Munitions, 2
Munitions Board, Army and Navy, 3, 6
English kaolin, strategic raw material, 109
stockpiling policy for antimony, 52
for asbestos, 69
for bauxite, 82
for chrome ore, 121
for cobalt, 131
for columbite, 135
for copper, 145
for magnesium, 293
Munitions and Supply, Department of, 156
Muntz metal, 164
Muscovite sheet mica, 4, 9–10, 326
light silver, dark silver, wine amber grades, 327

N

National Academy of Sciences, 80
Advisory Committee on Metals and Minerals, 245
National Academy of Sciences, alumina from nonbauxitic sources, 80
diamonds for grinding-wheel tooling, 177
National Bureau of Standards, grain size for diamond dust, 177
National Carbon Company, Ascheson Graphite Division, 203
National defense, 22
National Defense Council, 412
National Emergency Steels, 20, 219, 356
molybdenum, 340
National Fertilizer Association, 408
National Lead Company, 265
magnesium production, 288
titanium production, 505
National Paint, Varnish and Lacquer Association, 506
National Research Committee, atomic-bomb research, 202
National Research Council, apparatus testing mica, 329
National Zinc Company, indium, zinc production, 209, 561
Natural Soda Products Company, 450
Naval Bureau of Aeronautics, 187
Naval Research Laboratory, plastic-armor research, 187
Navy Department, 6, 10, 18, 412
development and conservation program, asbestos, 69
bauxite, 82
beryllium, 89
bismuth, 94
cadmium, 100
chrome, 120
cobalt, 131
columbite, 135
copper, 144–145
steel, 226
zinc, 560
investigation of foreign lead supplies, 259
Navy Electronics Research Laboratory, 98
Nazi political philosophy, 23
Nazi science of aggression, 25
Nazi smugglers, 12
Nazi-controlled Europe, aluminum, 45
Nelson, Donald A., 2
Neodymium (*see* Monazite sand)
Nepheline syenite, 4
Netherlands, 26
diamond cutting and polishing center, 178
inadequate supplies of phosphates, 60

Netherlands, silver under lend-lease, 444
tin self-sufficiency, 491
zinc, 565–566
Netherlands East Indies, mineral and metal production, bauxite, 84
china clay, 114
manganese, 307
monazite sand, 353
nickel, 366
phosphates, high-grade, 60
platinum, 400
tin smelter output, exports, 490–492, 496–498
Nevada, mineral and metal production, andalusite, dumortierite, 433
brucite, 281
chlorine, liquid, caustic, 287
copper, 141
diatomite, 415
fluorspar, 197
graphite, 203
iron-ore deposits, 222
magnesite, 277
magnesium plant at Gabbs, 286, 288
magnetite, crushed, 220
manganese, 304
molybdenite, 342
talc, 471
tungsten, 517
Nevyanskite, 381
New Caledonia, chrome ore production, exports, 125
nickel production, 363–364
New England Lime Company, 288, 294
New Hampshire, mineral production, beryl ore, 89
mica, sheet mica, development, 332
potash, soda feldspar, prices, 188, 190
sillimanite, 432
New Jersey, mineral and metal production, feldspar, price, 190
graphite, 203
insecticide clay, plastic clay, prices, 115
kaolin, 112
manganiferous zinc residuum, 305
sandstone, 413
zinc, 564
New Jersey Zinc Company, 563
New Mexico, mineral and metal production, bentonite, 113
calcite, optical, 104
columbite, 135
New Mexico, mineral and metal production, copper, 141
fluorspar, 193–194
lithium, 273
magnesium, 288
manganese, 304–305
mica, 329
molybdenite, 342
potash, 403, 405
tantalum, 479
uranium, 526, 530
vanadium, 550–551
New York, mineral and metal production, emery, garnet, 183–184
graphite, 203
lead, 254
magnesium, 288
mica prices, 336
potash, soda feldspar, prices, 188, 190
pyrites, 462
rutile, 504
soda ash, 450
talc, 470–471
vanadium, 548
wollastonite, 104
zinc, 564
New York Times, The, 442
New Zealand, bentonite deposits, 114
platinum production, 400
uranium, 543
Newfoundland, mineral and metal production, Buchans mine, lead-zinc output, 265
copper, 150
fluorspar, 198–199
iron ore, 236–237
lead, 260–261
pyrophyllite, 473–474
zinc, 566–567
Niagara Falls aluminum-reduction works, 35, 38
Nicaro Nickel Company, 363–364
Niccolite, 355
Nichrome, 358
Nickel (*a*), 4, 7, 10, 14
alloys with aluminum, copper, iron, 32, 355
consumption, 359
cupro-nickel, 357
domestic production, 358–360
foreign production, 361–366
imports, exports, 360

Nickel (*a*), kovar, 358
metallurgy, 356, 358
monel metal, scrap, 356, 358–360
occurrence, 355
Orford process, 356
prices, 366–367
properties, 355
stainless steels, 357
substitutes, 357
sulfide, silicate ores, 356
uses, 358
war, 356–357
Nickel alloys, 355
Nickel oxide, 355
Nickel plating, 355, 358
Nickel salts, 359
Nickel silver, 357
Nickel steels, 355–356
Nickel-cobalt alloys, 128
Nigeria, columbite production, 135–136
tantalite, tin ore, 480, 491, 495, 497
Niter, 368
Nitric acid, 368–369
Nitrogen compounds, 6
ammonia as raw material, 368–369
atmospheric nitrogen, 368
basic materials, 368
benzene, 370
block-buster bombs, 371
Chile saltpeter, 368–369
demolition bombs, 369
domestic production, 373–376
dynamite, 371
explosives, 369–370
fertilizer salts, 371
fixed nitrogen, 368
foreign production, 376–379
glycerin, 371
gun cotton, 371
Haber process, 368
Ostwald process, 368
phenol, 369
picric acid, 370
plastic explosives, 370
prices, 379–380
production methods, 369
properties, 368
sodium chloride, 368
sodium nitrates, 368–369
sodium sulfate, 368–369
sources, 368–369
synthetic nitrogen, 368
Nitrogen compounds, tetryl explosives, 370
toluene, 369
torpex, 370
tritonal, 370–371
uses, war, 369–373
Nitroglycerin, 371
Nonferrous metals, 19
as alloy constituents, antimony, 49
arsenic, 62
beryllium, 86
bismuth, 92
cadmium, 97
calcium, 103
cerium, 349
chromium, 117
cobalt, 128
columbium, 134
copper, 138
indium, 208
lead, 250
magnesium, 281
manganese, 298
mercury, 314
molybdenum, 339
nickel, 355
palladium, 387
platinum, 393
selenium, 427
silver, 435
sodium, 447
tantalum, 477
tin, 482
titanium, 501
tungsten, 513
zinc, 555
Nonmetallic minerals, 8
Nonmetallic or semimetallic elements as alloys, nitrogen, 368
phosphorus, 56
sulfur, 459
Noranda Mines, Ltd., 443
North Carolina, mineral and metal production, ceramic clays, prices, 115
columbite, 135
corundum, 169
kyanite, 247
lithium ore, 273
mica, prices, 327, 330, 336
molybdenite exploration, 342
monazite sand, 351
potash, soda feldspar, prices, 188, 190
quartz, ground, 413

North Carolina, mineral and metal production, talc, 471
thorium, 526, 540
tungsten, 517
vermiculite, 336
zircon, 579
North Continent Mines, 550
Northwest Magnesite Company, 280
Norway, metal and mineral production, aluminum, 46
cadmium, 101
copper, exports, 150, 152–153, 160
feldspar, 189
fluorspar, 199
graphite, 206
heavy water, 543
ilmenite, 507–508
iron ore, 236, 239
magnesium, 296
mica, 335–336
molybdenite, 344, 347
monazite sand, 353
nickel, refining, 363, 365
nitrogen, exports, 369, 378
osmium exports, 383
palladium, 391
pyrites, 464, 466
talc, 473
tungsten, 521
zinc, 565
zircon, 581
Nyasaland, bauxite occurrences, 78

O

Oak Ridge, Tenn., 272, 529
Ohio, mineral and metal production, ammonia-soda process, 450
fire clay, brick, prices, 113, 115
magnesium, 288
nitrogen, 376
sandstone, 413
strontium ore, 456
Oil, Paint and Drug Reporter, 244
prices, lithium compounds, 275
pyrophyllite, 475
salt cake, Glauber's salt, 452
talc, 474–475
uranium oxide, sodium uranate, 544
Oklahoma, tripoli, zinc production, 413, 564
Olin Corporation, aluminum production, 36, 38, 43
Olivine, 4
source of magnesium, 281
O'Mahony, Senator, 42
Oppenheimer, Prof. J. R., 530, 532
Optics, plastic, 410–411
Orange Free State, diamond mines, 180
Ordnance Department, U.S., molybdenum-steel uses, 341
Ore reserves, antimony, domestic, 51
Oregon, mineral and metal production, chrome, 122
diatomite, 413
mercury, 317–318
rutile, 504
zircon, 580
Ores, low-grade, 3, 9, 19
Orpiment (arsenic trisulfide), 62
Osmiridium (*see* Osmium)
Osmite, 381
Osmium, osmiridium, (*b*), domestic stocks, 383
foreign production, 383–386
imports, exports, 383–384
iridosmium (iridosmine), 381
occurrence, 381–382
platinum group metals, 381
prices, 386
properties, 381
uses, war, 382
Osmium alloys, 382
Oxychloride Cement Association, 278
Ozark Chemical Company, 450

P

Pacific Alkali Company, 450
Palestine, diamond cutting, polishing center, 178, 181
market for platinum metals, 215
potash exports, production, 406–407
Palladium (*b*), 4
allopalladium, 387
alloy heat treatment, 388
alloys with silver, nickel, 387
catalyst, 384
dental alloys, 388, 396
domestic production, stocks, 389–390
foreign production, 391–392
occurrence, 387
platinum group metals, 387
prices, 392
properties, 387–388

Palladium (*b*), secondary, 390
solidus temperature, 388
substitutes, 388
uses, war, 388–389
Palladium-platinum pair, 387
Panaminas, Inc., 563
Pan-Chemical Company, 456
Papua, iridium, osmiridium production, 215, 386
Paterson, Secretary of War, 139, 530
Patino, 493–494
Patino Mines and Enterprises, Consolidated, 493
Patronite, 546
Pauley, Edwin, 235, 344
report on zinc, lead, tin refining in Japan and China, 570
Pauling, Dr. Linus, 535
Pegram, Dean George B., 530
Pehrson, Elmer W., 6, 16, 24
ore reserve estimates, antimony, 51
asbestos, 68
bauxite, 81
chrome ore, 120
copper, 140–141
fluorspar, 194
iron ore, 221
lead, 258
manganese, 301
mercury, 318
mica, domestic block, 333
molybdenum, 341
nickel, 359
phosphate rock, 58
platinum, 398
potash, 405
silver, 441
sulfur, 461
tungsten, 516
vanadium, 551
zinc, 564
Pennsylvania, mineral and metal production, chrome ore, low-grade, 122
clay, fire, crude, fire-clay brick, prices, 113, 115
glaze spar, 188
graphite, 203
kaolin, 112
mineral earth pigments, 226
nickel ore, 359
sandstone, tripoli, 413
silver, 443
Pennsylvania, mineral and metal production, vanadium, 550, 552
Pennsylvania Salt Manufacturing Company, artificial cryolite production, 174
Pentlandite, 355
Peridotite, 468
Permanente Metals Corporation, 287–288, 292–294
Perry-Schroeder Mining Company, 425
Persia, iron-ore deposits, 241
Peru, 9
mineral and metal production, antimony, 52–54
bismuth, 93–95
cadmium, 101
copper, smelter production, 151–153
iron-ore, steel production, 241
lead, 259–261, 263
lead-zinc deposits, 264
mercury, 321
molybdenite, 344, 346
silver, 443
tungsten, 519–520, 522
vanadium, asphaltite, 546, 549, 552–553
zinc, 566, 568, 571
Petalite, 270
Phelps Dodge Corporation, 141
Phelps Dodge Refining Corporation, 142
Philippine Islands, mineral and metal production, chrome ore, 123–124
copper, 150, 159
iron ore, exploration, 235–237
lead, 265
Lepanto Consolidated Mining Company, 159
manganese, 306, 309
nickel, 365–366
silver, 444
Phlogopite sheet mica, 326–328
Phoenix aluminum extrusion plant, 40
Phosphate, calcium, 56
bone phosphate of lime, 61
brown-rock, 61
ferrophosphates, 56
land-pebble phosphate, 61
prices, 61
in steelmaking, 219
superphosphate of lime, 56
uses, war, 56–57
Phosphate Export Association, 59
Phosphate Mining Company, 59
Phosphate nonsilica glass, 57

Phosphate rock, 6, 56
exports, 60
occurrence, 56
production of fertilizers, 56
six classes of, 58
Phosphorus (phosphoric acid), component in salts, compounds, 57
elemental phosphorus as chlorinating agent, 57
produced at Muscle Shoals, 57
phosphate rock as source, 56
Pinite, 470, 472
Pioneer Potash Company, 405
Pitchblende, 526, 540
Pittsburgh Plate Glass Company, 450
Platinite, 395
Platinum black, 393–394
Platinum group metals, 10
Platinum ore (*a*), 4, 6, 12–13
alloys, 393
anodes, 394, 396
catalyst, 368, 394
domestic production, 397, 400
electroplating, 396
foreign production, 398–401
glass products, 394–395
imports, exports, 400–401
occurrence, 393
prices, 401
properties, 393
secondary, 397
substitutes, 395
sulfuric acid manufacture, 394
uses, science, industry, 394
war, 393, 396
wire, 393–394
Platinum-palladium pair, 393
Poland, mineral and metal production, bentonite, clay products, 114
cadmium, 101
indium, 210
iron mines, steel plants, 234
lead, 266
potash, 406–407
zinc, 566, 570–571
Polaroid Corporation, 103, 412
optical calcite, 105
Pollard, Dr. W. G., 272, 532
Pollock, Dr. H. C., 530
Polyhalite, 403
Portugal, mineral and metal production, beryl, 90
Portugal, mineral and metal production, ilmenite, 507–508
lithium ore, 274
mica, 336
pyrites, 464–465
tin smelter output, 490, 492
tungsten, 12, 521–522
uranium, 542
Postwar imports of essential materials, 126
Postwar plans, 25
Potash, 6, 294
caustic, 404
manure salts, 404, 408
muriate, 403, 407–408
muriatic acid, 403
occurrence, 403
pearl ash, 403
potassium carbonate, 403
potassium hydroxide, 403
potassium oxide, 403
prices, 407–408
production, domestic, 404–406
foreign, 406–407
properties, 403
refining process, 404–405
salts of tartar, 403
sulfate of potash, 408
uses, strategic, 404
Potash salts, 450
Potsdam conference, 27
Praseodymium (*see* Monazite sand)
Pratt, W. E., 450
Preclusive buying, 10–11
tungsten ore, 12
Pregel, Boris, 533
Premium-price plan, 21
Premium-quota plan, 21
Prentice, Bruce R., 532
Price Administration, Office of, 2, 18, 21
Maximum Price Regulation, arsenic, 64
cadmium, 99
calcite, optical, 105
chromium metal, ferrochromium, 120
cobalt, 130, 133
copper, 163
corundum, 169, 171
fluorspar, 199
iridium, 215
iron, gray, castings, 227
iron ore, 243
kyanite, 249
lead, 267–268

Price Administration, Maximum Price Regulation, magnesium, 287, 297
mica, 336–337
molybdenum, 344, 348
nickel, 367
nitrogen, 375
osmium, 386
palladium, 392
phosphate, 61
platinum, 401
potash, 406, 408
pyrophyllite, 475
quartz crystal, 415
rhodium, 418
ruthenium, 423
silver, 438, 444–445
steel, stainless, scrap, 229, 244
sulfur, 461
talc, 475
tin, 489
titanium pigments, rutile, ilmenite, 509
tungsten, 518
vanadium, 549, 554
zinc, 560, 572–574
Price Control Act, 200
Price controls, 5, 18, 21
ceiling on, 15, 18, 22
Price Decontrol Board, 498
Price stability, 22
Priority controls, 17
AA, AAA, and MM ratings, 17
CC ratings, 18
Production Management, Office of, 21, 44
calcium silicon controls, 104
rutile controls, 505
Production Requirements Plan, distribution of copper, 144
Psilomelane, 298, 300
Puerto Rico, manganese production, 300
Purnell, Rear Adm. William R., 530
Pyrite, 217, 459
Pyrolusite, 298–300
Pyrrhotite, 355, 459

Q

Quartz crystal (*a*), domestic production, 413
faced, unfaced crystals, 410
foreign production, 413–414
imports, 414
jewelry, 411
occurrence, 410
Quartz crystal (*a*), oscillator plates, 413
piezoelectric quartz, 410, 413
plastic optics, 4, 9, 12, 15
in cameras, telescopes, 412
prices, 414–415
radio grade, 410
rock crystal, 410
silica, 410
specifications, 410
uses, radio, 411
war, 411
Quebec Asbestos Producers Association, 70
Quotas, A, B, and C, 22

R

Radium, 350
Rare Metals Products Company, arsenic, 63
Rare Mineral and Metals Company, 352
Realgar, 62
Reciprocal trade agreements, 22, 23
Reconstruction, loans for, 26
Reconstruction Finance Corporation, 10, 21
aircraft, disposal of surplus, 42
aluminum-reduction plants, lease agreements on, 38
antimony, disposal of, 51
Fontana Steel Works, 225
investigation of foreign lead supplies, 259
kyanite production, 247
magnesium production, 287
mica machinery shipped to Brazil, 334
Reconversion, 16, 18
Remobilization of mining industry, 18
Republic Steel Corporation, 229
Research, fundamental and applied, 20
Research agencies, Armour, Mellon, Batelle, Southern, 20
Research Council, National, 20
War Metallurgy Committee, Beryllium, 88
Restrictive trade practices, 23
Revere Copper and Brass, Inc., 287
Reynolds Metals Company, 35–36
aluminum production, 35–36, 38, 40
bauxite from government stockpile, 80
Rhode Island, graphite production, 203
Rhodesia, Northern, cobalt, copper, vanadium production, 131–132, 151, 153, 158–159, 552–553
selenium production, 430
Southern, asbestos, chromite, lithium, tantalite production, 68–70, 122–123, 126, 274, 480

Rhodium (*b*), domestic refining, 417
foreign production, 418
imports, 418
jewelry, 417
prices, 418
properties, 416
uses, war, 416–417
Rhodium-iridium pair, 416
Rhodium-platinum alloy, 395
Rhodium-platinum gauze, 396
Rhodochrosite, 298, 300
Rhodonite, 298
Richmond Eureka Mining Company, arsenic production, 64
Rios, Juan A., 155
Riverbank aluminum-reduction works, 38
Riz Mineral Company, 580
Roneusil rustproof steel, 357
Roosevelt, President, 528–529
Roscoelite, 327, 526
source of vanadium, 546, 548
Rosiclare Lead and Fluorspar Mining Company, 194
Ruby, adamantine spar (*a*), 419
boules, 420
domestic production, 419–420
foreign production, 420
imports, 419
jewelry, 419
properties, 419
synthetic ruby, 419
use, war, 419
Ruhr, Belgium-Ruhr iron ore, 231
steel plants, 234
Rumania, 27
manganese exports, 307
smelter copper production, 153
Russia, 23, 26
mineral and metal production, aluminum, 46
antimony, 52
apatite and phosphate rock, 60
asbestos, 69–70
bauxite, 83
bentonite, clay products, 114
beryl, 90
bismuth, 93, 95
chromite, exports, 122, 125
columbium, 136
copper, 153, 155, 158
corundum, 170
diamond, 180
Russia, mineral and metal production, graphite, 205
ilmenite, 509
indium, 209
iodine, 210
iridium, 214
iron ore, 222, 231, 235, 242–243
lithium ore, 274
magnesite, dead-burned, 278, 279
magnesium, 296
manganese, 206–207, 310–311
mercury, 321–323
mica, 335–336
molybdenite, 344, 346
nickel, 365–366
osmium, 383
palladium, 391
platinum, 384, 398–400
potash, 406–407
selenium, 430
silver, 443–444
soda ash, 451
sulfur, 464
tin consumption, 490
topaz, 512
tungsten, 523
uranium, 544
vanadium, 553
zinc, 571
research in, 20
Rustless Iron and Steel Corporation, 396
chrome ore, 121
stainless steel, 226
Rustless Mining Company, chrome ore production, 122
Ruthenium (*b*), domestic refining, 422
foreign production, 422–423
imports, 422–423
platinum group metals, 421
prices, 423
properties, 421
uses, war, 421–422
Ruthenium-osmium pair, 421
Ruthenium salts, 421
Rutile, 4, 349–351, 501–504
Rutile Mining Company, 576

S

Sachs, Dr. Alexander, 528
St. Joseph Lead Company, 254, 260, 265
zinc production, 562–563, 569

St. Louis Smelting and Refining Company, cobalt production, 130
Salt, 4
Samarium (*see* Monazite sand)
Sand, ground, sandstone, 412
Sapphire (*a*), boules, 424
  domestic production, 425
  imports, 425
  natural Montana, 425
  phonograph needles, 425
  prices, 426
  properties, 424
  substitutes, 425
  synthetic, 424–425
  uses, war, 424
Sardinia, talc production, 473
Saudi Arabia, silver under lend-lease, 444
Scalzo & Pisano, emery production, 184
Scheelite, 513
Schoenite, 403
Schundler, F. E., & Company, 278
Schwarz, Michael, 147
Scientific Research and Development, Office of, 20, 412, 531
Scrap-metal industry, 19
  aluminum, brass, copper, ferrous, zinc, 16
Selenious acid, 427
Selenium (*b*), domestic production, 429
  exports, imports, 429
  ferroselenium, 427
  foreign production, 429–430
  invar alloy, 428
  metallurgy, 427
  occurrence, 427
  prices, 430
  properties, 427
  uses, war, 427–428
Senate Special Committee to Study Problems of American Small Business, 292
Senegal, ilmenite production, 508
Serpentine, 281
  substitute for talc, 470
Shattuck Chemical Company, S. W., 550
Sherman Anti-trust Act, 551
Sherritt Gordon Mines Ltd., 567
Shipley, Robert A., columbium ore production, 135
Shipping hazards, 15
Shipshaw power project, 44
Shotwell, Dr. James T., 539
Siam, ruby, sapphire production, 420, 426
  tin ore, exports, 491, 498
Sicilian Sulphur Consortium, 467
Sicily, sulfur production, 464
Siderite, 217
Sierra Leone, diamond production, 180
  iron-ore production, exports, 237, 241
  osmiridium, platinum occurrences, 386, 399–400
Silesia, metal production, iron, steel, 231
  lead, 266
  zinc, 570
Silica abrasives, prices, 410, 412, 415
Silica sand, 4
Silicomanganese, 4
Sillimanite, 4
  domestic production, 248, 432–433
  foreign production, 433
  kyanite trimorph, 431
  mullite, 431
  P.B. sillimanite refractories, 434
  prices, 434
  properties, 248, 431–432
  uses, 432–433
Sillimanite group, 431
Silver, 4, 10
  atomic-bomb manufacture, 436
  coinage, 435, 438
  domestic production, consumption, 440–442
  "fine silver," 435
  foreign production, 442–444
  "free silver," 440
  jewelry, silverware, 435
  "liquid silver," 437
  prices, 444–446
  properties, 435
  solders, 437
  uses, war, 435–438
Silver Purchase Act of 1934, 440, 445
Silver-lead alloy, 436
Silverman, Prof. Alexander, 534
Silver-tin alloy, 436
Simons, Dr. J. H., 193
Sink-float process (*see* Heavy-mediums separation)
Siserskite, 381
Skutterudite, 128
Small, John D., 380, 486
Smaller War Plants Corporation, 5
Smaltite, 128
Smithsonite, 556, 570
Smythe, Dr. H. D., 539
Snow Hill Coal Corporation, 463

Snyder, John W., 17, 126, 259, 313, 438
Soapstone, 468, 470–471
Soda ash, 447
Sodium, 4
  alkali industry, 448
  ammonia-soda process, 447
  borax, 447, 449
  caustic soda, 448
  domestic production, 449–450
  duty, 452
  electrolytic process, 447
  foreign production, 451–452
  imports, 450
  metallic sodium, uses, 448–449
  natron, 447
  occurrence, 447
  prices, 380, 452–453
  properties, 447
  refining, 448
  rock salt, 447
  salt cake, 447
  synthetic cryolite, 173
  trona, 447, 449
  uses, 448–449
Sodium bicarbonate, carbonate, 447–448
Sodium chloride, 450
Sodium nitrate, 371
Sodium sulfate, 447, 449–450
Soffman, Dr. J. G., 530
Solvay Process Company, 273, 376
South America, 9, 12
  copper, procurement by MRC, 154
    production, 149
  corundum production, 168
  mining projects, 12, 14–15
South American Gold and Platinum Company, 215, 358, 399
South Carolina, mineral production, kaolin, prices, 112, 114
    kyanite, 247
    manganese ore, 304
    mica, 329
    monazite sand, 351
    sapphire, 425
    sillimanite, 432
    thorium, 526, 540
    topaz, 511
South Dakota, mineral and metal production, andalusite, 432
    bentonite, 113
    beryllium ore, 89
    columbite, 135
South Dakota, mineral and metal production, lithium ore, 273
    potash feldspar, prices, 188, 190
    tantalum, 479
Southern Mineral Products Corporation, 57, 505
Southern Mining and Milling Company, 247
Southern Phosphate Corporation, 59
South-West Africa, mineral and metal production, beryl, 90
    copper, 150
    diamond, 180
    graphite, 206
    lithium, 273–274
    manganese, 15
    vanadium, 552–554
Southwestern Engineering Company, 580
  chromite production, 121
Spain, mineral and metal production, barite, 75
    bismuth, 95
    calcite, optical, 105
    copper, 151, 153–154
    fluorspar, 198–199
    iron, steel, 235, 242
    lead, 263
    lithium ore, 274
    mercury, 321–323
    potash, 406–407
    strontium ore, 456–457
    sulfur, pyrites, 464–466
    talc, 474
    tungsten, 12, 522, 523
    zinc, 566, 571
Sphalerite, 555–556
  associated with indium, 208
Spinel, 419–420, 426
  in superrefractories, 245
Spodumene, 4
    (*See also* Lithium)
Spokane aluminum-reduction works, 38, 42
  Trentwood and Mead plants, 43
Spot authorization plan, 16–17
Stabilization Administration, 267
Standards, Bureau of, 331, 410, 414
Standards of living, 23, 26
Stanley, Robert C., 357
Stannite, 483
State Department, 9, 12, 22, 24
  investigation of foreign lead supplies, 259
Steel, 8, 10, 18, 19
  castings, wire rope, 4

Steel, specialized, 12
steel in aluminum alloys, 32
world production, 241–242
Steel cartridge cases, 219
Steel Committee, Combined, 227
Steel industry, 224
Steel scrap, 227
(*See also* Iron and Steel)
Stettinius, Edward R., Jr., 373
Stibnite, 49
associated with arsenic, 62
Stockpile bill passed by Congress, 69
Stockpile items, 8
Stockpile schedules, 15
Stockpiles of deficient minerals and metals, 3–6, 8, 21
aluminum, 37–38
definition, 7
Stone & Webster, 532
Strategic commodities, 11
Strategic and critical minerals, 2–3
Strategic Materials Committee, 6
Strategic Services, Office of, 444
reports on Russian metal resources, 490
iron ore, 235
tungsten, 523
vanadium, 553
Strategy of Raw Materials, 305
Strontianite, 454
Strontium (*a*), alkaline earth, 103
beneficiation, 455–456
consumption, 456
domestic production, 455–456
duty, 458
flotation, 455–456
foreign production, 457
occurrence, 454
prices, 457–458
properties, 454
uses, war, 454–455
Strontium compounds, 454
Strontium salts, 454
Struthers Iron and Steel Company, 229
Stuart, Ralph C., 514
Styer, Lt. Gen. William D., 530
Sub-ore, 19
Subsidies, 23
Subsidy payments, 22
Sulfur and pyrites, 4
brimstone, 459, 464
cuprous pyrites, 459, 464
domestic production, 461
Sulfur and pyrites, exports, 461
Ferrox, Thylox, Nickel processes, 463
foreign production, 463
Frasch process, 459, 465
Freeman process, 459
imports, 466
prices, 467
properties, 459
smelter gases, 462
sodium sulfite, 460
solfatic type, 462
uses, war, 459–461
Sulfur dioxide, 460
Sulfuric acid, 460–461, 467
Sullivan Mining Company, cobalt production, 130
zinc production, 564
Sunshine Mining Company, 50
Supply-requirements Report, copper, 147
Surinam, bauxite production, stockpile, 78–79, 82–84
Surplus Property Act, 4
Geneva Steel Works, 225
magnesium production, 292
Surplus Property Administration, 42, 43, 293, 380
radium scrap, Regulation 9, 540
Surplus Property Board, 4
aluminum, economic and marketing problems, 37, 39, 230
studies of, steel marketing problems, 230
aircraft salvage, 42
magnesium production, 293
Swaziland, Havelock mines, asbestos production, 69–70
Sweden, metal and mineral production, aluminum, 46
arsenic, 63–64
bismuth, 95
china clay, 114
copper, 151–152, 160
feldspar, 189
iron, steel, 235–236, 242
Kiruna iron district, 222, 231
lithium ore, 274
magnesium, government controls, 296
mica, 336
selenium, 430
sulfur, pyrites, 464
uranium deposits, 542–543
Swift & Co., in phosphate cartel, 59

Switzerland, metal and mineral production, aluminum, 46
fluorspar, 198–199
iron ore, 238
magnesium, 296
synthetic ruby, saphire, 425–426
Sylvite, 403, 405
Symington, W. Stuart, 5, 42, 293
Synthetic Nitrate Syndicate, 379
Szilard, Dr. Leo, 528, 530, 543

T

Tacoma aluminum-reduction works, 35–36, 39, 43
Tactite, 513
Talc (*a*), ceramic uses, 469
domestic production, 471–472
duty, 475
flotation, 472
foreign production, 473–474
imports, exports, 473
Indian block, 4
lava lump, 9
prices, 474–475
properties, 468
pyrophyllite, 468, 471–472
steatitic lump-lava talc, 468
specifications, 468
uses, war, 468–470
Tantalite (*a*), cemented carbides, 477–478
domestic production, 479
ferrotantalum, 477
foreign production, 479–480
imports, exports, 479
occurrence, 477
prices, 480–481
properties, 477
substitutes, 477–478
uses, war, 477–478
Tantalum, 4, 9, 15, 477–481
Tantalum Defense Corporation, 479
Tariff barriers, 15
Tariff concessions, 24
Tasmania, osmiridium, platinum production, 385, 399
Taylor, Charles F., & Sons Company, 248
Taylor, Wayne C., 14
Teheran conference, 25
Tellurium, 427–429
Tenant Sons & Company, 352
Tennessee, mineral and metal production, ball clay, prices, 115
iron-ore deposits, 222
lead, 254
manganese, 304
phosphate-rock industry, 58
pyrites, 462
quartz, ground, 413
Tennessee Copper Company, pyrites production, 462
Tennessee Eastman Corporation, 436
Tennessee Valley Authority, Columbus, 57
ammonium nitrate production, 375
phosphate fertilizer plant, 58
Territorial Commissioner of Mines, Alaska, 54, 496, 523
chrome sales, 125
mercury sales, 319
Texas, mineral and metal production, ammonia-soda process, 450
bentonite, 113
fluorspar, 194
fuller's earth, 115
graphite, 203
magnesium, 286, 288
mercury, 318
potash, 405
sodium sulfate, 450
strontium ore, 455–456
sulfur, 459, 462, 467
Thailand, tungsten production, 522
Thallium, 20
Thomas, Dr. Charles A., 529
Thorium, 20
(*See also* Monazite sand)
Three Kids Manganese mine, 303
Tin (*a*), 4, 9–10, 14, 18–19, 23
alloys, 482
bronzes, 482–484
chemical uses, 483–484
collapsible tubes, 483–484
domestic production, consumption, 485–489
electrolytic tin plating, 484
foreign production, 490–498
prices, 21, 498–499
printers' alloys, 482
properties, 482
smelting, 483
stream tin, 482
substitutes, 483–485
terne plate, 483–484

Tin (*a*), uses, war, 482–484
white metals, 483–484
Tin plate, 483–484
Tin Processing Corporation, 485
Tin Sales Corporation, 498
Tintic Standard Mining Company, fluorspar, 193, 196
Titanite, 501
Titanium (*a*), 9
aluminum alloys, 32
beach sands, 504–505
domestic production, 504–506
ferrotitanium, ferrocarbontitanium, 501–502
flotation, 504
foreign production, 507–509
Kroll process, 501
metallurgy, 501–502
occurrence, 501
prices, 509–510
properties, 501
substitutes, 503–504
uses, war, 502–503
Titanium Alloy Manufacturing Company, 580
Titanium carbide, dioxide, 502–503, 506
Titanium Pigment Company, 505
Tobernite, 540
Todd-California Shipbuilding Corporation, 286
Tolman, Dr. Richard C., 539
Tonkin, tungsten production, 522
Topaz, domestic production, 511–512
foreign production, 247–248, 512
gem quality, 511
prices, 512
properties, 511
substitutes, 511
uses, war, 511
Torrance aluminum-reduction works, 39
sodium aluminate, Torrance Aluminum Products Company, 40
Trade agreements, reciprocal, 12
Trade barriers, 22, 23, 25
Trade discriminations, 25
Trade restrictions, 23, 26
Transvaal, corundum, diamond production, 170–172, 180
Treasury Department, Procurement Division, antimony, 52
asbestos, 69
bauxite, 82
Treasury Department, Procurement Division, beryllium, 89
bismuth, 94
celestite, 458
chrome ore, 121
cobalt, 131
columbite, 135
copper, 144–145
diamond, 178
manganese, 300–301
monazite sand, 352
quartz crystal, 414–415
ruby, sapphire, 426
rutile, 458
silver, 435, 437–441, 443, 445–446
talc, 458
tantalite, 458
tin, 458
tungsten, 458
vanadium, 458
zinc, 560
zirconium ore, 458
Tridymite, 410
Trilsch, Myron, 559
Triphylite, 270
Tripoli, uses, prices, 412, 415
Tri-State district, 21, 254
zinc production, 564
Troutdale aluminum-reduction works, 39, 43
Truman, President, 2, 3, 22, 26, 352, 440, 463, 488, 506
message to Congress on atomic bomb, 535–536
zircon prospects, 580
Truman Committee, 145, 284
Tungsten (*a*), 3, 6, 8–10, 15–16, 23
alloys, 514
carboloy, 513–515
domestic production, 516–519
duty, 523
ferrotungsten, 514
foreign production, 519–523
imports, exports, 519–521
metallurgy, 514
occurrence, 513
platenite, 516
powder metallurgy, 515
prices, 523–524
properties, 513
substitutes, 515–516
tool steel, 514–515

Tungsten (*a*), uses, war, 514–516
Tungsten carbide, 177, 513
Tunisia, iron-ore production, 237
phosphate-rock production, 60
refined lead exports, 263
strontium-ore production, 456–457
Turkey, 12
production of minerals and metals, chromite, 122–123
copper, 160
grain emery, 184
molybdenite, 346
sulfur, 466

U

Uganda, columbium-ore production, 136
tantalite production, 480
Ukraine, iron, steel production, 231
Ullmannite, 128
Underwood tariff law, 23
Union of South Africa, asbestos, 68–69
barite, 75
beryl, 89–90
bismuth, 95–96
calcite, optical, 105
china clay, bentonite, 114
chromite, 122–123, 125–126
columbium ore, 136
copper, 152–153
corundum, 168, 170–171
diamond, industrial, 179–180
diamond cutting, 181
fluorspar, 198–199
graphite, 206
iridium, 214–215
magnesite, 279
manganese, 306–307, 310–311
mica, 333, 335
nickel, 365
osmium, 384–385
platinum, 398–400
pyrites, 465
rhodium, 418
ruthenium, 422–423
tantalite, 479–480
tin, 490, 492
Union Carbide and Carbon Corporation, 551
U.S.S.R. (*see* Russia)
United Feldspar & Minerals Corporation, 273, 512
United Kingdom, exported antimony, 54
United Kingdom Commercial Company, preclusive buying in Turkey, chrome, copper ore, 125, 160
United Mining & Milling Company, 563
United Nations Organization, 26–27, 536–537
United States Alkali Export Association, Inc., 452
United States Commercial Company, preclusive buying in Turkey, chrome, copper ore, 125, 160
copper purchased in Canada, Chile, Cuba, 155–156, 158
lead purchased in Canada, Australia, 265
United States metal and mineral production, aluminum, bauxite, 46, 79
United States Purchasing Commission, mica purchases in Brazil, 334
United States Smelting, Refining & Mining Company, bismuth-lead produced, 94
United States Smelting Corporation, 563
United States Steel Corporation, Geneva Steel Works, 224–225
manganese production, 308
United States Vanadium Corporation, tungsten production, 517
Colorado plants, 540
vanadium ore, 549, 551
Uranate, 534
Uranium, 10, 15
alpha, beta, gamma rays, 525–526, 530–531
atomic bomb, 27, 202, 525–531, 533
atomic disintegration, 525
atomic pile, 531, 533
atomic power, 531
domestic production, 540
electromagnetic separation, gaseous-diffusion and thermal-diffusion processes, 531
foreign production, 540–544
ferrouranium, 534, 544
heavy water, 527–528, 543
international controls, 536–538
metallic, 531
neptunium, 525, 527–528
"neuclear fuel," 528
neutrons, 526–528, 531, 542
occurrence, 525–526
plutonium, 525, 528, 531, 542
prices, 544
primary reactor, 531

Uranium, properties, 525
radioactivity, 525
thorium, 525–526, 528, 532, 534, 538, 542–543
uses, 532–534
Uranium oxide, 526–527, 529
Uranium salts, 525
Urey, Dr. Harold C., 530, 536
Uruguay, talc production, 474
Utah, mineral and metal production, copper, 141
fluorspar, 197
iron ore, 222
molybdenite, 342
potassium-bearing brines, 405
sillimanite, 432
silver, 441
topaz, 511
uranium, 526, 540
vanadium, 550–551
Utah, University of, 37
Utah Copper Company, 141

V

Vanadinite, 546
Vanadium (*a*), 6–7, 10, 16, 555
domestic production, 548–551
duty, 554
ferrovanadium, 546–548, 550–553
foreign production, 552–554
imports, exports, 549, 552, 554
iron vanadate, 546–548
lead vanadates, 546, 548
metallurgy, 546
minette ore, 546
prices, 554
properties, 546
sodium vanadate, 546, 550
uses, war, 546–548
Vanadium Corporation of America, 505, 550–552
Colorado, Utah plants, 540
Vanadium oxide, 19, 547, 551
Vanadium pentoxide, 554
Vanadium sponge, 395
Vancouver aluminum-reduction works, 35, 38
Vascaloy-Ramet Corporation, 479
Venezuela, mineral and metal production, chromite, undeveloped, 124
chrysotile, 70
Venezuela, mineral and metal production, diamonds, 180
iron ore, 222, 231, 240
magnesite, undeveloped, 279
nickel, uranium prospects, 365, 544
Vermiculite, 4
prices, 336
Zonolite insulation, 327–329
Vermont, talc production, 471
VE-Day, 17–18, 25, 34, 144, 146, 148, 226, 234, 256, 258
nickel shortage, 360
VJ-Day, 4, 17–18, 27, 144, 197, 285
tin controls, 486, 489
unsettled conditions, 357
Vinegar Hill Zinc Company, pyrites production, 463
Vinson, Fred W., 44
Virginia, mineral and metal production, bauxite, 79
ceramic clays, prices, 115
kyanite, 246
lead, 254
manganese, 304
potash and soda feldspar, prices, 188, 190
quartz, ground, 413
rutile, brookite, 504
soda, ammonia-soda process, 450
zinc, 564
Virginia Polytechnic Institute, kyanite research, 246
Vogelsang, Erwin, 255, 487

W

Wad, 298, 300
Wall Street Journal, The, stockpile estimates, antimony, 51
asbestos, 68
bauxite, 79
beryllium, 88
bismuth, 94
cadmium, 99
chrome ore, 119
cobalt, 130
columbite, 135
corundum ore, 168
cryolite, 174
fluorspar, 195
indium, 209
iridium, 213

Wall Street Journal, The, stockpile estimates, iron, carbonye, 244
lead, 257
manganese, 301
mica, 332
molybdenite, 343
monazite sand, 352
osmium, 382
palladium, 390
platinum, 398
rhodium, 417
ruthenium, 422
tin, 485
tungsten, 518
vanadium, 549
Wallace, Henry A., 2, 10
War Assets Administration, 6
leases of aluminum plants, 40, 43
sale of copper scrap, 148
of steel plants, 225
surplus materials, 506
War Department, 6, 8, 10–11, 17–18, 374, 412, 556
development and conservation program, atomic energy, 539–540
beryllium, 89
bismuth, 94
cadmium, 99–100
chrome, 120
cobalt, 131
columbite, 135
copper, 144–145, 148
investigation of foreign lead supplies, 259
zinc, 560
domestic reserves of asbestos, bauxite, 69, 82
War Foods Administration, potash use, 408
steel use, 226
War Information, Office of, 80
alloy steels, 225
copper, 143
War Labor Board, 2
War Manpower Commission, 16, 258
War Mobilization and Reconversion, Office of, 5, 17, 259
War Powers Act, Second, 2
War Production Board, 2, 4–5, 7, 9–10, 21, 23, 25
allocation, 16–17
of cryolite, 174
Antimony Advisory Committee, 51
War Production Board, controls on metals and minerals, aluminum, 37–38, 41–42, 47
antimony, 50–51
arsenic, 63
asbestos, 68
barite, 74
bauxite, 79–80
bentonite, English china clay, 113
beryllium, 88–89
bismuth, bismuth chemicals, 94
cadmium, 98–100
calcium metal, 104
chrome ore, chromium metal, 119–120
chromic acid, chrome chemicals, 120–121
cobalt, 130
corundum, 168–169
diamonds, industrial, 178–179
ferrochromium, 120
ferrocolumbium, 135
fluorspar, 195–196
iridium, 214
iron and steel products, 227
kyanite, 248
lead, 255–256, 258
lithium, 274
magnesium, 283, 290, 292
mica, 331–332
molybdenite, 343
nickel, 360
nitrates, 377
nitrogen, 375
osmium, 382
palladium, 390–391
platinum, 397–398
quartz crystal, 413
rhodium, 417
ruby, sapphire, 419, 425
rutile, 505
sodium, 449
spodumene, 274
sulfur, sulfuric acid, 461
talc, 471, 473
tantalum, 478
tin, 485–487
topaz, 512
tungsten, 518
uranium, 535
vanadium, 548–549
zinc, 558–559
zircon, 580
Controlled Materials Plan, 144, 146, 169

War Production Board, Copper Producers' Advisory Committee, 144
graphite in short supply, 204
iodine import-export controls, 211
Lead Producers' Industry Advisory Committee, 255
lead requirements, consumption, 253, 255
lead stocks reduced, 254
magnesium, subsidy, production, 287, 289, 291
Materials Substitutions and Supply list, 4, 51
mica substitutes, 331
Period I Planning Board, aluminum, 34
copper, 148
iron, steel, 228
priority controls on copper, alloys, scrap, 144–147
purchases of aluminum, chrome ore, 43–44, 127
War Shipping Administration, manganese shipped from Chile, 309
War uses of metals and minerals, research, 20
Warmaking, minerals necessary to, 25
Washington, mineral and metal production, fluorspar, 197
magnesite, 277
magnesium, 288
manganese, 304
nickel prospects, 359
strontium ore, 455–456
Washington, D. C., 11, 21
Washington, University of, 36
Weisskopf, Dr. Victor R., 529
West End Chemical Company, 450
West Virginia, manganese production, 304
nickel plant, Huntington, 362
nitrogen production, 374
Western Fluorspar Corporation, 193–194
Western Hemisphere cooperation, 12, 25
Western Union, 579
Westinghouse Electric Company, 472, 514, 580
lamp division, 341
Westvaco Chlorine Products Corporation, 278
magnesium production, 288
Wheeler, Dr. John A., 532
Whitehall Company, columbium-ore production, 135
Whiting, domestic, whiting substitute (*see* Chalk)
Wiens, Dr. Jacob H., 98
Wierton Steel Company, 564
Wiggans, E. J., 580
Wigner, Eugene, 530
Willemite, 555
Williston, S. H., 318
Wilson, Charles E., 144
Wilson, I. W., 36–37, 44
Wilson, Philip D., 2, 148, 255, 267, 565
zinc prices, 573
Wisconsin, pyrites production, 463
Witherite, domestic sources, 72
foreign sources, 75
uses, 72
in beet sugar, 72
in magnesium alloys, titanium pigments, 72
Withers, Inc., corundum mining in South Carolina, 169
Wolframite, 513
Wollastonite, 104
Woolwich Arsenal, 370
World economic affairs, 25
World Minerals and World Peace, chromite, magnesium, 123–124, 297
World peace, 25–26
World War, First, 267, 299
copper price, 162
industrial diamonds, 176, 180
metal prices, 127
molybdenite production, 342, 345
monazite, cerium, 350
World War, Second, advanced mineral technology, 506
copper price, 162
exploitation of minerals, 352
fluorspar, 191
industrial diamonds, 181
metal prices, 126
minerals of continental shelf, 463
World-security charter, 25–26
Wormser, F. E., 257
Wrather, W. E., 24
Wright, Charles Will, 12
Wulfenite, 339
Wyman-Gordon Company, 284
Wyoming, mineral production, bentonite, prices, 113, 115
chrome ore, emergency reserves, 122
Glauber's salt, 450
potash feldspar, 188
rutile, 504

Wyoming, mineral production, tantalum ore, 479
trona, 447
tungsten ore, 517

Y

Yalta conference, 25–26
Yancey Cyanite Company (Mas-Celo Mines), 246–247
Yttrium, 20
(*See also* Monazite sand)
Yugoslavia, mineral and metal production, antimony, 52–53
bauxite, 84
bismuth, 95
Bor copper mines, 161
chrome, 124–125
copper, 152–153, 155
iron ore, 237
lead, 260, 263, 266
magnesite, 279
molybdenite, 346–347
tin, 497
Trepca lead-zinc, 266
zinc, 571

Z

Zinc (*a*), 4, 6, 10, 14–16, 19, 22, 24
aluminum alloys, 30
brass, 556–557
by-products, 557
domestic production, 558–565
foreign production, 565–572
imports, exports, 566–567
Zinc (*a*), lithopone, 558
low-grade ore, 560
metallurgy, 556–557, 562
occurrence, 556
pigments, 561
prices, 21, 572–575
properties, 555–556
rolled zinc, 562
scrap, 560
secondary zinc, 561
slab-zinc specifications, 556
spelter, 555, 559–560
substitutes, 556, 558
uses, war, 556–558
Zinc oxide, 556–558
Zinc Producers Association Proprietary, Ltd., 569
Zinc sulfide, 72, 558
Zincite, 555–556
Zinnwaldite, lithia-iron mica, 270, 327
Zircon, 349, 577
Zirconium (*a*), 4, 349–351
alloys, 577–579
domestic production, 579–580
ferrozirconium, 577–578
foreign production, 581
imports, exports, 581–582
metallurgy, 577
prices, 582
properties, 577–578
uses, war, 577–579
Zirconium oxide, 577–578
Zirconium Products Company, 580
Zirconium silicate, 577
Zirconyl sulfate, 579
Zuni Milling Company, fluorspar, 194