THE ELECTRIC FURNACE IN THE IRON AND STEEL INDUSTRY

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Demand for electricity is rapidly increasing in iron and steel and related industries. Ferro-alloys, all of which are electric-furnace products except ferromanganese, are now applied in small amounts to almost all steels for gas and impurity elimination. The growing use of alloy steels, in which ferro-alloys are used in larger quantities, has not only added to current requirements by increasing ferro-alloy manufacture, but also has extended the use of the electric furnace in alloy-steel ingot manufacture. The nonoxidizing atmosphere of the electric furnace is increasing its employment in melting steel scrap for castings. There is a marked tendency toward the use of electric furnaces in heat treatment of steels and an increasing application of electric arc welding. The electrification of mechanical operations in steel and rolling mills is progressing rapidly.

Electric-furnace production of ferro-alloys has developed as an industry distinct from the steel industry. Blast-furnace manufacture of ferromanganese is carried on in large measure by iron and steel producers. Ferrosilicon forms about 40 percent of all ferro-alloy manufacture. Its production increased 12 percent between 1928 and 1929. The manufacture of electric ferrosilicon in the United States in 1929 required approximately 1,000,000,000 kilowatt-hours of energy. Other electric furnace ferro-alloys were less than 5 percent of the total ferro-alloy tonnage in 1929, but this manufacture represented an increase of 24 percent in 1 year. The electricity consumed in this production exceeded 260,000,000 kilowatt-hours. While ferromanganese is produced in the blast furnace in the United States, the 78,000 long tons imported from Canada and Norway were electric furnace made. Had it been economically profitable to manufacture all ferromanganese consumed in the United States in the electric furnace, power to the extent of over 4,000,000,000 kilowatt-hours would have been consumed in such manufacture.

One percent of all steel ingots produced in 1929 in the United States was melted or refined in the electric furnace; this represented a 17-percent increase over 1928. The larger part of electric-furnace ingot production was alloy steel. While 26 percent of all iron and steel castings were melted in the electric furnace, almost 50 percent of those alloyed were melted in this nonoxidizing furnace. Electric-furnace production of iron and steel ingots and castings consumed almost 400,000,000 kilowatt-hours of power in 1929. Steel annealing or steel hardening in electric furnaces added approximately 200 kilowatt-hours of energy per ton so annealed or hardened.

Although iron ore has been reduced to wrought iron and to steel of high quality in the electric furnace, such reduction has not been able to compete with blast-furnace practice. Some metallurgists believe that the depletion of Lake Superior hematite iron ores in about 30 years will result in the development of the country's magnetite iron-ore deposits and in their reduction by low-temperature processes. Such processes may be all electric, or preheating may be done in a rotary fuel furnace followed by melting and refining in an electric furnace. Present experiments place the energy requirements of the duplex process at less than 400 kilowatt-hours for 1 ton iron and at 600 to 850 kilowatt-hours per ton of steel. Some steel producers believe iron ore will be secured from South America and China and that blast furnace practice will continue but move nearer the coast.

Major operating units of the iron and steel industry were located near coking-coal supplies; ferro-alloy factories located near hydroelectric developments. As approximately 5.5 tons of raw materials and supplies enter into 1 ton of finished steel according to present practice, transportation costs become an important factor in present production costs.

The principal raw materials for pig iron are iron ore, coke, and limestone; for ferro-alloys, silicon, manganese, chromite, tungsten, vanadium, molybdenum, titanium, uranium, and zirconium. Limestone and silicon quartz are found in abundance in this country. Seven eights of all iron ore now comes from the Lake Superior region, a region without coking coals. The principal coking coal fields are in western Pennsylvania, a section without iron ore. Only in Alabama are coking coal and iron ore produced in adjacent fields. Manganese ore is imported chiefly from Soviet Russia, Brazil, India, and British West Africa; chromite is shipped from Rhodesia and Cuba; tungsten comes from China; vanadium from Peru; and uranium from the Belgian Congo.

Although some iron ore is mined in Wyoming, Utah, Colorado, and Washington, and a market for magnetite ores would materially add to the amounts available in Pacific Coast and Rocky Mountain States, the only western State now believed to have extensive and rich iron-ore deposits is Wyoming. Washington, Colorado, and Utah produced coke from their respective bituminous coal fields in 1929. These States have some excellent deposits of coking coal. Although Wyoming has large reserves of high-grade bituminous coal, this is not regarded as coking coal.

The small amounts of manganese ore produced in this country were mined in Montana, Arizona, Arkansas, Virginia, and Georgia. While deposits containing 35 percent or more manganese are not extensive in the United States, large reserves of lower grade ores are found in Washington, California, Nevada, Arizona, New Mexico, Montana, Colorado, and in Minnesota. Efforts to concentrate these ores to the grade demanded by the steel manufacturers are reported to be at the trial commercial plant stage.

California is the only State producing chromium. Deposits are numerous in California and in Oregon, while Washington and Wyoming have some known reserves. Tungsten is found in Colorado, Nevada, Arizona, New Mexico, California, Washington, and South Dakota. The largest known reserves of uranium and vanadium ores are in Colorado and Utah; Colorado also has largest molybdenum deposits, although these three minerals are also found in other Pacific Coast and Rocky Mountain States.

When the World War cut off our imports of these alloying minerals and of ferro-alloys, the Nation turned to the Pacific coast and to the Rocky Mountains for ferro-alloy materials.

At present, the market for ferro-alloys is in Pennsylvania and Ohio, where almost 60 percent of all steel is produced. The market for finished steel is also largely centered in Atlantic Coast and Lake States. The Pacific coast consumes approximately 2,500,000 tons of steel out of a total consumption of 56,000,000 tons. Only a sixth of Pacific coast demands are met by Pacific coast steel works. While these works fill approximately 60 percent of orders for merchant bar, they do not produce pipe for local oil, gas, and water companies; they produce only a small part of the tin plate for the Pacific coast canning industry. The growing demand of food industries for stainless steel, a chromium steel alloy which resists acids and salts, should interest Pacific coast mining and metal manufacturing, canning, and packing industries. The export market for United States steel products is largely in Canada, the Orient, our own insular possessions, and in South and Central America.

The Electric Furnace in the Iron and Steel Industry

THE ELECTRIC FURNACE IN REDUCTION OF IRON ORE

1. The reduction of iron ore in an electric furnace has been the object of much research. Iron and steel of highest quality have been produced in such a furnace both in this country and abroad. But only in Norway, Sweden, and Italy is electric-furnace iron being produced on a commercial scale. At present, it is claimed that there is so small a market for electric-furnace iron or steel in this country that such iron and steel cannot be produced in sufficient quantity to permit a satisfactory market price.

ELECTROTHERMAL REDUCTION

2. *Foreign operating furnaces.*—In Scandinavian countries, magnetite is the chief iron ore smelted; the furnace is the shaft type "Gronwall Electrometal." In this furnace, there is an arched smelting chamber surmounted by a shaft. Six electrodes extend into the ore and charcoal charge; they are supplied with 3-phase current from 3 transformers. Furnace gases are withdrawn from the top of the furnace, washed, and recirculated through the ore to aid in its reduction. The electric energy required in 4,000-horsepower furnaces of this type was between 2,000 and 2,500 kilowatt-hours per ton of iron, dependent upon the kind of iron made and the percentage of iron in the ore. While Swedish furnaces use about 0.4 ton of charcoal per ton of iron produced as the reducing agent, in Italy, coke is used in the charge.

3. *California experiment.*—Experiments were carried on at Pitt River in Shasta County, Calif., from 1907 to 1914. Very pure magnetite was available here, as was limestone. Charcoal was brought by rail. Silica had to be added to make a slag. A rectangular furnace was employed. In a furnace of 3,000 kilowatts, 2,200 kilowatt-hours were required per ton of pig iron. Operations were discontinued when the charge for power was raised from $12 to $25 per horsepower year, although some pig iron was again produced in 1918.

4. *Low temperature reduction methods.*—Some metallurgists are of the opinion that the rapid depletion of hematite ores in the Lake Superior region will bring about the development of the country's deposits of magnetite and pyrrhotite, ores not desirable for standard blast-furnace reduction but which lend themselves to low temperature-reduction methods. The processes patented for the reduction of magnetite ore employ a rotating tube or kiln form of furnace. The ore is reduced by carbon which is either mixed with the ore charge or by passing hydrocarbon gases through the charge. The oxide in the iron ore is reduced by carbon monoxide at a temperature of from 600° to 900° C. An electric furnace may be used to finish the metallic sponge, the gases formed in this furnace being employed to reduce and preheat the ore in the first rotary furnace. Or the magnetite may be fed into an electrically heated tube, electrical contacts of nichrome being used for heating. Crude oil is sprayed upon the magnetite which, upon gasification, serves to reduce the iron oxides.

5. It is claimed that if the carbon and magnetite ore is preheated before entering the electric furnace, less than 400 kilowatt-hours will be necessary for a reduction to sponge iron, and that only from 600 to 850 kilowatt-hours are required to produce 1 ton of steel. If, however, a standard type arc furnace is employed, about 2,000 kilowatt-hours are required per ton of steel produced.[9]

6. *Hydrogen in place of carbon monoxide.*—While iron ores are reduced by carbon monoxide, it has been established that hydrogen effects reduction of hematite ores more readily and at as low a temperature as 700° C. Hydrogen has not been applied because it has been too costly. Where byproduct hydrogen is available as at electrolytic caustic-soda plants, such application may become feasible as the hydrogen not only reduces the iron but removes phosphorus and sulphur in gaseous form.

7. *Electrodeposition of iron from iron ore.*—Other metallurgists are working upon the electrodeposition of iron from iron ore. The iron ore is placed in vessels through which an acid solution is circulated. Either a soluble or insoluble anode is used. The cathode revolves. It is estimated that at Grenoble, France, over 900 kilowatt-hours were required to deposit 1 ton of iron. Experiments have been under way at Emeryville, Calif.

8. *Electrodeposition of iron from scrap or cast iron.*—Electrolytic iron has been in use for magnetic purposes for a number of years. Only recently, however, has the process been extended to wider fields in the United States. The Niagara Electrolytic Iron Co. began the manufacture of iron tubes by electrodeposition in 1925 at Niagara Falls. Seamless tubes with very thin walls are produced.

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[9] Smalley, Oliver, and Hodson, Frank, describe Pehrson-Prentice plant in Sweden and Scotland and Carsil process in paper presented before American Electrochemical Society, Apr. 28, 1927.

9. The cells are concrete troughs rendered waterproof with a liquid sulphur. The cathode is a revolving mandrel. Bars of cast iron placed below the cathode are the anode. Ferrous chloride forms the electrolyte. The current flowing from the anode through the electrolyte to the cathode deposits the iron on this revolving mandrel. When a desired thickness of deposit is obtained the mandrel is lifted out of the cell and the metal is annealed. The tube is then stripped from the mandrel which had been greased to facilitate this process. Final annealing takes place in an electric annealing furnace heated by nichrome-resistance elements to 1,900° F.

ELECTRIC IRON CASTINGS

10. The use of the electric furnace for the production of iron castings of superior strength and uniformity of grain is increasing in this country, especially for high-pressure valve castings and for castings suitable for severe service stress such as cylinder heads for Diesel engines. It is also being employed for alloy-iron castings the use of which is increasing.

11. *Production methods.*—Two methods of producing electric iron castings are employed. In one, the metal is first melted with a minimum of coke in a cupola. The molten metal is run into an electric arc furnace where desired alloy additions are made. After the metal reaches the desired temperature (1,385° to 1,550° C.), iron is tapped off. At regular intervals, fresh molten cast iron is added to the electric furnace. This process requires but approximately 115 kilowatt-hours per ton of iron employing a 3-ton furnace and 130 kilowatt-hours per ton with a 1-ton furnace. In the continuous melting process, a cold charge is melted directly in the electric furnace, the other steps being the same as in the Duplex process just described. About 550 kilowatt-hours are consumed by a 3-ton electric furnace for the second heat and about 650 kilowatt-hours for the first heat.

12. *Cost of production.*—The cost of manufacture of electric iron for stove plate by the continuous process is cited by G. I. Simpson, chief electrical engineer, Pittsburgh Furnace Corporation:

Cost per ton of electric iron

Scrap metal	$11. 97
Alloys	1. 27
Power	4. 66
Refractories	. 60
Electrodes	2. 18
Water	. 11
Melting loss	1. 13
Furnace labor	1. 08
Total cost of metal in ladle per ton [10]	23. 00

13. As is pointed out by Mr. Simpson, when the cost of the continuous melting process and the Duplexing process are compared, it is not only the cost of electricity as compared with costs of coke and blast that must be considered, but the over-all investment, the floor space, the operating and maintenance labor costs, all of which are lower in the continuous process.

[10] Simpson, G. I., Electric Furnace Iron. Paper before American Electrochemical Society, May 1930.

The Electric Furnace Production of Ferro-Alloys

THE IMPORTANCE OF FERRO-ALLOYS IN STEEL MANUFACTURE

14. Ferro-alloys are essential raw materials in steel manufacture. They serve two functions: When added in small amounts, they act as scavengers removing undesirable elements from the steel; when added in larger amounts, they improve the properties of steel, forming alloy steels having varying characteristics.

15. *Scavengers.*—In open-hearth and Bessemer steel, oxygen or oxides are present in harmful quantities; by adding ferrosilicon, ferro-zirconium, ferromanganese, or other alloys, the silicon, zirconium, and manganese unite with the oxygen, are precipitated out, and leave the steel. Sulphur is also eliminated by ferromanganese which is added to almost all steels now manufactured. Ferrosilicon is the principal deoxidizer employed in the open-hearth process and enters into 90 percent of all steel manufactured in the United States. Ferro-zirconium, besides being a deoxidizer, is a corrective of nitrogen, sulphur, and phosphorus content. Calcium-silicon is often used after the application of cheaper ferro-alloys to remove the last traces of oxygen and sulphur.

16. *Alloy steels.*—When applied as alloys with steel, each ferro-alloy, or combination of ferro-alloys, imparts varying qualities to the steel. Steels containing 3.25 to 4.5 percent silicon have high magnetic permeability and high electrical resistance; they are manufactured into sheets for use in electrical apparatus. Duriron has 14 to 15 percent silicon and is used for castings which must resist acids and chemicals. Ferromanganese increases the strength and durability of steels. A steel containing 1.5 to 2 percent silicon and 1 to 2 percent manganese is made into springs.

17. Ferrochromium is applied to a number of steels in varying amounts. For heavy-duty machinery, metal-working steels, and for structural steels, from 1 to 2 percent chromium is used. High-speed tool steel contains approximately 4 percent, valve steel 7 to 9 percent chromium and 2.5 to 4 percent silicon. Stainless steel manufactured into cutlery contains 12 to 14 percent chromium. Tungsten is also added to high-speed steels in the proportion of 10 to 20 percent to maintain the cutting edge of steels at high temperatures. It is used in saw steels and in magnetic steels to increase the magnetic retentivity. Molybdenum, uranium, vanadium, titanium, tantalum, phosphorus, nickel, boron and aluminum ferro-alloys, in small amounts, add to the strength or increase other qualities imparted by the alloys used more extensively.

POWER CONSUMPTION AND PRODUCTION COSTS

18. Ferrosilicon and all other ferro-alloys, with the exception of ferromanganese, are electric-furnace products. Ferromanganese is a blast-furnace product although it can, of course, be produced in the electric furnace and is being so manufactured at Welland, Canada. As the production of ferrosilicon exceeds that of all other electric-furnace ferro-alloys, the process by which it is produced will be described first.

19. *Ferrosilicon.*—All ferrosilicon containing over 12 percent silicon is manufactured in the electric furnace. Open-top electric furnaces

are employed. Larger sizes have 3 carbon electrodes and take 3-phase current while smaller furnaces have but 2 electrodes and single-phase current. The electrodes for a 2,400 kilowatt-furnace are 24 inches by 8 feet in length and weigh over 2,000 pounds each. These electrodes hang above the furnaces and extend into the raw material to the depth of at least a foot. As the lower end is consumed, they are automatically lowered into the charge.

20. The charge to produce a 50 percent silicon alloy is generally composed of 50 percent silicon rock, averaging 98.5 percent silica, 27 percent coke breeze, and 23 percent steel turnings. Coke may be replaced by the cheapest carbonaceous material containing no phosphorus or arsenic. The silica is reduced to silicon by the coke at temperatures of about 6,000° F. It dissolves in the steel and is tapped from the furnace. The steel is necessary because the element silicon volatilizes at the temperature of its reduction and would be carried out of the furnace as a gas. When the alloy is cold, it is cleaned and broken into lumps for shipment to steel mills. Furnaces are charged and tapped at least every 2 hours.

21. The 50-percent grade ferrosilicon requires approximately 5,000 kilowatt-hours of energy, the 70-percent grade about 6,000-kilowatt hours. Power at $15 per horsepower-year forms about 20 percent of the cost of manufacture.

Estimated cost of producing 1 ton of 50-percent ferrosilicon

Electricity: 5,000 kilowatt-hours at $0.0023	$11. 50
Quartz: 1.3 tons at $3.50	4. 55
Coke: 0.7 ton at $2.75	1. 93
Turnings: 0.6 tons at $9	5. 40
Electrodes: 60 pounds at $0.07	4. 20
Miscellaneous supplies	1. 50
Labor	16. 00
Capital charges on $50 per ton at 30 percent	15. 00
Total	60. 08

22. *Electric-furnace manufacture of ferromanganese.*—Ferromanganese, or the alloy containing about 80 percent of manganese, as well as spiegeleisen, the alloy with about 20 percent manganese, are usually manufactured in the blast furnace as the temperatures of the blast furnace are sufficient to reduce manganese ore or ferruginous manganese ores. When ferromanganese is produced in the electric furnace it is smelted with anthracite or coke, limestone and fluorspar being employed as fluxes. While iron is present in the ore, it may be necessary to add more iron trimmings. Graphite electrodes are consumed at a rate of 65 pounds per ton of ferromanganese. The current necessary to produce 1 ton of 75 percent ferromanganese is approximately 4,400 kilowatt-hours while the 80 percent grade may require as high as 6,600 kilowatt-hours.

23. *Ferrochromium.*—Chromite, or a chrome iron ore, is smelted with carbon in an electric furnace. The ore is usually self-fluxing although lime and fluorspar is sometimes employed. Carbon, equal to about 30 percent the weight of the ore, is mixed with chromite. A 60-percent ferrochromium requires approximately 6,000 kilowatt-hours of energy, while the 65 percent with an 80 percent recovery takes up to 9,000 kilowatt-hours. With power at $15 a horsepower-year, power costs from about 12 percent of the total cost of producing 60 percent ferrochromium.

24. The ores mined in California and Oregon contain a larger proportion of iron than those imported from Rhodesia or New Caledonia. Work undertaken on the electric-furnace smelting of these ores in 1918 developed more difficulties in securing a high chromium alloy with low carbon content. A ton of ferrochromium was produced containing 64 percent chromium and 5.6 percent carbon by the consumption of 7,200 kilowatt-hours of electricity. The charge was made up of 16,473 pounds of chrome ore, 4,215 pounds of coke, 452 pounds lime, 2,907 chromium slag, and 1,130 pounds of sand.[11]

25. *Ferromolybdenum.*—Molybdenite contains approximately 59.5 percent molybdenum and 40 percent sulphur, while wulfenite is made up of 26 percent molybdenum and 56 percent lead. The molybdenite is concentrated by flotation and wulfenite by ordinary milling methods. The wulfenite concentrate is treated with sodium sulphide forming sodium molybdate and lead sulphide, the latter going to the lead smelter. Either the concentrate molybdenite or the sodium-molybdate slag may serve as the concentrated ore for ferromolybdenum. These are smelted with carbon and lime, together with enough iron for the grade being manufactured, or with silicon. A single-phase electric furnace is used, a graphite electrode being suspended in the center. A 70 percent grade ferromolybdenum, made from molybdenite, required 8,000 kilowatt-hours per ton produced, while the same grade made from sodium molybdate required about 9,000 kilowatt-hours of energy.

26. The Climax Molybdenum Co., with plant at Langeloth, Pa., is manufacturing calcium molybdate by adding calcium chloride to sodium molybdate. They claim that calcium molybdate can be introduced directly to electric steel without being manufactured into ferromolybdenum.

27. *Ferrovanadium.*—Vanadium oxide, produced by a chemical process from the ore, is reduced in an electric furnace by silicon. Lime is added to flux the silica resulting from the oxidation of silicon while steel turnings are used to alloy with the vanadium. The resulting product containing 30 to 35 percent vanadium and 3 to 4 percent silicon requires about 6,800 kilowatt-hours of electricity per ton. The silicon content may be reduced by melting the electric furnace product with a vanadium oxide, lime, and fluorspar. Ferrovanadium may also be produced in an open-hearth furnace by use of aluminum shot, the alumina formed being slagged off by soda ash or fluorspar. Iron turnings are added.

28. *Ferrotungsten.*—Although tungsten powder is added directly to steel, it is more often applied as ferrotungsten. As tungsten has the highest known melting point of any metal, 3,350° C., or about 6,000° F., it is essentially an electric-furnace product. Concentrated ore is reduced by carbon in a small circular furnace having one electrode. Lime and fluorspar are employed as fluxes. The ores usually have sufficient iron content. The slag is poured off as it accumulates. The ferrotungsten is infusible; consequently, when a sizable button has been found, the furnace is cooled, torn down, and the button removed. This smelting process which produces a 70 to 75 percent grade of ferrotungsten requires about 4,200 kilowatt-hours per short ton. As this metal contains too much carbon, it is remelted

[11] Keeney, R. M., Manufacture of Ferro-Alloys, in Transactions American Institute Mining and Metallurgical Engineers, vol. LXII, 1920.

with an oxidizing charge. Usually tungsten ore concentrate and fluorspar are added to the ferrotungsten. This refining requires approximately 3,400 kilowatt-hours per short ton of metal. Or the manufacture of a ton of ferrotungsten from concentrated ore requires approximately 7,600 kilowatt-hours of electricity.

29. *Ferro-uranium.*—Ferro-uranium is used to only a limited extent in certain steels to increase toughness and elasticity. Uranium metal must itself be prepared in an electric furnace with carbon, calcium carbide, or silicon. Ferro-uranium has been obtained in an arc furnace by using a pure oxide of uranium and pure iron. A low-ash coke and lime and fluorspar were added. The hearth was water-cooled. From 6,000 to 10,000 kilowatt-hours of electricity have been required under varying conditions.

30. *Ferrophosphorus.*—Ferrophosphorus is a byproduct of the electric-furnace production of phosphoric acid. Over 200 pounds of 18 percent ferrophosphorus is obtained per ton of phosphoric acid when usual grades of phosphate rock and coke are employed. (See p. 173, Power in Fertilizer Material Production.) It is also manufactured in the blast furnace.

31. *Ferrotitanium.*—Ferrotitanium is obtained from titaniferous iron ores. These ores are heated in an electric-arc furnace to a temperature approaching 2,000° C. The ore, mixed with carbon, is usually placed on a bath of iron. The resulting product contains about 10 to 15 percent titanium and 5 to 8 percent carbon. While the carbon present does not interfere with the use of the ferrotitanium as a deoxidizer and nitrogen remover, it may be removed by the thermit process whereby powdered aluminum is mixed with the metal and ignited.

ELECTRIC FURNACE STEEL

32. More than a fourth of all steel castings manufactured in 1929 were produced in the electric furnace. About 1 percent of our steel ingots were made in the electric furnace. Yet the tonnage of electric steel ingots exceeded the tonnage of electric castings, for 532,392 long tons of electric steel ingots were produced as against 419,039 tons of electric steel castings in 1929.

33. *Melting in electric furnace.*—Production of steel in an electric furnace varies with the character of the charge and the type of steel to be made. It may be merely a melting process, where high grade steel scrap is charged and ferro-alloys may or may not be added. Some pig iron or iron ore may also be added if necessary, to lower the carbon content. After the molten steel has stood, impurities float on the surface and are removed. This molten steel may be poured into ingot molds or castings molds. An acid-lined furnace may be used for pure metal melting. The advantage of this process, as compared with open-hearth melting, is that oxidizing can be avoided more efficiently in the electric furnace. A steel results that is equal to the crucible furnace product. As electric-furnace melting is cheaper than crucible melting, the electric furnace has largely replaced the crucible furnace.

34. *Refining in electric furnace*—Or the electric furnace may be used for refining an impure metallic charge. Steel scrap or pig iron containing more sulphur or phosphorus than is desired in the finished

steel is fluxed with limestone, 300 to 500 pounds being used for 6 to 8 ton charge of steel scrap while 600 to 800 pounds are necessary when some iron ore is employed. The furnace must have a basic lining; frequently burnt magnesite is employed. As the metal is melted, the limestone and oxide of iron will rise through the fluid metal forcing a slag to the top. Manganese and silicon are oxidized and join the slag. Phosphorus is then oxidized. This slag is skimmed off. Sulphur is removed by adding carbon to a slag containing no oxide of iron. Sometimes broken carbon electrodes are employed for this purpose and to raise the carbon content of the steel.

35. *Superrefining in electric furnace.*—Or the electric furnace may be used for a superrefining of steel from the open-hearth of Bessemer furnaces, replacing the old crucible furnace. It is less expensive to melt an impure charge in these furnaces than in the electric furnace; for, in the production of steel from pig iron, oxidizing conditions are essential to remove carbon. As the value of the electric furnace lies in its nonoxidizing atmosphere, it cannot oxidize out carbon without the addition of much steel scrap or ore. But after steel has been made in the Bessemer or open-hearth furnace, the electric furnace can remove oxides, sulphur, and dissolved gases from the molten metal more efficiently than other furnaces.

TYPES OF FURNACES USED

36. *Arc furnaces.*—Steel castings are usually melted in direct-heating arc furnaces in this country. The majority of such furnaces in use in 1929 had 3 tons or less capacity. The furnaces are boxlike in shape and, for the basic process, are lined with magnesite brick with an inner lining of calcined granular magnesite mixed with slag binder. Silica brick and silica sand are applied to the steel furnace for acid processes. Electricity is supplied through graphite or carbon electrodes introduced through the furnace roof. The metal charge is placed on a boxlike hearth. A short arc is produced between the charge and the electrodes. Many furnaces operate on 3-phase alternating-current with 3 electrodes, although single-phase furnaces with 2 electrodes are used for small tonnage. The distance between electrodes and the molten bath is regulated automatically to produce a steady heat.

37. Ingot production requires larger furnaces, 25 to 35 tons being usual. The power requirements per ton decrease with the size of furnace as heat losses are less in larger furnaces.

38. *Induction furnace.*—Use of the induction furnace is increasing for moderate tonnage work. The coreless type consists of a coil of copper pipe to which is supplied an alternating current. A graphite crucible containing the steel is placed within the coil but separated from it by insulation. The alternating current in the coil induces an alternating current in the crucible walls which heat its contents. High-frequency current is used.

39. Other induction furnaces have a primary winding above the secondary winding which consists of a ring of the molten steel to be heated. The transfer of current from the primary to the secondary windings is assisted by an iron core looping through the two windings making a closed loop around them. Electrodes are not required in induction furnaces.

40. *Power consumption.*—Major differences in power consumption are determined by the character of the charge. A molten charge from the open-hearth or Bessemer furnace requires much less heat to refine than does a cold charge that must first be raised to the melting point by electricity. For example: A 20-ton arc furnace employing graphite electrodes required 680 kilowatt-hours of energy to refine 1 ton of steel from a solid charge; a similar furnace took but 210 kilowatt-hours to refine a molten charge. Roughly, therefore, while melting requires about 500 kilowatt-hours, refining and deoxidizing takes but 200 kilowatt-hours. An induction furnace melting a solid charge of 18 tons required 865 kilowatt-hours per ton.

41. The following power consumption figures are compiled from a paper by Delton T. Waby which received the 1929 award from the Western Society of Engineers. It is evident that a 3-ton foundry furnace consumes about 600 kilowatt-hours per ton of castings.

TABLE 1.—*Electricity and electrodes consumed in melting iron and steel*

Product	Size of furnace	Furnace lining	Pounds of electrodes consumed per ton	Kilowatt-hours per ton
	Short tons			
Alloy steel ingots	25	Basic	10.5 graphite	525
	10	do	8 graphite	650
	3	do	17 carbon	600
Steel valve castings and fittings	6	do	11 graphite	625
	3	do	14 graphite	760
	2	Acid	4 graphite	600
Manganese steel castings	6	Basic	9.5 graphite	592
	3	do	do	590–660
Miscellaneous steel castings	6	Acid		590
	6	Basic	9.5 graphite 25 carbon	600 640
	3	Acid Basic	5 to 5.5 graphite 19.8 carbon	500–564 615
	2	Acid	9 graphite 16.5 carbon	600
	0.5	do	10 carbon	700

42. Dr. E. F. Northrup, inventor of the coreless induction furnace, gives the following figures for melting various charges of steel in this type of furnace:

Carbon-chromium steel, 710 kilowat-hours per ton.[12]
Manganese steel, 590 kilowatt-hours per ton.
2 percent nickel steel, 670 kilowatt-hours per ton.
Nickel-chromium steel, 525 Kilowatt-hours per ton.

43. The basic costs of producing a ton of foundry steel are estimated to include the following items:

Charge:	
Heavy scrap: 570 pounds at $0.007	$3.99
Light scrap: 1,760 pounds at $0.007	12.32
Power: 615 kilowatt-hours at $0.003	1.85
Carbon electrodes: 20 pounds at $0.05	1.00
Labor: 1 man at $1 per hour; 2 men at $0.60 per hour	2.30
80 percent ferromanganese: 13 pounds at $0.04	.52
50 percent ferrosilicon 11 pounds at $0.04	.44
Total	22.42

44. These figures do not take into account general plant labor, repairs, or miscellaneous supplies; nor do they consider overhead,

[12] First heat of day in cold furnace.

depreciation, or capital charges. It is obvious, however, from these figures that power costs at 3 mills form less than 8 percent of the operating cost in electric steel production.

Electric Heat Treatment of Steels

45. Almost all alloy steels and many carbon steels are heat treated, or subjected to heating and cooling in a solid state, in order to impart specific characteristics to the steel. Heat-treatment may take the form of annealing, toughening, hardening, tempering, drawing, carburizing, and casehardening. There is a marked tendency toward the use of electric furnaces in these operations.

46. *Annealing.*—Annealing treatment is given to steel castings to refine their coarse-grain size and thereby increase strength and elasticity; to cold-worked steel to restore ductility; to cold-drawn wire to permit further drawing; to hot-forged steel to relieve internal stresses produced in the forging. The steel is gradually heated above the critical stage (790° to 925° C.—1,454° to 1,697° F.) and held at this temperature for about 45 minutes per each inch of thickness of the object.[13] When the grain has been refined, the object is cooled, slowly if a soft, ductile metal is desired, and quickly by quenching, if strength and elasticity are necessary. Sometimes objects are reheated and cooled.

47. *Toughening, hardening, and tempering.*—Structural steels are frequently "toughened" by heating the steel above the critical range, quenching in water or oil, drawing by heating below the critical range, and cooling in air or oil. Tool steels are "hardened" by slow heating and rapid cooling, and tempered at reheating temperatures below 316° C. Machine parts, which must withstand friction and shock, are carburized and casehardened which involves hardening on the outside by increasing the carbon content. Low-carbon steels or iron are heated in contact with carbonaceous material below their respective melting points and absorb some of the carbon. The objects are cooled, reheated, and quenched in water or oil. They are then tempered in an oil or salt bath.

TYPES OF FURNACES

48. Electric furnaces for annealing, toughening, hardening, drawing, tempering, or carburizing are built in the same designs as those developed for fuel-fired furnaces. They may be of the batch type, where batch after batch of castings or forgings or sheets are placed in the furnace and renewed. They may be of the continuous type where objects are loaded into one end of the furnace and move slowly through the furnace; or a car may pass through the furnace; or they may have revolving hearths.

49. Electric heat-treating furnaces are usually of the metallic-resistor type. The resistor is made of alloys of chromium and nickel or of carbon and graphite. It is heated by the electric current and in turn heats the steel. Furnace heat is automatically controlled.

50. For example: An electric continuous furnace for annealing plate or cold-rolled steel holds the carbon resistors in carbonaceous troughs on piers. Carbon electrodes at each end of the trough lead

[13] Committee on heat treatment of American Society for Testing Materials.

the current to the carbon resistors. The material is placed on cars which pass slowly through the furnace. The arched furnace roof, together with the carbonaceous troughs and the carbon resistors, radiate their heat to the steel on the cars. The heat of the steel is also utilized to heat cold material on cars coming in the opposite direction in tunnels at each end of the furnace. This furnace requires about 400 kilowatt-hours of energy per ton of strips or sheets heated to 1,200° F.

51. Other furnaces have heating elements around the side of the furnace chamber, the low-resistance terminals coming through sealed bushings in the walls. Only 216 kilowatt-hours of energy was required to anneal laminating plates in such a furnace filled with non-oxidizing gas (15 percent hydrogen and 85 percent nitrogen).

52. *Power consumption.*—R. M. Cherry of the General Electric Co. gives the following figures on electrical consumption for various electric furnaces operating continually.[14]

Process	Temperature	Type furnace	Kilowatt-hours per ton
	° *F.*		
Steel annealing	1,500	Batch or continuous	182–286
		Continuous counterflow	133–200
Hardening	1,500	Batch or continuous	182–286
Drawing	600	Batch or continuous	57–100
		Continuous counterflow	40–67
Steel casing and annealing	1,650	Batch	200–250
Carburizing	1,650	Batch or continuous	182–500
Cast iron	1,350	Batch	182–333
		Continuous counterflow	80–133

He states that furnace ratings should be 15 percent above these actual requirements.

53. *Costs.*—Comparisons of costs of annealing sheets in elevator-type furnaces heated by electricity and by oil are reported by A. N. Otis of the General Electric Co. in a paper presented before the American Society for Steel Treating, October 1928. Sheets were loaded on steel plates in the electric furnace while long pots were employed in the oil furnace. Plates cost $18 each and lasted through 30 anneals of 3.5 tons each; pots cost $400 each and lasted through 50 anneals. Or plates cost $0.17 per ton and boxes $2.28 per ton. Two hundred and sixteen kilowatt-hours electricity cost $2.70; 57.80 gallons of oil $3.30. Labor costs were approximately the same. Or direct operating costs varied by $2.71 per ton in favor of the electric furnace.

54. The same engineer gives the following cost data for annealing tool steel in covered boxes, employing a car-type furnace of 10-ton capacity. Continuous operation is assured and heating temperatures range from 1,450° to 1,650° F.; the treating requires 15 to 24 hours for heating and 20 to 30 hours for cooling.

Costs of annealing 1 short ton tool steel bars

Capital costs: 16 percent on $10	$1.60
Power, 400 kilowatt-hours at $0.015	6.00
Boxes	.65
Labor	2.20
Total annealing costs	10.45

[14] Electrical World, Dec. 7, 1929.

55. A new method of treating high-speed steel has been announced. A salt bath is heated by current flowing through the bath from an immersed electrode.

56. *Extensive application of electric heat treatment.*—The Bethlehem Steel Co. has installed an all-electric heat-treating equipment in its alloy steel plant for alloy and special steels. Bars from the rolling mills enter a roller hearth furnace on a continuous roller line whose rolls oscillate back and forth eight times each minute. The furnace consists of two chambers placed end to end. The first is a preheating chamber operating at 800° F.; the second, a high-temperature chamber which can reach 1,650° F. As the hot steel bars are discharged from the high-temperature chamber, a crane lifts them from the roller line to the quenching tank. The length of time in the quenching tank is controlled by a time switch which causes the crane to automatically lift them out on to unloading skids. Two pit furnaces are used for annealing, having a capacity of 1,098 kilowatts. From these furnaces, bars are given a mild heat treatment in two car-bottom annealing furnaces with a capacity of 675 kilowatts, after which they are ready for the straightening and testing machines.

57. At the Fordson plant of the Ford Motor Co., electric furnaces are used for heat treating and forming of spring leaves, heat treatment of crank shafts, connecting rods, gears, and other parts, and for heating forging stock. These forging furnaces, operating at 2,350° F., produce a ton of forgings with a consumption of 500 kilowatt-hours of electricity.

58. *Electric arc welding.*—Pipe and structural steel mills are employing electric arc welding on a large scale. In the older method of welding, a metal electrode is melted into a space between the two pieces to be welded, the pieces melting sufficiently to effect the juncture. The newer method is a resistance welding process requiring no welding metal. The two edges of the skelp are fused into a continuous seam by alternating current at high amperage in a welding machine. Electrical consumption is given as 0.25 kilowatt-hour per linear foot of welded joint.

Ore Resources Essential to Iron and Steel Production

59. More than 73,000,000 long tons of iron ore, more than 42,000,000 net tons of coke, 13,000,000 bushels of charcoal, and over 15,000,000 tons of limestone were consumed in blast furnaces in the production of pig iron in 1929.

IRON-ORE DEPOSITS AND PRODUCTION

60. *Iron-ore shipments.*—Almost seven eighths of all iron ore shipped from mines in the United States in 1929 came from the Lake Superior iron-ore region. Minnesota shipped 61.5 percent of all iron ore, Michigan 22.3 percent, and Wisconsin 2.4 percent. Alabama was the only other State in which appreciable amounts of iron ore were mined, her shipments totaling 6,600,000 long tons. Wyoming mined 639,000 long tons; Utah, 325,000; Colorado, 50,000; and Washington State, 5,000, or less than 0.1 percent of the total tonnage of the United States. Some 3,000,000 tons of iron ore were imported. More than one half of this came from Chile. Other ores were im-

ported from Cuba, Algeria and Tunisia, Spain, Sweden, Greece, Canada, and Newfoundland.

TABLE II.—*Iron ore shipped from mines in the United States* [1]

State	1925, gross tons	1926, gross tons	1927, gross tons	1928, gross tons	1929	
					Gross tons	Percent
Total	63, 924, 763	69, 292, 832	61, 232, 473	63, 432, 826	75, 602, 734	100. 0
Alabama	6, 891, 081	6, 871, 412	6, 508, 419	6, 159, 863	6, 637, 299	8. 8
California	352	282				
Colorado	8, 642	35, 535	32, 206	52, 713	50, 754	(2)
Georgia	79, 488	51, 642	50, 312	73, 052	59, 316	(2)
Michigan	15, 254, 003	16, 699, 984	14, 532, 831	14, 241, 102	16, 838, 568	22. 3
Minnesota	38, 022, 237	40, 961, 361	35, 563, 177	38, 129, 018	46, 470, 243	61. 5
Missouri	40, 043	124, 371	78, 605	94, 899	171, 456	. 2
Montana	3, 672	724	2, 837	1, 640		
New Jersey	164, 523	212, 152	202, 720	350, 616	285, 115	. 4
New Mexico	172, 959	216, 269	214, 747	184, 623	171, 585	. 2
New York	413, 517	659, 741	936, 850	767, 743	875, 564	1. 2
North Carolina	22, 011	14, 798	32, 528		30, 575	(2)
Ohio	2, 410					
Pennsylvania	917, 255	1, 088, 634	1, 124, 883	1, 013, 791	1, 151, 130	1. 5
Tennessee	164, 073	138, 307	121, 220	128, 478	101, 796	. 1
Utah	268, 529	296, 943	222, 879	320, 655	324, 885	. 4
Virginia	76, 302	49, 703	66, 897	27, 970	232	(2)
Washington	830	1, 702	550	1, 012	5, 018	(2)
Wisconsin	933, 214	1, 238, 885	937, 935	1, 394, 371	1, 789, 721	2. 4
Wyoming	489, 622	630, 387	602, 877	491, 280	639, 477	. 8

[1] U.S. Bureau of Mines: Compiled from Iron Ore, Pig Iron and Steel.
[2] Less than 0.1 percent.

61. *Character of commercial ores.*—Iron rarely occurs native but is a part of other minerals, the most used of which are the iron oxides and the carbonates. The commercial value of ore depends on the kind and quantity of its impurities. Copper and titanium are so objectionable that ores containing them are rarely used. Too high a phosphorus or sulphur content is undesirable. Volatile impurities, such as water, carbon dioxide, and organic matter, add weight and, consequently, increase the cost of transportation and the cost of firing the furnace. Ore of great value in blast-furnace practice contains enough lime to be self-fluxing.

62. *Lake Superior iron ores.*—Hematite, an anhydrous oxide ore, has been the principal iron ore used in United States blast furnaces. It occurred in great abundance in the Lake Superior region of Minnesota, Michigan, and Wisconsin; in smaller amounts in central New York and in the Appalachian region of Alabama, Georgia, Tennessee, and Virginia, and in eastern Wyoming. Small deposits were found in Pennsylvania, Maryland, eastern Wisconsin, Utah, and California. The hematite of the Lake Superior district averaged 51 percent iron content in 1929. The ore reserves in Minnesota were estimated to be 1,242,060,000 tons by the United States Bureau of Mines; the reserves of Michigan, 168,350,000 tons. At the present rate of consumption of these ores, this supply will last less than 25 years. The large steel companies have merged with iron-ore producers, so that control of this Lake Superior ore is largely held by the United States Steel Corporation, the Bethlehem Steel Corporation, the Republic Steel Corporation, and the National Steel Corporation.

63. *Southern Appalachian ores.*—The Alabama ore is also chiefly hematite and is nearly self-fluxing. The iron content of ore from

Jefferson County, the chief producing county, averages 36.67 percent iron, although higher contents are found in some sections. Brown ore is widely distributed in Alabama but is not pure enough to have present commercial value. While some iron ore is produced in Georgia, Tennessee, and Virginia, deposits are small and distinctly subordinate. North Carolina has several types of iron ore widely distributed, but in relatively small quantities. Reserves of magnetite ores with titanium content are believed to be approximately 600,000 tons.

64. *North Atlantic ores.*—The predominating iron ore of New York, Pennsylvania, and New Jersey is magnetite, a crystalline compound of oxides of iron, although some hematite is produced in New York for pigment use and carbonate ore is mined in Pennsylvania. Pennsylvania was the largest producer of magnetite, the ore averaging about 40 percent iron, but it is high in sulphur and must be roasted before smelting. New York and New Jersey ores range from 61 to 67 percent iron. While these ores contain more iron than those in use in this country, their phosphorus content is higher than that of ores in the Lake Superior region. Large bodies of titaniferous magnetite are located at Lake Sanford, N.Y.; these may be of value in the future.

WESTERN IRON ORES

65. *Wyoming.*—Wyoming has several rich iron deposits. Ore being produced in 1929 was hematite containing 53.5 percent iron, some manganese, but little phosphorus, and no sulphur. Hematite is found in Carbon County, north of Rawlins; this is said to contain 65 percent iron and no phosphorus. In the Seminole Mountains there are large deposits containing from 55 to 68 percent iron, and in Fremont county, near Atlantic City, are located other large deposits. There are large dikes of titaniferous iron ore in Iron Mountain in Albany County; this contains 55 percent iron, but the 14 to 25 percent titanium oxide present makes the deposit valueless for present blast-furnace conditions. Cast iron was produced electrically from this ore in 1905–6. Two tons of this iron and 1 ton of briquets made from Pacific coast magnetite sands were smelted, with a consumption of 3,760 kilowatt-hours of power.[15]

66. *Utah.*—In 1929 Iron County, in Utah, produced hematite containing 52 percent iron, 2 percent manganese, and 0.29 percent phosphorus. It is estimated that about 40,000,000 tons of iron ore are to be found about 35 feet below the surface in the southwestern corner of the State in Iron and Washington Counties.

67. *Colorado and New Mexico.*—The only iron property operated in Colorado in 1929 was near Villa Grove in Saguache County. This ore is brown ore, or a hydrate ferric oxide, and averages about 44 percent iron. New Mexico produced magnetite ores carrying 51 percent iron and some manganese near Fierro, Grant County, in 1929. Other deposits of value are in Jarilla Mountains near San Pedro, about White Oaks, Capitan, and Jicarilla Mountains; at Ticalate and in the Gallinas Mountains; in the Cuchillo range near Glorieta; and at Silver City.

68. *Washington.*—The only iron mine active in Washington State in 1929 was the Big Iron mine in Stevens County; this pro-

[15] Ball, Sydney H. Titaniferous Iron Ore of Iron Mountain, Wyo. 1906.

duced a magnetite ore low in phosphorus and of high iron content. In Kittitas County, both magnetite and hematite ores are reported with low sulphur and phosphorus content. Iron ores have been reported from other sections of the State but are scattered.

69. Small quantities of brown ore are mined from time to time in California, Idaho, Nevada, and Montana, ore which is used either as flux in smelting copper and other nonferrous metals, or in pigment manufacture. California has magnetite ores.

70. *Other American deposits.*—Development of Brazilian iron deposits is beginning. The Italoira Ore Co., Ltd., has signed a contract with the Government of Brazil to mine 3,000,000 tons of iron ore annually from deposits situated in the State of Minas Geraes. The concession comprises a mountain estimated to contain 190,000,000 tons of hematite. The ore is hematite containing 67 to 68 percent iron. The company is partially financed by Americans. The Bethlehem Steel Co. owns rich mines in the Province of Coquincho, Chile, from which 1,500,000 tons of iron ore were shipped in 1928. Dutch and Swedish interests are prospecting in the south central part of Chile. It is believed that iron-ore deposits are extensive in both Brazil and Chile.

71. Cuba has been mining hematite since 1884 at Firmesa. Other deposits of soft ore are located on the north coast, while the Province of Pinar del Pio has small deposits of high-quality ore.

Canada produces titaniferous ores. Newfoundland has great beds of iron ore which dip under Conception Bay.

72. *European reserves of iron ore.*—Since the acquisition of Lorraine, France is second to the United States in the mining of iron ore. While this section produced 43,000,000 metric tons in 1927, the northwestern coast of France produced but 2,000,000 tons of iron. Lorraine ores are a brown hematite high in phosphorus. Germany, since the loss of Lorraine, has but scattered iron deposits.

73. The United Kingdom mines red hematite in parts of Lancashire, Cumberland, and Cornwall, but her best ores are imported from Spain, where deposits of hematite have been worked for many years. British interests have acquired heavy interests in Brazilian deposits.

74. Belgium mines limonite ore near Antwerp. Austria, Hungary, Yugoslavia, and Czechoslovakia are fairly well supplied with good iron ore. Sweden has about 1,750,000,000 tons of iron ore in Lapland and in the central part of the country. In the extreme northwest of Norway mines are estimated to contain 1,000,000,000 tons of iron ore. Polish deposits are low-grade.

75. While known iron resources of Russia are said to have over 1,000,000,000 tons of iron content, actual iron reserves in the Kunsk region, in the Ural Mountains, and in northern and western Russia are believed to contain many more billions.

76. *China.*—Iron-ore production in China is estimated to be about 1,500,000 tons per year. Her iron-ore reserves are very extensive, however, estimates of reserves capable of large scale production running close to the billion mark, of which 555,000,000 tons are classed as potential reserves. The richest and most accessible iron region lies along the Yangtze River below the Gorges. The ores in this region are a mixture of hematite and magnetite containing about 60 percent iron and are adapted to open-cut mining.

While the best-known ore body, Tayeh, contains but 32,000,000 tons, other bodies carrying smaller iron content extend farther downstream.

77. Other deposits are located in South Manchuria along the watershed between the Hun-ho and the Yahu Rivers. But the ore bodies are not continuous. Farther west there are larger bodies of ore, the largest of these being at Kungchangling, Niaverkhou, and Anshan. In the Hsuanlung district of the "Peking Grid", hematite ore of good grade and adapted to open-cut mining is found. North Shantung has some workable deposits in close proximity to a coal field; this ore is self-fluxing.[16]

78. *Iron-ore deposits of other countries.*—The iron and manganese ore depsits in Algeria and Tunisia are demanding attention. The Ouenza reserve in Algeria is said to have 50,000,000 tons. In Tunisia ores are high in arsenic. Hematite reserves in the Marampa Hills of Sierra Lione are reported to be extensive. Southern Australia produced about 600,000 tons of iron ore in 1918.

79. *World iron-ore and pig-iron production.*—The United States mined 39 percent of the world's iron ore, while France mined 27 percent in 1929. Great Britain and Sweden were the only other countries mining as much as 5 percent of the world's supply. But while the United States produced 44 percent of the entire pig iron, France manufactured but 13 percent. Much of French iron ore was turned into pig iron in Germany, where blast-furnace production exceeded in small measure French production. Sweden, too, manufactured but a small amount of her iron ore into pig iron. Belgium, however, produced 4 percent of the world's pig iron. Such countries as Cuba, Newfoundland, Chile, Spain, Algeria, Tunisia, and Morocco exported most of their iron ore.

TABLE III.—*World iron-ore and pig-iron production in 1929* [1]

Country	Iron-ore production		Pig-iron production [2]	
	Metric tons	Percent	Metric tons	Percent
Total	188, 159, 821	100. 0	98, 543, 330	100. 0
North America	76, 423, 244	40. 6	44, 486, 974	45. 1
Canada	(3)		1, 189, 037	1. 2
Cuba	682, 095	. 4		
Newfoundland	1, 541, 334	. 8		
United States	74, 199, 815	39. 4	43, 297, 937	43. 9
South America	1, 842, 343	1. 0	70, 000	. 1
Brazil	30, 000	(4)	[5] 70, 000	. 1
Chile	1, 812, 343	. 9		
Europe	103, 227, 434	54. 9	50, 160, 285	51. 0
Austria	1, 891, 381	1. 0	458, 973	. 5
Belgium	(3)		4, 095, 940	4. 2
Czechoslovakia	1, 807, 663	1. 0	1, 644, 515	1. 7
France (including Alsace-Lorraine)	51, 028, 000	27. 1	12, 550, 940	12. 7
Germany	(3)		13, 397, 000	13. 6
Hungary	251, 860	. 1	367, 951	. 4
Italy	866, 480	. 5	672, 280	. 7
Luxemburg	7, 571, 206	4. 0	2, 906, 093	2. 9
Netherlands	(3)		253, 776	. 3
Norway	650, 000	. 4	[5] 134, 000	. 1
Poland	659, 207	. 4	704, 437	. 7
Russia (including Russia in Asia)	7, 100, 000	3. 8	4, 000, 000	4. 1

See footnotes at end of table.

[16] Smith, Wilfred. A Geographical Study of Coal and Iron in China. 1926.

TABLE III.—*World iron-ore and pig-iron production in 1929*—Continued

Country	Iron-ore production		Pig-iron production	
	Metric tons	Percent	Metric tons	Percent
Europe—Continued.				
Spain	6,546,648	3.5	752,618	0.8
Sweden	11,000,000	5.8	489,677	.5
Great Britain	13,427,043	7.1	7,701,200	7.8
Yugoslavia	427,946	.2	30,885	(4)
Asia	2,306,952	1.2	3,340,314	3.4
China	[5] 1,000,000	.5	[5] 300,000	.3
Chosen	551,814	.3	155,514	.2
British India	(3)		1,370,000	1.4
Unfederated Malay States	755,138	.4		
Japan			1,514,800	1.5
Africa	4,358,592	2.3	16,510	(4)
Algeria	2,196,182	1.2		
Belgian Congo	50,000	(4)		
Morocco—Spanish	[6] 1,061,424	.6		
Rhodesia—Northern	3,613	(4)		
—Southern	3,406	(4)		
Southwest Africa	38,697	(4)		
Tunisia	977,000	.5		
Union of South Africa	38,270	(4)	16,510	(4)
Australia	1,256	(4)	337,975	.3
Queensland	1,256	(4)		
All other countries			[5] 131,272	.1

[1] Compiled from U.S. Bureau of Mines, Iron Ore, Pig Iron, and Steel in 1929.
[2] Includes ferro-alloys.
[3] For the following countries, 1929 iron-ore production is not available: Mexico, British India, Japan, French Morocco, New South Wales, South Australia, New Zealand, Belgium, Greece, Netherlands, Portugal, Rumania, Switzerland, Northern Ireland, and Germany. Germany's production of iron ore has been as follows in recent years: 1925, 5,742,542 metric tons; 1926, 4,594,939 metric tons; 1927, 6,315,186 metric tons; 1928, 6,296,261 metric tons.
[4] Less than 0.1 percent.
[5] Approximate production.
[6] Exports.

80. *Coke production and coal resources.*—Although some charcoal is applied in special types of iron production, coke made from bituminous coal is quite generally used in smelting. The axiom "Iron comes to coal" still holds today. From 12 to 15 percent of the annual output of bituminous coal is carbonized.

81. *Coke production and coal mining by States.*—Pennsylvania is the largest coke-producing State, as well as the largest coal-producing State. Ohio ranks second in coke; part of its coking coal is shipped from Pennsylvania, Kentucky, and West Virginia. Indiana also secured coking coals from these three States. Alabama, which ranks fourth in coke production, consumes only Alabama coal in such production. New York, ranking fifth in coke, is dependent on Pennsylvania and to some extent on West Virginia, Kentucky, and Virginia for her coal supply.

82. Colorado is ninth in coke production. All bituminous coal used in the manufacture of her coke comes from her own Trinidad fields. Utah manufactured about 300,000 tons of coke in 1929, most of which was produced from Carbon County, Utah, coals. Washington States' production of coke was 65,600 tons, all of which was carbonized from Washington bituminous coal chiefly from Pierce County. Pierce County coals are analyzed as having 51 percent

fixed carbon with heating value of 13,000 B.t.u.; Carbon County, Utah, coals have 47.8 percent fixed carbon with 12,500 B.t.u.; while Trinidad District high grade bituminous coals have 58.7 percent fixed carbon with heating value of 13,780 B.t.u.

TABLE IV.—*Production of coke and bituminous coal in 1929 by States* [1]

State	Production of coke		Production of bituminous coal	
	Short tons	Percent	Short tons	Percent
Total	59, 490, 600	100. 0	532, 352, 000	100. 0
Pennsylvania	19, 592, 900	32. 9	142, 400, 000	26. 7
Ohio	8, 480, 300	14. 3	23, 712, 000	4. 5
Indiana	6, 392, 700	10. 7	17, 970, 000	3. 4
Alabama	4, 738, 800	8. 0	17, 690, 000	3. 3
New York	4, 201, 800	7. 1		
Illinois	4, 179, 000	7. 0	60, 085, 000	11. 3
West Virginia	1, 934, 000	3. 3	138, 015, 000	25. 9
New Jersey	908, 300	1. 5		
Colorado	719, 000	1. 2	9, 890, 000	1. 9
Virginia	309, 000	. 5	13, 138, 000	2. 5
Utah	299, 000	. 5	5, 250, 000	. 9
Tennessee	199, 400	. 3	5, 750, 000	1. 1
Washington	65, 600	. 1	2, 530, 000	. 5
Kentucky			60, 575, 000	11. 4
Wyoming			6, 600, 000	1. 2
Iowa			4, 130, 000	. 8
Missouri			3, 860, 000	. 7
Oklahoma			3, 484, 000	. 7
Montana			3, 183, 000	. 6
Kansas			3, 040, 000	. 6
New Mexico			2, 640, 000	. 5
Maryland			2, 660, 000	. 5
North Dakota			1, 950, 000	. 4
Arkansas			1, 800, 000	. 3
Texas			1, 060, 000	. 2
Michigan			770, 000	. 1
Other States, Alaska	7, 470, 800	12. 6	170, 000	(2)

[1] Estimated by the U.S. Bureau of Mines.
[2] Less than 0.1 percent.

WESTERN COAL RESOURCES

83. *Washington coals.*—Washington State contains coals ranging from lignite to anthracite at Cowlitz Pass, Carbonado, and Glacier. In King County, there are large areas of coal-bearing strata varying from subbituminous to coking bituminous along the western edge of the Cascade Mountains. The eastern portion of Pierce County has both coking and noncoking coals as well as a small area of anthracite. Other deposits, either small in size or of low quality, are found in Kittitas, Lewis, and Thurston Counties.

84. *Oregon and Idaho coals.*—The most important coal region in Oregon is the Coos Bay coal field. This is a subbituminous coal of little present market value. The coal used in the State is shipped from Wyoming, Utah, and Washington. Although Idaho has a small coal area near the Wyoming line, it is badly faulted. Consequently, it is cheaper to secure necessary coal from Utah and Wyoming.

85. *Montana and Wyoming coals.*—While the State of Montana has large reserves of coal, it is chiefly subbituminous and lignite. Only a little coking coal is available within the State. Wyoming also has large reserves of coal, some of which is high-grade bituminous. Along the western edge of the State, in the southwestern section called the

Green River region, lower zones contain bituminous coal but it is not a coking coal.

86. *Utah and Colorado coals.*—The Uinta coal field of Utah, extending from Provo into Colorado, has high-grade bituminous coal of coking quality. Other sections of the State have large coal deposits of somewhat lower grade. Colorado has a large number of coal areas of varying quality. In the southwestern portion of the State high-grade bituminous coal is found. Some coal near Durango is excellent coking coal. In south central Colorado where the Trinidad District is located, there are extensive areas of coking coal.

87. Western British Columbia has important coal producing areas, and Alberta is believed to have very great coal reserves of many types.

88. *Limestone.*—Limestone, essential in blast-furnace practice for fluxing iron ore, is available in large quantities in all States except North Dakota. The extent of limestone deposits are so enormous that no effort has been spent in estimating the available tonnage. Production occurs near the particular point where a demand exists.

89. *Silica.*—Silica applied to the manufacture of ferrosilicon is obtained from quartz and quartzite, that is, massive rock quartz, vein quartz, or quartz crystals. The quartz must be quite free of lime, alumina, arsenic, and phosphorus, and have a very high silica content.

90. As quartz is distributed quite generally in the Appalachian States and in the Western States, and as it is mined from open cuts, it is a cheap commodity that can carry only small freight charges. Consequently, it is usually quarried close to local consuming centers. In fact, manufacturers of ferrosilicon frequently quarry their own silica rock. The only importations come from Canada by boat to electrometallurgical plants near the international boundary.

91. States which produced quartz in 1929 were: California, Nevada, Arizona, and Colorado; Maine, Massachusetts, and Connecticut; New York, Pennsylvania, Maryland, and Virginia; North Carolina, Tennessee, and Alabama; and Michigan and Wisconsin. Only a part of this production was consumed in ferrosilicon manufacture, much being a lower grade quartz used for copper smelting. Quarrying began at Marblemount, Wash., November 1930, to supply the Northwest Mineral Products Co. of Burlington, Wash., with quartz containing 99.5 percent silica.

92. Quartzite is chiefly produced in central Pennsylvania near Mount Union and Hollidaysburg. While much is used for refractory purposes, some enters into ferrosilicon production. Quartzite is also mined near Canon City, Colo., near Anaconda, Mont., in New York, Virginia, Alabama, North Carolina, and Wisconsin.

93. Location of quartz or quartzite deposits is usually shown by State reports so that a manufacturer requiring this mineral in quantity need only determine the purity and extent of local deposits.

94. *Manganese ore.*—Approximately 724,648 tons of manganese ore containing 35 percent or more manganese was consumed in the manufacture of ferromanganese in 1929. Of this amount, 664,269 tons were imported and 60,379 tons were produced in the United States. Approximately nine tenths of all domestic ore came from Montana, Georgia, Arkansas, and Virginia. Soviet Russia, Brazil, India, and British West Africa were the principal countries from

which imports were received. Domestic shipments of ferruginous manganese ore containing from 10 to 35 percent manganese and used to manufacture spiegeleisen in the blast furnace, totaled 78,191 tons. Shipments of manganiferous iron ore containing from 5 to 10 percent manganese and employed in manufacturing manganese pig iron were 1,110,067 tons in 1929.

95. Manganese forms a part of many minerals and is widely distributed. But deposits of ore containing 35 percent manganese, known as "manganese ore" which is necessary for the production of ferromanganese, are not extensive in the United States. A committee of Government and private geologists, metallurgists, and engineers investigated 1,850 deposits in 1925 and reported the known tonnage of this grade ore in the United States ranged from 1,400,000 to 3,000,000 tons. Maximum production of manganese ore was reached in 1918 when 305,869 long tons were mined.

WESTERN RESERVES

96. *Montana.*—Montana is, at present, the largest producer of manganese ore, four companies including the Anaconda Copper Mining Co. being engaged in mining manganese ore. The manganese districts center around Butte and Philipsburg. In the Butte District where rhododirosite ore is mined, the ore averages 37.6 percent manganese which is concentrated to a sinter averaging 57.8 percent. The reserves of two mines in the district were estimated at 497,000 tons and 100,000 tons, respectively. Chemical ore is mined in the Philipsburg District. Late estimates place these reserves at 1,780,000 tons of which about 30 percent is crude ore containing 35 percent or more manganese.[17]

97. *Arizona.*—Three companies were producing manganese ore of 35 percent content in 1929 in Arizona, one being a copper mining company, the Phelps Dodge Corporation. The high grade ore is near Bisbee and is estimated to be about 50,000 tons. Production for 1929 totaled 3,905 long tons. Low grade or ferruginous manganese ore deposits are extensive and development is beginning near Congress and Winslow as well as at Bisbee.

98. *California.*—California has produced some manganese ore from time to time, principally from the old Ladd Mine, San Joaquin County. Colorado has widely distributed ferruginous manganese ore deposits in the Leadville District which are reported to produce 45,000 tons. Idaho has a high-grade deposit of manganese ore near Cleveland, Bannock County, but is believed to be small. In 1929, 3,181 tons were mined by the Western Manganese Co. Two other companies are located at Lava Springs. Some manganese is produced in the Las Vegas field of Nevada; this totaled 1,357 long tons in 1929.

99. *New Mexico.*—New Mexico has a number of deposits of manganiferous ore, manganiferous silver ore, and ferruginous iron ores. These deposits occur in Socorro, Luna, Grant, Lona Ana, and Sierra Counties. Production is being carried on by three companies near Deming, and 2,190 long tons of high grade ore were shipped in 1929, while shipments of ferruginous manganese ore were the largest made by any State, or 56,624 long tons. Utah has very small known deposits of high grade ore.

[17] U.S. Geological Survey Press Release. 1929.

100. *Washington.*—In Washington State, developed deposits in the Olympic Peninsula were exhausted. In the early part of 1928 a new lens was cut having a tenor of better than 50 percent manganese. No production is officially reported.

SOUTH ATLANTIC RESOURCES

101. *Georgia.*—Georgia ranked second in the mining of manganese ore in 1928, 1 company producing 4,727 long tons; but in 1929, 2 companies produced but 489 tons. Carterville is the chief producing district where hydraulic mining is done. A new concentrator installed in 1929 will have an annual capacity of 140,000 tons of ore averaging 40 to 50 percent manganese. Occurrences of manganese are found in a number of other counties in Georgia.

102. Arkansas produced 2,605 tons in the Batesville-Cushman District. The deposits are irregular and usually in numerous pockets surrounded by clay containing no ore. Alabama developed some deposits during war years but only a little production has been continued by two companies. Tennessee deposits of manganese ore are in the area including Carter County; three companies mined but 498 tons in 1929.

103. In Virginia, five companies operating in 1929 produced 2,583 long tons of manganese ores. Mining operations have been confined chiefly to Bland, Frederick, and Smythe Counties.

LOW GRADE MANGANIFEROUS AND FERRUGINOUS ORES

104. Domestic reserves of low grade ferruginous and manganiferous ores, that is, ores containing less than 35 percent manganese are extensive. Much effort has been expended in developing processes by which such ores, which vary greatly in kind, can be concentrated to higher content at a cost that will permit them to compete with foreign manganese ores. Efforts are also being made to manufacture ferromanganese directly from manganiferous ores.

105. Reports of the Bureau of Mines list our low-grade deposits as follows:

Extensive deposits of bentonite, a manganese silicate, have been located in the Olympic Mountains, Wash.

Large tonnages of silicate and carbonate manganese are disclosed after deep mining in San Joaquin County, Calif.

In Nevada, there are large bodies of ferruginous manganese ore, some of which is now utilized at Provo, Utah, in the manufacture of pig iron.

Deposits of both ferruginous and manganiferous ores are extensive in Utah.

New Mexico ore reduction problems are similar to those of the Cuyuna ores of Minnesota; at present, New Mexico mines large amount of ferruginous ore.

Montana has large quantities of a mixture of carbonates and silicates of manganese and quartz which must be separated.

Colorado ores also are extensive but present metallurgical problems.

The Cuyuna Range of Minnesota has very extensive deposits of manganiferous iron ore, which must be separated from associated iron and phosphorus and waste materials. The Bradley process of separation based on leaching with ammonium sulphate is being brought to the commercial production stage. The Bureau of Mines station at Minneapolis is investigating the feasibility of producing ferromanganese from these manganiferous iron ores.

The manganiferous zinc residues obtained from franklinite beds in New Jersey, after their zinc content is washed out, is the present largest source of ferruginous manganese.

FOREIGN RESERVES OF MANGANESE ORES

106. Russia has very extensive deposits of high-grade manganese ore. The Tchiaturi deposits in the Republic of Georgia are regarded as the largest in the world estimated to contain from 44,000,000 to 200,000,000 tons. The Nikopol deposits in southwestern Russia are believed to contain 10,000,000 tons of commercial ore; they have been leased to German companies.

107. Known deposits of India are also large. Brazil's largest developed deposits are in the Lafayette District west of Rio de Janeiro, and are estimated to contain over 9,000,000 tons. Many undeveloped, and at present, inaccessible deposits are believed to exist in Brazil. Chile also has deposits which are difficult to reach, at present. Cuba is estimated to have reserves amounting to 700,000 tons chiefly in the Orienta Province.

108. The Gold Coast of Africa is estimated to hold at least 10,000,000 tons of high-grade ore. Morocco, Tunis, and Algeria are producers of some high-grade manganese. South Africa is believed to have rich deposits which are just being investigated.

109. *Chrome ore.*—Commercial chromium is secured from the mineral chromite, which in a pure condition, contains 68 percent chromic oxide (Cr_2O_3) and 32 percent iron oxide (FeO). The content of commercial chromite, however, varies from 35 to 55 percent chromic oxide, the higher grades being used for ferrochromium and in the chemical industries.

110. *Production and imports.*—The ferro-alloy manufacturers desire ores containing at least 45 percent chromic oxide and an iron content of not more than one fourth the combined iron and chromic oxides. Out of total of 317,810 long tons of ore consumed in the United States, only 180 tons were shipped from mines in this country. This ore came from California. More than half the imports were from Rhodesia. Cuba exported 53,000 tons; French New Caledonia, Greece, and British India between 21,000 and 27,000 long tons; while the Union of South Africa shipped 17,500 tons to the United States.

111. Prior to the World War, New Caledonia was the principal source of chromium. In 1918, under the stress of wartime conditions, United States mines shipped 82,430 long tons. California and Oregon were the largest producers, while some mining was done in Washington, Montana, Wyoming, Pennsylvania, Maryland, and North Carolina. With the cessation of hostilities, ore was imported again from foreign countries. Pacific coast operations could not compete in New York, New Jersey, and Pennsylvania markets with this foreign ore.

112. *Deposits in western United States.*—The Klamath Mountains in northwestern California and southern Oregon contain chromite ore

in abundance. It is scattered in the Sierra Nevada range and in the coast range of California from Santa Barabara to the mouth of the Klamath River. The Blue Mountains in eastern Oregon also contain deposits. The chromite mined in 1918 varied in grade. The largest deposits of 45 to 55 percent chromic-oxide ore were located in Eldorado, Placer, and Calaveras Counties of California. Grant County, Oreg., shipped the largest amount of ore. The counties of Oregon that shipped chromite ore in 1918 were: Baker, Coos, Curry, Douglas, Grant, Jackson, Josephine, and Wheeler Counties.

113. Some chromite ore was shipped from Cypress Island, Wash., in 1917 and 1918. Other deposits are reported to contain from 44 to 51 percent chromic oxide near Mount Hawkins, Kittitas County. Workable deposits are also said to exist near Nighthawk in Okanogan County.

114. Chromite is found in Boulder Creek, Colo., and in southern Montana. This ore, however, contains less than 40 percent chromic oxide and about 18 percent iron oxide and is, therefore, below the grade demanded by ferro-alloy manufacturers.

115. In Wyoming, chromite occurs abundantly at Deer Creek. It has been mined from time to time since 1908 and has been used both in refractories and in ferro-alloys.

116. At one time, Maryland supplied the United States with chromite. Deposits are small, however, It is stated that high-grade ore is to be found in North Carolina but that deposits are scattered. In 1929, the Southern Chromium Co. began prospecting in Troup County, Ga.; first shipments analyzed 33.8 percent chromic oxide.

117. While Alaskan deposits are believed to be extensive, little surveying has been done in this peninsula.

118. *Other American deposits.*—In the last few years, chromite has been found in the Sudbury Basin Mines and west of Armstrong Station, Ontario. The latter ore is reported to assay over 48 percent chromic oxide; it will be exploited by the Consolidation Chromium Co. Ore is also found in Quebec and on Scottie Creek, British Columbia.

119. In Cuba, the Bethlehem Steel Co. operates a deposit at Camaguey, yielding a refractory grade of ore. It is stated that higher-grade ore is available at other mines and that much chromiferrous ore is available.

120. *African deposits.*—Southern Rhodesia produces half the world supply of chromite. The ore in the Selakive district assays between 45 and 50 percent chromic oxide, while that in the Umarukwes and Darwendale areas contains over 50 percent chromic oxide. These deposits are reported to be very large. Transportation facilities from mines to the seaport are being improved. The Union of South Africa is a sharp competitor of Rhodesia in the world chromite market. The reserves are not as high grade but as they are large and near transportation facilities, such ores are sold at a lower price.

121. *Other countries.*—Turkish chromite dominated the world's market prior to 1903. A Swedish company holds two claims from which first shipments were made in 1930 and British and French interests are seeking concessions.

122. In New Caledonia, the Tiebaghi Mine at the northern end of the island has been one of the world's richest producers. Deposits are

552—33——27

operated in British India, but lack of transportation facilities hampers production. Extensive low-grade deposits occur in Indo-China.

123. Greece produces annually a number of thousands of tons of chromite, principally from Thessaly and the Khaldike Peninsula. The ore carries from 38 to 40 percent chromic oxide and is used mainly as refractory material. Production of chromite is beginning in Russia after a 13-year interruption. In the Ural Mountains there are large reserves of low-grade ore. Only high-grade ore, from other sources or from the concentration of low-grade ores, has been exported to the United States.

TUNGSTEN ORES

124. *United States resources.*—Tungsten minerals found in the United States are ferberite, an iron tungstate; wolframite, an iron-manganese tungstate; hubnerite, containing more manganese than wolframite; and scheelite, a calcium tungstate.

125. The largest deposits of ferberite are in the Boulder district of Colorado where several firms are operating. Wolframite and hubnerite are found in largest amounts in Nevada, Arizona, New Mexico, and South Dakota. The Nevada-Massachusetts Co., operating in the Eugene Mountains of Nevada, were the largest producers of tungsten concentrates in the United States. Scheelite is located in San Bernardino and Inyo Counties of California where some production is taking place. A few tons of tungsten ore was mined at Jardine Mountain. Tungsten ore of the several types has been mined in Stevens County, Wash., it is also reported in Okanagan, Ferry, and Yakima Counties.

126. *Foreign resources.*—But while 830 short tons of tungsten concentrate (60 percent WO_3) were produced from United States mines in 1929, 4,978 tons of concentrate were imported. This imported ore came largely from China where wolframite is obtained by surface mining; although importations from South America and Australia increased.

127. The principal producing counties of China are Kiangsi and Kwangtuang. At present the industry is disorganized, due to internal disturbances with the resulting stimulation of production in other countries. The tungsten industry of South America is located in the Argentine, in Bolivia, and in Peru. While valuable wolfromite deposits have been developed the industry cannot compete with Chinese ore when the Chinese price is low. The Malay Peninsula also has important deposits near Tavoy, Nugari, Moulmeiu, and Thalan.

128. Tungsten deposits are extensive in Portugal; there are three calciners who ship arsenic as a by product of the tungsten industry. Large reserves are believed to exist in Russia although only a little prospecting has been done. Tungsten ore was produced in the provinces of Central Australia, New South Wales, Queensland, Tasmania, and Western Australia, in 1929. South Rhodesia also produced some tungsten.

129. *Molybdenum ores.*—The United States is the largest producer of molybdenum ores. Molybdenum occurs chiefly in molybdenite (MOS_2) and wulfenite ($PbMoO_4$). Molybdenite is widely scattered in western States. The largest deposit being worked commercially is at Climax, Colo.; while smaller deposits occur in Nevada, California, New Mexico, and Arizona. Wulfenite is also scattered in the

southern Rocky Mountain States, the largest developed deposit being at Mammoth, Ariz.

130. In 1929, the molybdenum content in concentrates averaging 75 to 90 percent molybdenite, totaled 2,015 tons. More than four fifths of this was produced by the Climax Molybdenum Co. operating at Climax, Colo. The Molybedenum Corporation of America produced at Sulphur Gulch, N.Mex.; the Southern Copper Mining Co. at Helvetia, Ariz.; and the Minerals and Metals Corporation, near Sahuarita, Ariz.

131. In 1929, the Molybdenum Mines Co., of Yakima, Wash., prospected properties at Deep Creek, Yakima County, and at Omak, Okanogan County. The deposits at Deep Creek are said to contain a high-grade ore while those at Omak are similar to beds at Climax, Colo., where ore averages 1 percent or less molydenum. Deposits are reported also from Chelan, Ferry, Pend Oreille, and Stevens Counties.

132. The major problem of the molybdenum industry is not in finding sources of ore but in securing an adequate market for such ore. Molybdenum exports are increasing.

133. *Vanadium ores.*—Vanadium now used in the United States is secured largely from the ore patronite, an impure vanadium sulphide, found in Minazraga, Peru. The mines are operated by the Vanadium Corporation of America. Importations totaled 9,760 tons in 1929.

134. A vanadium mica mineral, roscoelite, is worked in Colorado. The United States Vanadium Corporation, a Union Carbide and Carbon Co. subsidiary, is the leading producer. The United States Vanadium Corporation shipped some gold-silver vanadium ore to Europe via San Pedro, Calif., in 1929. Concentrates from its Colorado mines are shipped to the electrometallurgical plants of the company.

135. Carnotite, important because of its radium and uranium content, also carries some vanadium oxide; this is found in southwestern Colorado (near Rifle) and in eastern Utah. Production of these ores for their vanadium content has begun. A lead vanadate, vanadinite, is scattered in Western States. In Arizona, this occurs with wulfenite, or lead molybdate; other deposits are located in California, Nevada, and New Mexico.

136. Southwest Africa is second to Peru in the production of vanadium ore and ships to European markets. A ferrovanadium plant has been built in Rhodesia.

137. *Uranium.*—Pitchblende, carnotite, autunite, and torbernite are the principal uranium ores. All these ores contain radium, so that uranium has become a byproduct of radium production. Pitchblende has been found in Gilpin County, Colo.; in North Carolina, South Carolina, South Dakota, Texas, and Connecticut; the Colorado deposit is the only one of commercial importance. Carnotite deposits of southwestern Colorado and eastern Utah, however, form the largest known source of radium-bearing ores in the United States. These occur southwest of Green River in Utah and to the west of the LaSal Mountains; in Colorado, deposits occur in Dolores, San Miguel, and Montrose Counties.

138. In 1929, shipments of 13 short tons of uranium ores were made from Moab, Utah, and from Colorado. It was reported that claims near Thompsons, Grand County, Utah, and an old property in Gilpin County, Colo., would be operated in 1930.

139. Over 136 short tons of uranium oxide and salts were imported in 1929. In Katanga, Belgian Congo, exceptionally rich uranium oxide minerals are being mined. In Cornwall, England, in Austria, and in Saxony, the mineral is associated with nickel-cobalt veins. Portugal has granted 90 or more concessions for mining radium ores. Uranium ores are also found in several localities in Australia.

140. *Zirconium.*—Zircon contains about 67 percent zirconium oxide or zirconium and 33 percent silica. It is widespread in its occurrence but is found in commercial quantities at only a few places. Pablo Beach, Fla., produced several thousand tons yearly, but activity was discontinued during 1928. Henderson County, N.C., has an abundant supply of zircon crystals but they are scattered. Virginia, New Jersey, and Oklahoma are reported to contain zircon-bearing ores and rocks. Mr. Paul M. Tyler of the United States Bureau of Mines states that at this time no zirconium is being mined in the United States.

141. The mineral baddeleyite, containing iron, silica, and zirconium oxide is found in quantity in Brazil, although it occurs in Ceylon, Sweden, Italy, and Montana.

142. *Titanium.*—Rutile and ilmenite are the principal commercial ores of titanium. A subsidiary of the Metal & Thermit Corporation shipped both types of ore from Nelson County, Va., in 1929. The Vanadium Corporation of America acquired properties in Nelson and Amherst Counties, Va., and a third company was drilling in Nelson County. Beach deposits of California are being examined.

143. Ilmenite sand is reported from Travancore, India, and from Senegal. Imports amounted to 25,072 short tons in 1929. Rutile is imported from St. Urbain, Quebec, and from Norway.

144. Large deposits of titaniferous ores occur in New York State, North Carolina, Wyoming, and smaller quantities are found in several other States.

Production of Ferro-Alloys and Iron and Steel

FERRO-ALLOY PRODUCTION

145. *Development of industry.*—Ferrosilicon was first manufactured in this country at Spray, N.C., in 1898. At about the same time, the production of ferrochromium was begun at this plant to meet the demand for armor plate in the building of a new American Navy after the Spanish-American War. Other plants were erected at Holcomb Rock, Va., and at Kanawha Falls, W.Va. In 1907, the Union Carbide Co. purchased these three plants, together with the patents on ferrosilicon, ferrochromium, silicon carbon, metallic silicon, and titanium carbide, and formed the Electro-Metallurgical Co. of America, which is our largest manufacturer of ferro-alloys today.

146. Demand for alloy steels during the war brought about the establishment of ferro-alloy plants in the following States:

Ferrosilicon	California, Iowa, Massachusetts, Maryland, New York, Pennsylvania, and Tennessee.
Ferromanganese	Washington, Oregon, California, Montana, and Alabama.
Ferrochromium	California, Iowa, Pennsylvania, and New York.
Ferromolybdenum	California and Pennsylvania.
Ferrotungsten	Colorado, Pennsylvania, and Maryland.
Ferrotitanium	New York.
Ferrouranium	Pennsylvania.
Ferrovanadium	Pennsylvania.

147. While many of these companies could not meet competitive conditions after the World War, the location of plants operating in periods of stress has its importance. The ferromanganese production at Washington State was done in electric furnaces, smelting manganese ores from Philipsburg, Mont., with coke, limestone, and metallic iron.

148. *Manufacturers of ferro-alloys.*—In 1929, the following producers, other than blast furnace producers, were manufacturing ferro-alloys in the United States:

Location	Company	Products
Alabama: Anniston	Federal Phosphorus Co. of America	Ferrophosphorus.
Iowa: Keokuk	Keokuk Electro-Metals Co	Ferrosilicon.
New Jersey: Jersey City	Metal and Thermit Corporation	Ferrotungsten. Ferrotitanium. Ferrochromium. Ferrovanadium.
New York: Niagara Falls	Electro-Metallurgical Co. (unit of Union Carbide & Carbon Corporation)	Ferrosilicon. Ferrochromium. Calciumsilicon. Ferrozirconium. Siliconzirconium. Tungsten, vanadium, and other alloys.
	Norton Co	Ferrosilicon.
	Pittsburgh Metallurgical Co	Ferrosilicon. Ferrochromium. Ferromanganese. Ferrosilicon-aluminum.
	Titanium Alloy Manufacturing Co	Ferrotitanium.
	Vanadium Corporation of America	Ferrosilicon. Ferrochromium. Ferrosilicon-manganese. Ferroaluminum-silicon.
Ohio:		
Columbiana	United States Vanadium Corporation (owned by Union Carbide & Carbon Corporation).	Ferrovanadium.
Philo	Ohio Ferro-Alloys Co	Ferrosilicon. Ferromanganese. Ferrophosphorus.
Pennsylvania:		
Kirway	Vanadium Corporation of America	Ferrovanadium. Ferrotungsten. Ferromolybdenum. Ferrochromium. Ferrotitanium and zirconium.
Langeloth	Climax Molybdenum Co	Calcium molybdate.
Washington	Molybdenum Corporation of America	Ferromolybdenum. Ferrotungsten.
York	York Metal and Alloy Co	Ferrotungsten. Ferromolybdenum. Ferrovanadium.
Tennessee: Chattanooga	Southern Ferro-Alloys Co	Ferrosilicon.
Virginia: Holcomb Rock	Electro-Metallurgical Co. (unit of Union Carbide & Carbon Corporation).	Ferrochromium.
West Virginia: Glen Ferris	Electro-Metallurgical Co. (unit of Union Carbide & Carbon Corporation).	Ferrosilicon. Ferrochromium.

The Baltimore Electro-Alloy Co., Baltimore, Md., was idle in 1929.

149. It is obvious that ferrosilicon production takes place principally at Niagara Falls, N.Y., and in Tennessee and West Virginia, while the manufacture of ferrochromium and the other ferro-alloys occurs in nine States.

150. *New plants.*—The Union Carbide & Carbon Corporation is building two new power projects in West Virginia to serve a new plant to be erected for the Electro-Metallurgical unit at Boncar, W.Va. The hydroelectric power plant is being built on the New River between Hawk's Nest and Gauley Junction. It will have 4

units of 35,000 horsepower each and transmission lines will run 6 miles to Boncar. It is estimated that 80,000 horsepower will be delivered to the Boncar plant for manufacturing ferro-alloys. At Boncar there will be a steam electric plant made up of two steam turbo-generators, each having a capacity of 22,000 kilovolts.

151. This company manufactures ferromanganese in Norway under a long term contract with the Norwegian Government. It pays $8 per horsepower year for power, gets coals from Newcastle, iron from the White Sea coast, and manganese from Central Africa where it has developed a manganese property.

152. While the Electro-Metallurgical Co. is by far the largest producer of ferro-alloys, other companies have a firm hold on certain metals entering into alloy production. The Vanadium Corporation of America not only owns vanadium properties in Peru, but owns 50 percent of the capital stock in the Rhodesian Vanadium Corporation which has acquired chrome ore reserves in Rhodesia. It also owns titanium reserves in Virginia. With the acquirement of the United States Ferro-Alloys Corporation of Niagara Falls, deposits of silica rock were securêd at Lewiston, N.Y., and deposits of chrome ore at Black Lake, Quebec. The Climax Molybdenum Co. operates the largest molybdenum mines in the United States at this time.

PRODUCTION BY KIND AND AMOUNT

153. *Increases in production.*—The manufacture of ferro-alloys is steadily growing in the United States. Since 1913, production has increased 146 percent, since 1919, 81 percent. Between 1928 and 1929 there was a growth in production of approximately 14 percent. All kinds of ferro-alloys share in this increase although in varying degrees. Ferrosilicon manufacture has increased 223 percent since 1913, ferromanganese and spiegeleisen 107 percent, and other ferro-alloys 213 percent. Since 1919 the increase in each group has been more nearly equal or from 88 percent for ferrosilicon to 78 percent for ferromanganese and spiegeleisen. In the last year the "other ferro-alloys," including chiefly chromium, vanadium, zirconium, titanium, tungsten, and molybdenum gained 24 percent as against 12 percent for ferrosilicon.

TABLE V.—*Production of ferro-alloys in the United States* [1]

Year	Total (gross tons)	Ferrosilicon		Ferromanganese and spiegeleisen		Other ferro-alloys	
		Gross tons	Percent of total	Gross tons	Percent of total	Gross tons	Percent of total
1929	856,768	341,222	39.8	476,655	55.6	38,891	4.6
1928	754,066	303,595	40.3	419,213	55.6	31,258	4.1
1927	707,413	278,277	39.3	394,346	55.7	34,790	5.0
1926	674,312	245,605	36.4	395,106	58.6	33,601	5.0
1925	584,255	226,472	38.7	325,784	55.8	31,999	5.5
1919	472,556	181,751	38.4	269,603	57.1	21,202	4.5
1915	391,424	131,617	33.6	247,406	63.2	12,401	3.2
1913	347,983	105,715	30.4	229,833	66.0	12,435	3.6

[1] Compiled from American Iron and Steel Institute, Annual Statistical Report for 1929.

154. *Ferromanganese.*—In view of the fact that ferromanganese is added to almost all steel for sulphur removal as well as to structural

or other very hard steels, it is not surprising to find that it forms more than half of the total tonnage of ferro-alloys produced. As that manufactured in the United States is not an electric-furnace product, it is only of indirect interest here. About half of the ferromanganese produced in blast furnaces is for the maker's own use. But the ferromanganese imported from Norway and from Welland, Canada, is an electric-furnace product manufactured by American capital.

155. *Ferrosilicon.*—Ferrosilicon forms about 40 percent of all ferro-alloy manufacture. Approximately one half of this is made in the electric furance, a small proportion is a byproduct in the manufacture of fused alumina abrasives, and the remainder, or low silicon-content alloy, is manufactured in the blast furance. This, too, enters into many steels as a scavenger. It is also combined, in the electric furnance with zirconium and with calcium to produce a more effective scavenger. And it is used by itself or combined with ferromanganese, or with aluminum, or with chromium, to produce special steel alloys. In addition to our own production of 341,222 long tons of ferrosilicon, we imported 8,704 tons from Canada and 1,849 tons from Norway.

156. *Other alloys.*—Unfortunately, separate production figures are not available for other ferro-alloys. Altogether, such manufacture formed less than 5 percent of the total tonnage of ferro-alloys. Ferrochromium has the largest application of these alloys, entering into stainless steel and iron, valve steels, high-speed steels, metal-working steels, structural steels, nitric acid plant apparatus, seamless tubing, and a number of other products.

PIG IRON AND STEEL INGOT AND CASTINGS PRODUCTION[18]

157. *Pig iron produced in each State.*—Out of a total production of 41,757,215 long tons of pig iron in 1929, all but 9,013,852 tons was for the "maker's own use." Pennsylvania manufactured a third of all pig iron, and Ohio 23 percent; but Ohio held foremost rank as a seller of pig iron to foundries and other independent manufacturers. Utah and Colorado, together, produced 1.4 percent of the Nation's pig iron.

TABLE VI.—*Production of pig iron by States*[1]

States	1913[2]	1919[2]	1925	1926	1927	1928	1929	
	Long tons	*Long tons*	*Long tons*	*Long tons*	*Long tons*	*Long tons*	*Long tons*	*Per cent*
Total	30, 966, 152	31, 015, 364	36, 116, 311	38, 698, 417	35, 858, 232	37, 401, 648	41, 757, 215	100. 0
Pennsylvania	12, 954, 936	12, 276, 585	12, 239, 776	13, 231, 890	11, 466, 457	12, 052, 405	14, 016, 015	33. 6
Ohio	7, 129, 525	7, 102, 627	8, 767, 772	9, 261, 405	8, 407, 243	9, 017, 025	9, 702, 005	23. 2
Indiana and Michigan	1, 775, 883	2, 715, 659	4, 119, 811	4, 377, 068	4, 199, 517	4, 583, 065	5, 085, 615	12. 2
Illinois	2, 927, 832	2, 558, 213	3, 604, 255	3, 656, 688	3, 588, 463	3, 942, 412	4, 357, 905	10. 4
New York[3]	2, 187, 620	2, 070, 288	2, 070, 854	2, 599, 517	2, 615, 556	2, 366, 890	2, 804, 698	6. 7
Alabama	2, 057, 911	2, 130, 092	2, 815, 688	2, 933, 796	2, 758, 387	2, 517, 485	2, 704, 733	6. 5
Maryland and Virginia	631, 774	563, 411	799, 243	881, 561	941, 501	1, 028, 596	1, 124, 762	2. 7
West Virginia and Kentucky[4]	315, 731	413, 091	650, 483	513, 994	697, 184	862, 706	862, 001	2. 1
Colorado and Utah[5]	----------	----------	484, 420	608, 834	613, 627	600, 366	602, 106	1. 4
Wisconsin and Minnesota	367, 326	605, 619	468, 479	537, 499	455, 727	339, 267	379, 162	. 9
Tennessee	280, 541	190, 514	95, 530	96, 165	114, 570	91, 431	118, 213	. 3
All other States[6]	337, 073	389, 265	----------	----------	----------	----------	----------	-----

[1] Compiled from American Iron and Steel Institute. Annual Reports.
[2] Includes ferro-alloys.
[3] In 1913 and 1919, New Jersey production was included; from 1925 to 1929, Massachusetts production was included.
[4] In 1913 data was included from Mississippi; in 1919, from Georgia and Texas.
[5] In 1913 and in 1919, production for Colorado was included in All other State production.
[6] Includes California, Colorado, Connecticut, Iowa, Maine, Massachusetts, Missouri, Montana, Oregon, and Washington.

[18] All statistics on iron and steel production are compiled by the American Iron and Steel Institute.

158. *Increase in electric furnace production of steel ingots and castings.*—In 1929, 142 plants in the United States were producing steel ingots and 295 plants in the United States and United States possessions were manufacturing steel castings. The total production of all plants was 56,433,473 long tons. Of this amount, 951,431 tons were made in electric furnaces, the highest record as yet attained.

159. *Castings.*—Out of a total tonnage of 1,580,000 castings, 26 percent, or 419,039 tons, was made by the electric process. The use of the electric furnace is exceeded only by the open hearth process for steel castings production. In 1915, but 3 percent of all steel castings were manufactured in the electric furnace, in 1918, 8 percent, and in 1928, 28.6 percent. While proportional increases do not occur each year, the tendency is to increase the use of the electric furnace and to lessen the employment of the crucible and bessemer furnaces in steel castings production. The increase from 1928 to 1929 was 20 percent.

160. *Ingots.*—Only 1 percent of steel ingots, or 532,000 long tons, was produced in electric furnaces in 1929. But in 1915, only 0.1 percent was so manufactured, and in 1918 only 0.9 percent. The increase in the application of the electric furnace in ingot production from 1928 to 1929 was 17 percent.

TABLE VII.—*Production of steel ingots and castings by processes* [1]

STEEL INGOTS

Year	Total gross tons	Electric		Crucible	Bessemer	Open hearth	Miscellaneous
		Gross tons	Percent of total				
1929	54, 850, 433	532, 392	1. 0	5, 762	7, 091, 680	47, 220, 599	----------
1928	50, 325, 393	453, 692	. 9	6, 516	6, 591, 745	43, 273, 440	----------
1927	43, 776, 717	371, 278	. 8	7, 696	6, 153, 703	37, 244, 040	----------
1926	46, 936, 205	325, 278	. 7	13, 452	6, 891, 502	39, 705, 973	----------
1925	44, 140, 738	335, 978	. 8	17, 729	6, 670, 128	37, 116, 903	----------
1924	36, 811, 157	225, 977	. 6	21, 096	5, 846, 153	30, 717, 931	----------
1923	43, 485, 665	279, 914	. 6	42, 127	8, 416, 576	34, 747, 048	----------
1922	34, 568, 418	191, 057	. 6	27, 561	5, 871, 565	28, 478, 235	----------
1921	19, 224, 084	84, 404	. 4	6, 877	3, 977, 129	15, 155, 357	317
1920	40, 881, 392	346, 956	. 8	70, 536	8, 778, 107	31, 685, 495	298
1919	33, 694, 795	272, 942	. 8	62, 563	7, 172, 743	26, 186, 174	373
1918	43, 051, 022	403, 068	. 9	113, 782	9, 215, 392	33, 318, 561	219
1917	43, 619, 200	239, 632	. 5	122, 882	10, 320, 688	32, 935, 737	261
1916	41, 401, 917	126, 048	. 3	120, 341	10, 916, 248	30, 238, 978	302
1915	31, 284, 212	46, 348	. 1	99, 026	8, 194, 737	22, 943, 770	331

CASTINGS

Year	Total gross tons	Electric gross tons	Electric percent of total	Crucible	Bessemer	Open hearth	Miscellaneous
1929	1, 583, 040	419, 039	26. 5	883	30, 829	1, 132, 289	----------
1928	1, 218, 787	348, 568	28. 6	1, 253	28, 450	840, 516	----------
1927	1, 158, 468	294, 809	25. 4	1, 340	38, 024	824, 295	----------
1926	1, 357, 558	326, 445	24. 0	2, 041	43, 066	986, 006	----------
1925	1, 252, 786	279, 534	22. 3	1, 833	53, 834	917, 585	----------
1924	1, 120, 782	206, 549	18. 4	1, 377	53, 437	859, 419	----------
1923	1, 458, 031	235, 958	16. 2	1, 952	67, 512	1, 152, 609	----------
1922	1, 034, 508	154, 982	15. 0	1, 045	47, 733	830, 748	----------
1921	559, 713	85, 095	15. 2	736	38, 809	434, 445	628
1920	1, 251, 542	155, 196	12. 4	1, 729	104, 980	986, 400	3, 237
1919	976, 437	111, 510	11. 4	1, 009	98, 819	762, 520	2, 579
1918	1, 411, 410	108, 296	7. 7	1, 330	160, 844	1, 140, 830	110
1917	1, 441, 407	64, 911	4. 5	3, 834	159, 272	1, 213, 156	234
1916	1, 371, 763	42, 870	3. 1	9, 351	142, 791	1, 176, 449	302
1915	866, 824	23, 064	2. 7	14, 756	92, 476	735, 332	1, 196

[1] Compiled from American Iron and Steel Institute, Annual Statistical Report for 1929.

161. *Alloy-steel ingots and castings production.*—The increase in ferroalloy manufacture is reflected in the increase in alloy-steel production. In 1929, 3,957,207 long tons of alloy steel was manufactured, 3,764,287 tons being in ingot form and 192,920 tons in castings. This represented 7 percent of all steel manufactured in 1929, 6.9 percent of all ingots, 12.2 percent of all steel castings. This manufacture took place in 30 States as well as in the District of Columbia and Alaska.

162. The electric furnace plays a much more important part in the production of these alloy steels than in total steel production. For 11 percent or 415,963 long tons of all steel ingots produced was melted in the electric furnace and almost half of alloy-steel castings (94,067 tons) was made by the use of electricity as compared with 1 percent and 26 percent, respectively, of all ingots and all castings manufactured.

163. *State production.*—Pennsylvania produced over 20,000,000 tons of the 56,000,000 tons of steel ingots and castings made in 1929; Ohio manufactured 13,000,000 long tons, or, almost 60 percent of the United States steel production occurs in these two States. Indiana and Illinois rank next with productions of 6,663,000 and 4,784,000 tons, respectively. Production for Western States is not given separately. Washington is grouped with Colorado, Oklahoma, and Kansas, these four States manufacturing 887,692 long tons of steel. Oregon and Utah had a production of 18,288 long tons and California, Canal Zone, and Alaska of 527,301 tons.

TOTAL PLANT CAPACITIES AND ELECTRIC FURNACE CAPACITIES

164. *Steel ingot capacity.*—The total ingot capacity of the United States as determined by a special survey committee of the American Iron and Steel Institute, was in excess of 63,000,000 long tons; 773,890 tons was electric-furnace ingot capacity. Pennsylvania and Ohio had 59 percent of the total ingot capacity, and 59 percent of the electric-furnace capacity. California has eight steel ingot manufacturing plants with a capacity of 642,700 tons of which 2 percent is electric-furnace capacity. Colorado has but one plant of 800,000 tons capacity, none of which is electric. Utah has one ingot manufacturer. Washington State steel mills have a capacity of 155,000 long tons of ingots, of which almost 10 percent is electric-furnace capacity.

165. *Steel-castings capacity.*—The 295 operating castings plants have an annual capacity of 2,098,000 long tons. One fourth of this is electric-furnace castings capacity. While Pennsylvania has 30 percent of the total capacity it has but 15 percent of the electric-furnace castings capacity. Ohio and Illinois rank almost on an equality in total castings capacity while Illinois has 14 percent of the electric-furnace capacity.

166. Oregon has four all-electric steel castings plants with a combined possible production of 9,450 long tons. California can produce 41,700 tons of electric castings in 19 of her 21 castings mills. Washington and Utah have an electric castings capacity of 15,500 long tons.

Data for all other States is given on the following table.

TABLE VIII.—*Annual capacity of steel ingots and steel castings in 1929 by States* [1]

State	Steel-ingot capacity: Total capacity: Number of plants	Steel-ingot capacity: Total capacity: Annual capacity	Steel-ingot capacity: Total capacity: Percent of country's capacity	Steel-ingot capacity: Electric-furnace capacity: Number of plants	Steel-ingot capacity: Electric-furnace capacity: Annual capacity	Steel-ingot capacity: Electric-furnace capacity: Percent of country's capacity	Steel-castings capacity: Total capacity: Number of plants	Steel-castings capacity: Total capacity: Annual capacity	Steel-castings capacity: Total capacity: Percent of country's capacity	Steel-castings capacity: Electric-furnace capacity: Number of plants	Steel-castings capacity: Electric-furnace capacity: Annual capacity	Steel-castings capacity: Electric-furnace capacity: Percent of country's capacity
		Long tons			*Long tons*			*Long tons*			*Long tons*	
Total	142	63, 067, 546	100. 0	46	773, 890	100. 0	297	2, 097, 995	100. 0	186	528, 415	100. 0
Alabama	4	2, 032, 000	3. 2	0	0	------	5	22, 700	1. 1	3	4, 200	. 8
California	8	642, 700	1. 0	3	14, 500	1. 9	21	62, 200	2. 9	19	41, 700	7. 9
Colorado	1	800, 000	1. 3	0	0	------	3	10, 700	. 5	2	5, 700	1. 1
Connecticut	1	140, 000	. 2	0	0	------	5	6, 850	. 3	4	4, 100	. 8
Delaware	1	340, 000	. 5	0	0	------	} [2] 4	[2] 22, 500	1. 1	[2] 2	[2] 6, 800	1. 3
District of Columbia	1	1, 800	([3])	1	500	([3])						
Georgia	1	92, 000	. 1	0	0	------	[4] 4	[4] 6, 950	. 3	[4] 3	[4] 4, 950	. 9
Illinois	11	5, 455, 000	8. 7	4	87, 600	11. 3	19	322, 900	15. 4	11	74, 600	14. 1
Indiana	5	7, 320, 600	11. 6	1	8, 000	1. 0	10	86, 860	4. 1	4	11, 910	2. 3
Kentucky	2	850, 000	1. 3	0	0	------	----	--------	------	----	--------	------
Maryland	2	1, 759, 200	2. 8	1	15, 000	1. 9	([2])	([2])	([2])	([2])	([2])	([2])
Massachusetts	1	190, 000	. 3	0	0	------	[5] 12	[5] 27, 255	1. 3	[5] 5	[5] 13, 940	2. 6
Michigan	2	520, 000	. 8	2	14, 000	1. 9	16	55, 600	2. 7	14	32, 500	6. 2
Minnesota	1	540, 000	. 9	0	0	------	8	17, 950	. 9	4	10, 250	1. 9
Missouri	2	305, 000	. 5	0	0	------	[6] 11	[6] 148, 050	7. 1	[6] 6	[6] 17, 750	3. 4
New Jersey	2	230, 000	. 4	1	25, 000	3. 2	5	16, 910	. 8	2	11, 000	2. 1
New York	11	2, 827, 650	4. 5	8	126, 450	16. 3	14	136, 060	6. 5	7	21, 200	4. 0
Ohio	24	14, 903, 400	23. 6	3	225, 000	29. 1	32	325, 850	15. 5	20	65, 950	12. 5
Oklahoma	1	45, 000	([3])	0	0	------	[7] 5	[7] 13, 200	. 6	[7] 4	[7] 12, 200	2. 3
Oregon	----	--------	------	----	--------	------	4	9, 450	. 5	4	9, 450	1. 8
Pennsylvania	51	22, 304, 996	35. 4	18	230, 640	29. 8	68	638, 280	30. 4	31	82, 460	15. 6
Rhode Island	1	38, 000	([3])	----	--------	------	----	--------	------	----	--------	------
Texas	1	7, 500	([3])	1	7, 500	1. 0	[8] 11	[8] 14, 240	. 7	[8] 8	[8] 11, 805	2. 2
Utah	1	23. 000	([3])	----	--------	------	[9] 15	[9] 17, 850	. 9	[9] 13	[9] 15, 500	2. 9
Virginia	2	4, 700	([3])	2	4, 700	. 6	4	4, 400	. 2	3	3, 900	. 7
Washington	2	155, 000	. 3	1	15, 000	1. 9	([9])	([9])	([9])	([9])	([9])	([9])
West Virginia	3	1, 540, 000	2. 4	0	0	------	3	26, 800	1. 3	2	2, 800	. 5
Wisconsin	----	--------	------	----	--------	------	16	102, 550	4. 9	14	62, 750	11. 9
Canal Zone	----	--------	------	----	--------	------	2	1, 890	([3])	1	1, 000	. 2

[1] Compiled from Report of Committee on Special Survey of Capacity, American Iron and Steel Institute, Annual Statistical Report for 1929.
[2] Maryland included in figures for Delaware and District of Columbia.
[3] Less than 0.1 percent.
[4] Includes Tennessee and Florida.
[5] Includes New Hampshire.
[6] Includes Iowa.
[7] Includes Arkansas, Nebraska, Kansas.
[8] Includes Louisiana.
[9] Figures for Utah include Washington.

PRINCIPAL STEEL-INGOT PRODUCERS

167. More than 80 percent of the steel-ingot capacity in the United States is controlled by 11 steel companies. The United States Steel Corporation is by far the largest manufacturer, having an ingot capacity of over 24,000,000 long tons. In 1929 this corporation produced 41.6 percent of the iron ore of the country, 29 percent of the coke, 22 percent of ferromanganese, spiegeleisen, and other ferroalloys, and 39 percent of the pig iron. Its production of steel ingots and castings was 38.75 percent of the total United States production. It manufactured 50 percent of the steel rails and 35 percent of all

rolled products. Thirty-nine percent of tinplate and terneplate was produced in its mills.[18]

168. United States Steel Corporation plants include the following:

American Bridge Co., with plants at Ambridge, Pen-coyd, Pittsburgh, Pa.; Chicago; Canton and Toledo, Ohio; Gary, Ind.; Minneapolis, Minn.; Elmira, N.Y.; Trenton, N.J.

American Sheet & Tin Plate Co., with operating plants in 10 towns in Pennsylvania, in 4 Ohio towns, in Gary and Elwood, Ind., and in Chester, W.Va.

American Steel & Wire Co., with plants in 5 Pennsylvania towns; in Cleveland, Ohio; in Anderson, Ind.; in DeKalb, Waukegan, and Joliet, Ill.; in Worcester, Mass.; New Haven, Conn.; in Trenton, N.J.; in Fairfield, Ala.; and in San Francisco, Calif.

Carnegie Steel Co., with plants in 11 Pennsylvania cities and towns and in 3 Ohio cities and towns.

Illinois Steel Co., with plants at Gary, Ind.; Joliet and South Chicago, Ill.; and at Milwaukee, Wis.

Lorain Steel Co., of Johnstown, Pa.

Minnesota Steel Co., of Duluth, Minn.

National Tube Co., with plants at McKeesport, Elwood City, and Pittsburgh, Pa.; Lorain, Ohio; and Gary, Ind.

Tennessee Coal, Iron, & Railroad Co., of Alabama.

United States Steel Products Co., manufacturing foundry and basic pig iron at Ironton, Utah; steel ingots, castings, and hot-rolled products at Pittsburgh, Calif.; electric steel, carbon, and alloy steel castings at Portland, Oreg.; and ingots, castings, and hot-rolled products at Torrance, Calif.

169. The second largest steel manufacturer is the Bethlehem Steel Co. with an ingot capacity of 8,000,000 long tons. Its plants are located chiefly in Pennsylvania, although there are single plants at Lackawanna, N.Y., and at Wilmington, Del.; and shipbuilding and ship-repairing plants at Baltimore, Md.; Quincy and Boston, Mass.; and Alameda, San Francisco, and Los Angeles, Calif. Its subsidiary, the Pacific Coast Steel Corporation, produces steel ingots, blooms, billets, and finished rolled and forged products at Vernon and South San Francisco, Calif., and at Seattle, Wash.

170. The Republic Iron & Steel Co. has an ingot capacity of 4,900,000 long tons. Its plants are in Alabama, Illinois, Indiana, and Ohio. The capacity of the Youngstown Steel & Tube Co. is 3,240,000 long tons. Mills are located in Illinois, Indiana, and Ohio. The Inland Steel Co. has plants in Indiana, Illinois, and Wisconsin, with a total ingot capacity of 1,800,000 long tons. The American Rolling Mill Co.'s works are located at Ashland, Ky.; at Butler, Pa.; and in Ohio.

171. The Colorado Fuel & Iron Co. produces pig iron, ferromanganese for own use, wire products, gray iron pipe and castings, and hot-rolled products at works in Pueblo, Colo. Their total capacity is 1,138,000 long tons.

172. Other large steel companies are the Corrigen, McKinney Steel Co.; the Wheeling Steel Corporation; Jones & Laughlin Steel Corporations, and the National Steel Corporation. These have capacities ranging from 1,000,000 to 3,000,000 tons.

173. *Western iron and steel works and rolling mills.*—The taking over of Pacific coast iron and steel works by the United States Steel Corporation and the Bethlehem Steel Co. was an interesting development of 1929. Western plants are listed below. The capacities given are approximate only and sometimes exceed those reported for States by the American Iron and Steel Institute. They indicate only in a general manner the size of existing plants.

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[18] American Iron and Steel Institute. Annual Statistical Report for 1929.

Location	Company	Approximate plant capacity
California:		
Emeryville	Botchford Steel Co.	60,000 tons ingots.
Huntington Park	Southern California Iron & Steel Co. (subsidiary of Bethlehem Steel Corporation).	85,000 tons ingots.
Pittsburg	Columbia Steel Corporation	192,000 tons ingots and castings.
Torrance	Columbia Steel Corporation (United States Steel Corporation subsidiary).	171,000 tons ingots and castings.
Sacramento	Southern Pacific Co.	9,000 tons ingots.
San Francisco	Pacific Coast Steel Corporation (Bethlehem Steel Co. subsidiary).	155,000 tons ingots.
Do	Simmons Co.	10,000 tons merchant bars and finished goods only.
Do	American Steel & Wire Co. (United States Steel Corporation subsidiary).	Wire products only.
Colorado: Pueblo	Colorado Fuel & Iron Co.	800,000 tons ingots.
Utah:		
Ironton	United States Steel Products Co. (United States Steel Corporation subsidiary).	175,000 tons foundry and basic pig iron.
Midvale	Western Steel & Foundry Co.	46,000 tons ingots.
Washington:		
Lowell	United Steel Co.	3,600 tons finished products only.
Seattle	Northwest Steel Rolling Mills	15,000 tons ingots.
Do	Pacific Coast Steel Corporation (Bethlehem Steel Corporation subsidiary).	140,000 tons ingots.

174. In addition to these ingot steel works, the following foundries are located in the Pacific Northwest:

Location	Company and product	Approximate plant capacity
		Short tons
Oregon:		
Portland	Electric Steel Foundry Co., manganese-alloy and carbon-steel castings.	3,120
Do	Tennent Steel Corporation, carbon and alloy steel	1,200
Do	United States Steel Products Co. (United States Steel Corporation subsidiary), electric castings.	1,800
Washington:		
Bremerton	United States Navy Yard, castings for marine use	240
Everett	Tennent Steel Corporation, carbon and alloy steel	1,200
Hoquiam	Lamb-Grays Harbor Co., steel jobbing	420
Seattle	Olympic Steel Works, jobbing foundry	1,200
Do	Pacific Car & Foundry Co., railway equipment	7,416
Do	Washington Iron Works, carbon- and alloy-steel castings	4,200
Do	Tennent Steel Corporation, carbon and alloy steel	1,920
Sedro-Woolley	Skagit Steel & Iron Works, steel castings	600
Spokane	Union Iron Works, steel castings for own use	180
Tacoma	Atlas Foundry & Machine Co., general jobbing and sawmill castings.	240
Do	Lidgewood Pacific Co., machine castings	1,500
Do	Tennent Steel Corporation, carbon and alloy steel	1,800

ROLLED IRON AND STEEL

175. Steel ingots are usually subjected to further treatment before they are ready for the consuming market. In 1929, over 40,590,000 long tons of steel and 475,000 tons of iron were rolled into smaller sections and different marketable shapes.

176. *Plates and sheets.*—Three tenths of this tonnage was finished as plates and sheets. In this are included black plates for tinning. Although the largest number of plate and sheet works are in Ohio

and Pennsylvania, Washington has 1 mill making universal plates, and California has 3 mills: 1 making black plates on tin mills; 2, black sheets on sheet or job mills; and 1, universal plates. Two thirds of all plates are purchased by railroads, for building construction, or by oil, gas, and mining operators. While a fourth of our sheet production enters the automobile industries, sheets are used extensively in a number of industries.

177. *Merchant bars.*—Merchant-bar tonnage, or bars made in standard dimensions for supplying the open market, reached 6,471,000 long tons in 1929. These were rolled in 128 bar mills in 22 States.

178. *Structural shapes.*—Structural shapes, applied principally to building construction and to railroads, were manufactured in 56 mills in 17 States. Pennsylvania rolled 59.5 percent of the total tonnage of 4,780,000 long tons. California had four works; Washington, Utah, and Colorado each had one structural iron and steel mill.

TABLE IX.—*Finished products of iron and steel rolling mills in 1929* [1]

Products	Total		Iron (long tons)	Steel (long tons)
	Long tons	Percent		
Total	41,069,416	100.0	475,049	40,594,367
Plates and sheets	12,436,312	30.3	3,127	12,433,185
Merchant bars	6,471,146	15.8	154,690	6,316,456
Structural shapes	4,778,020	11.6	71	4,777,949
Skelp, flue, and pipe iron or steel	3,517,238	8.6	151,556	3,365,682
Wire rods	3,134,409	7.6	375	3,134,034
Rails	2,722,138	6.6		2,722,138
Hot-rolled strips and flats for cold-rolling	2,502,793	6.1		2,502,793
Blanks or pierced billets for seamless tube	1,382,171	3.4		1,382,171
Bars for reinforced concrete work	952,350	2.3	557	951,793
Long angle splice bars, tieplate bars, etc	924,803	2.3	49,375	875,428
Rolled forging blooms, billets, etc	527,336	1.3	2,701	524,635
Bands and cotton ties	384,706	0.9	1,982	382,724
Hoops	204,246	0.5		204,246
Rolled sheet piling (not including fabrication)	102,494	0.3		102,494
Blooms, billets, sheet bars, etc., for export	40,015	(2)		40,015
Railroad ties	13,718	(2)		13,718
Nail and spike plate	9,827	(2)	12	9,815
Other finished hot-rolled products	965,694	2.4	110,603	855,091

[1] Compiled from American Iron and Steel Institute, "Annual Statistical Report for 1929."
[2] Less than 0.1 percent.

179. *Pipe and tube material.*—Skelp for welding into tubes and pipes was rolled in 35 plants in seven States. Production totaled 3,500,000 tons. Manufacture of blanks or pierced billets for seamless tubes reached 1,382,171 tons in 1929.

180. *Other rolled products.*—Rails found 6.6 percent of total rolling-mill production. Only 723 tons were of electric furnace steel. Titanium entered into 486 tons and other alloys into 1,479 tons of steel rails. Wire rods were rolled by 48 works in 15 States. Production was 7.6 percent of the total rolled iron and steel. The production of other rolled forms is given in table IX.

PRODUCTION BY STATES

181. States rank in the same order for the production of finished rolled products as they do in the production of ingots. Pennsylvania, Ohio, Indiana, and Illinois manufacture 78 percent of all rolled

products. No other State produces as much as 5 percent of the total. Together, Washington, Utah, and Colorado steel mills turned out 701,000 tons of rolled products; California and the Canal Zone, 378,788 long tons.

TABLE X.—*Production of rolled forms of iron and steel by States in 1929* [1]

States	Total		Iron (long tons)	Steel (long tons)
	Long tons	Percent		
Total	41,069,416	100.0	475,049	40,594,367
Pennsylvania	14,860,360	36.2	193,406	14,666,954
Ohio	8,811,822	21.5	63,388	8,748,434
Indiana	5,144,991	12.5	59,685	5,085,306
Illinois	3,232,611	7.9	54,932	3,177,679
New York	1,869,302	4.6	20,036	1,849,266
West Virginia	1,298,332	3.2	1,727	1,296,605
Delaware, Maryland, and Virginia	1,248,607	3.0	18,059	1,230,548
Alabama	1,216,334	2.9		1,216,334
Michigan, Wisconsin, and Minnesota	848,827	2.1	4,084	844,743
Colorado, Utah, and Washington	701,218	1.7		701,218
Kentucky, Tennessee, Georgia, and Texas	692,243	1.7	10,493	681,750
California and Canal Zone	378,788	0.9	514	378,274
Missouri and Oklahoma	301,552	0.7	17,480	284,072
Maine, Massachusetts, Rhode Island, and Connecticut	266,592	0.6	2,565	264,027
New Jersey	197,837	0.5	28,680	169,157

[1] Compiled from American Iron and Steel Institute, "Annual Statistical Report for 1929."

STEEL MARKETS

DOMESTIC MARKETS

182. *Major consuming industries.*—The building and construction industry and the automotive industry now vie with each other for first place as steel consumers. In 1928 and 1929, the largest amount of iron and steel was purchased for automobile manufacture; in 1927 and 1930, the largest tonnage of rolled products went into building and construction. Railroad companies afford the third largest outlet for rolled products at present, although from 1922 to 1926 they ranked first as steel consumers. These three industries absorb approximately 50 percent of all rolled steel.

183. The construction industry is especially interested in structural shapes, while it takes from 10 to 20 percent of bars, plates, sheets, pipe, wire, and strip steel.[19]

184. The automobile industry buys heavily of strip steel and consumes from 25 percent to over 30 percent of all steel sheets and bars. The railroads consume from 10 to 20 percent of plates, bars, and structural shapes. Under "railroads" is included trackwork, buildings, bridges, cars, and locomotives.

185. *Minor consuming industries.*—Oil, gas, and water companies are the heaviest consumers of pipe, and rank with the construction industry in the use of plates. Almost three fourths of all tin plate is made into metal containers. Agriculture requires approximately 18 percent of all steel wire produced.

186. According to the calculations of "The Iron Age," [20] industries consumed the following proportions of rolled steel in 1930:

[19] These figures are quoted from "The Iron Age," which collects annually sales figures from 57 steel producers, representing 96 percent of the industry.
[20] "The Iron Age," Jan. 1, 1931.

	Percent
Building and construction	19
Automobile and automobile parts manufacture	15.5
Railroads	15
Oil, gas, water, mining, and lumber industries	11.5
Metal containers	6
Agricultural machinery and implements	4
Exports	5.5
Machinery, other than agricultural	3
Electrical manufacture	2
Stoves and metal furniture	2
Shipbuilding	1.3
Miscellaneous	15.2

187. *Consumption of alloy steels.*—The growth in alloy-steel production is due to the use of this steel in automobiles, for at least seven tenths of all alloy steel enters into their manufacture. Tools, both hand and machine, require less than 3 percent of all alloy steel produced, and agricultural implements but 2.5 percent.

188. *Pacific coast market.*—While major consuming markets are in the East and Middle West, the interest of large steel companies in Pacific coast plants is indicative of the increasing demand for steel due to the growth of population and the greater diversification of western industries. Only about a sixth of Pacific coast steel market needs are met by Pacific coast plants at the present time.

189. The Pacific coast, including British Columbia, is estimated to consume 425,000 tons [21] of tin plate, or about one fifth of the total amount produced in the United States, in its canning industries. Only about 10 percent of this tin plate is manufactured on the Pacific coast. The all-rail freight rate on tin plate from Pittsburgh to San Francisco, Los Angeles, Portland, and Seattle is $0.75 per 100 pounds.

190. The pipe and seamless tubing market on the Pacific coast is estimated to be about 400,000 tons, none of which is produced on the Pacific coast. The oil, gas, and water companies consume the largest amount of pipe. Freight rates on pipe are $1.15 per 100 pounds from Pittsburgh and $1 per 100 pounds from Chicago to Pacific coast cities.

191. Rail consumption on the Pacific coast is estimated by Mr. Simpson to be 200,000 tons, plate consumption 175,000 tons; neither rails nor plates are produced locally. Structural steel consumption is approximately 225,000 tons, of which 20 percent is manufactured by Pacific coast mills; sheets to the extent of 175,000 tons are consumed, of which 30 percent is produced locally.

192. About 270,000 tons of merchant bars for general work are produced on the west coast while consumption reaches about 450,000 tons. Total consumption of rolled steel is estimated to be approximately 2,500,000 long tons.

193. Mr. John A. Topping, vice president American Iron and Steel Institute, states in his brief to the Committee on Ways and Means, House of Representatives, "High transportation costs narrow our market, so much so in fact, that many mills are unable to market their products at Gulf, Atlantic, and Pacific seacoast points at anything like a reasonable profit, and in many cases at a loss." He speaks of European competition on rolled products, and Indian and Chinese competition on pig iron in the Pacific coast markets.

[21] Estimates by William Simpson, president Simpson Construction Co. Given in address before convention of iron, steel, and allied industries of California, 1930. Quoted in Iron Trade Review, Feb. 27, 1930.

EXPORTS AND IMPORTS OF IRON AND STEEL AND FERRO-ALLOYS

194. Exports of iron and steel products of all types totaled in excess of 3,000,000 tons in 1929 while imports totaled 736,000 tons. While 46,000 tons of pig iron were exported chiefly to Canada and Japan, 147,760 tons were imported principally from British India, England, and the Netherlands.

195. *Ferro-alloys.*—Exports of ferro-alloys were as follows: 1,574 tons of ferromanganese and spiegeleisen chiefly to Canada; 46 tons of ferrotungsten, tungsten metal, and wire chiefly to Germany; 5,772 tons of ferrovanadium and other ferro-alloying ores and metals, chiefly to Canada, Germany, and England.

196. Manganese alloys estimated on basis of 80 percent manganese were imported from Norway, England, and Canada to the extent of 78,481 long tons. Ferrosilicon, with a content of 9,424 tons silicon, came in from Canada and Norway. Tungsten and alloys, with a content of 3,040 tons tungsten, were shipped chiefly from China and England. Ferrochromium, chromium metal, and chromium-vanadium imports reached 667 tons, coming chiefly from Sweden, Switzerland, and Norway.

197. Steel in the form of ingots, blooms, billets, slabs, or sheet bars was exported only to a small extent and then chiefly to Canada. Japan and Italy purchased between 150,000 and 188,000 tons of steel in this condition. Iron- and steel-scrap exports totaled 557,000 long tons, however.

TABLE XI.—*Exports of iron ore, pig iron, and steel ingots, blooms, slabs, and sheet bars during 1929 by country of destination* [1]

Country	Iron ore		Pig iron		Steel ingots, blooms, billets, slabs, and sheet bars	
	Tons	Value	Tons	Value	Tons	Value
Total	1,304,417	$4,774,842	46,357	$830,225	42,578	$1,499,644
Belgium			590	18,654		
Canada	1,295,178	4,741,457	23,431	447,122	23,496	983,130
Chile			848	16,962	2	85
China	25	120	50	1,915	175	10,450
Cuba	27	732	261	5,879		
France			898	28,081		
Germany			531	16,988		
Italy			90	3,551	7,019	155,765
Japan			16,930	224,658	7,120	187,903
Kwantung					401	19,465
Netherland West Indies					105	5,282
New Zealand			14	470	2,415	63,967
Panama			392	10,831	78	6,022
Peru			711	13,501	25	1,842
Philippine Islands			880	20,457	1,410	44,919
Spain					177	3,371
United Kingdom	9,186	32,518	209	7,512	40	2,082
All others	1	15	522	13,644	115	15,361

[1] Compiled from U.S. Bureau of Foreign and Domestic Commerce, Foreign Commerce and Navigation of the United States, 1929.

198. The larger amount of exports was in the form of finished rolling-mill products. Tin plate, terneplate, and structural shapes exceeded all other finished forms exported. Tin plate and terneplate was shipped principally to Japan and Canada, China, Argentina, Mexico, British India, Siam, Cuba, Chile, and other South American countries.

Structural shapes go chiefly to Canada. Plates and sheets go in largest measure to Canada, Japan, and the Philippine Islands. Wire goes in large quantities to the Argentine. In fact, the principal markets for United States iron and steel mill products are Canada, our own insular possessions, Japan, China, South America, and Central American countries.

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BIBLIOGRAPHY

Year	Author	Title
1929	American Iron & Steel Institute	Annual Statistical Report.
1923	do	Do.
1929	do	Directory.
1930	Bailey, T. F. (Baily Furnace Co.)	Production of Gray Iron from Steel Scrap in the Electric Furnace. Paper presented before the American Institute of Mining and Metallurgical Engineers, February.
1929	Barrett, E. P., Joseph, T. L., Wood, C. E.	Research Aids in Fostering Domestic Industry. Engineering and Mining Journal, Feb. 23.
1928	Boylston, H. M.	Iron and Steel.
1928	Brewster, M. W. (General Electric Co.).	Economies in Automatic Welding. Iron Age, Aug. 2.
1929	Finlayson, F. E. (General Electric Co.).	Anneals Magnetic Iron Electrically. Iron Age, Oct. 17.
1927	Hodson, Frank; Smalley, Oliver	Development in the Low Temperature Reduction of Iron Ore. Paper presented before American Electrochemical Society, April.
1927	do	Manufacture of Steel in "One Process" Direct from Ore. Paper presented before American Electrochemical Society, April.
1926	Liddell, Donald M.	Handbook of Non-Ferrous Metallurgy.
1927	Longmuir, Percy	The Direct Production of Pure Iron. Paper presented before the American Electrochemical Society, April.
1930	MacBain, J. T. (electrometallurgical division, Union Carbide & Carbon Corporation).	Ferro-Alloys as Factors in Steel Production. Address before Toronto section of Canadian division of Mining and Metallurgy, February.
1917	New York State Museum	Bulletin 193.
1931	Northrup, Dr. E. F. (vice president, Ajax Electrothermic Corporation).	Tonnage Melting by Coreless Induction. Iron Age, Jan. 15.
1931	do	Power Problems in High-Frequency Melting. Iron Age, Jan. 22.
1931	do	Typical Installation of Coreless Induction Furnaces. Iron Age, Jan. 29.
1928	Otis, A. N. (General Electric Co.)	Progress Made in the Use of the Electric Furnace for Heat Treating. Paper presented before American Society for Steel Treating, October.
1930	Pike, Robert D.; West, George H.; Steck, L. V.; Cummings, Ross, Little, B. P.	Electrolytic Iron from Sulphide Ores. Paper presented before American Institute of Mining and Metallurgical Engineers, February.
1920	Rodenhauser, W.; Schoenawa, J.; Vom Bauer, C. H.	Electric Furnaces in the Iron and Steel Industry.
1928	Roush, G. A.	The Mineral Industry During 1928.
1929	do	The Mineral Industry During 1929.
1930	Scott, Wirt S. (Westinghouse Electric & Manufacturing Co.).	Comparative Heat Treating Costs. Electrical World, May 17.
1930	do	Economic Use of Electric Furnaces. Electrical World, Dec. 26.
1930	Simpson, G. L. (Pittsburgh Electric Furnace Co.).	Electric Furnace Iron. Paper presented before American Electrochemical Society, May.
1924	Sisco, Frank	The Manufacture of Electric Steel.
1926	Smith, Wilfred	A Geographical Study of Coal and Iron in China.
1923	Stansfield, Alfred	The Electric Furnace for Iron and Steel.
1930	Steel Founders Society of America	Directory.
1930	Tyler, Paul M. (U.S. Bureau of Mines).	Minor Metals. Engineering and Mining Journal, Feb. 8.
1929	United States Department of Commerce: Bureau of Foreign and Domestic Commerce.	Commerce Reports, Sept. 9.
1930	do	Commerce Reports, Apr. 9.
1929	do	Foreign Commerce and Navigation of the United States.
1916	Bureau of Mines	Mineral Resources of the United States.
1918	do	War Minerals Investigation.
1926	do	Mineral Resources of the United States.
1927	do	Do.
1929	do	Chromite in 1928.
1931	do	Chromite in 1929.
1930	do	Iron Ore, Pig Iron, and Steel in 1929.
1930	do	Rare Metals in 1929.

Bibliography—Continued

Year	Author	Title
	Department of the Interior:	
1906	Geological Survey	Titaniferous Iron Ore of Iron Mountain, Wyoming, in contributions to Economic Geology.
1908	Bulletin 359	Magnetite Deposits of the Cornwall Type in Pennsylvania.
1910	do	Manganese Deposits of the United States.
1919	do	The Deposits of Manganese Ore in Mexico, in contributions to Economic Geology.
1920	do	Chromite in 1918.
1921	do	World Atlas of Commercial Geology.
1922	Bulletin 735	The Magnetite Ores of Western North Carolina and Eastern Tennessee.
	House of Representatives:	
1921	Committee on Ways and Means	Hearings on General Tariff Revision.
1929	do	Hearings on General Tariff Readjustment.
1927	Waby, Delton T	Electric Iron and Steel Performance. Electrical World, Dec. 7.
1929	do	Electric Steel Melting in Europe. Electrical World, Aug. 17.
1930	Yersen, T. D	Electrolytic Iron from Sulphide Ores. Mining and Metallurgy, April.
1926	do	Large Ferro-Alloy Output in South. Iron Age, Aug. 19.
1928	do	Electrolytic Iron—Its Inception and Development. Engineering, Mar. 23.
1929	do	Byers New Process for Wrought Iron. Iron Age, Aug. 8.
1930	do	New Process Wrought Iron Mill Opened. Power, Oct. 21.
1930	do	Electric Annealing Chosen After Trying Oil and Gas. Electrical World, Sept. 13.
1930	do	Bethlehem's Heat Treatment Shop. Metal Progress, December.
1930	do	Producing Electric Welded Pipe. Steel, Aug. 14.
1930	do	Great Changes Overtake Steel. Magazine of Wall Street, Nov. 15.

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