

struction of those dams and through the dams above the mouth of the Snake when river traffic justifies the cost of locks.

(2) Additional dams, with locks, for navigation only, at points 14 and 40 miles above the mouth of the Snake. These will be contingent on the development of a commerce justifying through canalization above the mouth of the Snake to the vicinity of Wenatchee, Wash.

249. It is recommended that the above-stated plan be adopted by the United States as its guide in controlling and supervising development of the Columbia River above tidewater, navigation being considered chargeable with the cost of locks through dams below the mouth of Snake River and subject to contribution of not over \$5,000,000 toward the cost of those dams; and that the plan for the tidal section of the river remain as at present, viz: Improvement as needed to meet the requirements of seagoing and river traffic.

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APPENDIX I

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RÉSUMÉ OF ESSENTIAL FACTS CONCERNING ELECTRO-CHEMICAL AND OTHER MAJOR POWER CONSUMING INDUSTRIES

1. Electrochemistry was first applied commercially to the manufacture of products which required temperatures too high to be achieved successfully with fuels or which could be dissociated from other materials only by electric current. The products which were rendered commercially available by electrochemical processes at the close of the nineteenth and at the beginning of the twentieth century, namely, aluminum, fused aluminous abrasives, calcium, calcium carbide, calcium cyanide, artificial graphite, silicon, silicon carbide, ferro-silicon, sodium, phosphorus, and refined copper are still manufactured solely by such processes. To their ranks have been added other ferro-alloys, metallic magnesium, fused quartz, fused mullite, tungsten, cadmium, bismuth, and a number of other substances, all requiring electrochemical treatment but for which there is still limited demand. In the last 15 years, electrochemical processes have also been extended to the manufacture of products long made by other processes, either because greater purity of product could be achieved by electrical methods or because such methods proved more economic under specific conditions. Today, caustic soda, phosphoric acid, potassium hydroxide, carbon bisulphide, the chlorates and hypochlorites, as well as the gases hydrogen and oxygen, are

produced electrochemically as well as by other methods. Today, zinc from complex ores and copper from mixed ores are precipitated electrochemically. There is a steadily mounting tonnage of steel ingots and castings, of iron castings, of copper alloy ingots and castings, that is either melted or heat-treated electrically.

2. The trend toward wider use of electricity has gone so far that it would be difficult to determine what industries should be classed as electrochemical industries. On the other hand, electrochemical processes remain sharply defined. Therefore, this study deals with the position of electrochemical processes and products in industry as organized and operating in 1929 and 1930, without attempting to draw lines of demarkation between electrochemical and other industries.

RELATIVE IMPORTANCE OF ELECTROCHEMICAL PRODUCTS IN POWER CONSUMPTION

3. Electrochemical processes consumed more than a tenth of the total electricity generated for industrial purposes in 1929. In excess of seven billion kilowatt-hours (7,000,000,000 kilowatt-hours) were consumed in the electrochemical processes required to produce 50 substances. As the total number of products manufactured in the United States runs into many hundreds, the importance to power markets of products requiring electrochemical processes is obvious.

4. But the significance of individual electrochemical products in power development varies greatly. Industries whose products can be manufactured solely by electricity necessarily carry a stable current load and require a reliable current supply. But at least 22 electrochemical products out of the 50 covered by this report are manufactured in such small quantities today, that, individually, they have little present power market value save as they may add to a specific power load by being manufactured along with other electrochemical products. Each represents a potential power load, however. As a contrast, ideal products from the viewpoint of power development such as aluminum and ferro-alloys, require large amounts of current per ton so that a cheap and abundant source of power is a manufacturing essential; they are produced in large manufacturing establishments, have developed markets, and give promise of expanding markets.

5. While only aluminum and ferro-alloys can be said to meet all these conditions following the year of general business depression, 1930, other products meet the first three specifications—large unit consumption, large productive capacity, established markets—while a question mark would be placed as to the date when markets may expand beyond present plant capacities. The electrolytic precipitation of zinc from complex ores with the recovery of cadmium and other metals, the precipitation of copper from oxide and mixed ores, the manufacture of calcium carbide, silicon carbide and fused alumina, necessarily require heavy unit and heavy total current loads. The electrochemical manufacture of caustic soda and phosphoric acid must compete with other methods of manufacture, but such electrical production already consumes large amounts of electricity. Growth will depend upon the success with which electrochemical processes meet competition from fuel and chemical processes. On the other

hand, the electrolytic production of oxygen and hydrogen has not yet assumed large proportions although future conditions may make such production feasible in competition with other methods.

6. The electrolytic refining of copper, the electric melting and heat-treatment of copper alloys, the electric melting and heat-treatment of steel ingots and iron and steel castings require a much smaller number of kilowatts of electricity per ton handled than do other electrochemical processes, but the tonnage of these industries is so great, the operating units so large, that total current requirements are heavy. All copper, except pure Lake copper, is already electrolytically refined; only an expansion in amount of copper produced will materially increase the market for current in copper refineries. In copper alloy mills, in steel works and rolling mills, however, the electric furnace is replacing coal, oil, or gas fired equipment; replacements in themselves will add greatly to the electric load carried by such mills in the future.

7. Consideration of electrochemical processes in steel works and rolling mills draws attention to industries whose installed horsepower is very large even though no manufacturing processes are electrochemical. First among such industries is paper and wood pulp manufacture, which is exceeded only by steel works and rolling mills in total installed horsepower as well as in total installed electric horsepower. Power is required for steam and for mechanical purposes only. Its cost forms about 7 percent of the market price of manufactured paper as compared with power costs of 8 percent to 14 percent for electrochemical products which are dependent upon electric heat or electric deposition. As power forms but 3 percent of the market value of products in all manufacturing establishments, power costs are almost as important in the production of some types of paper and wood pulp as they are in some electrochemical products. Total electricity consumed in pulp and paper mills is also greater than in many electrochemical factories. Paper consumption is increasing. It seems advisable, therefore, to include pulp and paper along with electrochemical products when considering probable future industrial power needs of the country.

8. Other industries whose total installed horsepower is large but which consume electricity chiefly for mechanical purposes, such as cotton goods manufacture, lumber and lumber products, foundry and machine shops, railroad car and general shop construction and repair are organized in many units so that the power requirements per plant are small. Power costs form 2 percent or less of the value of marketed products. Obviously, location near a large power supply is not a consideration in these industries.

SPECIFIC POWER REQUIREMENTS OF ELECTROCHEMICAL PRODUCTS AND PULP AND PAPER

9. Power requirements of electrochemical processes employed in the United States or in Canada and Europe are listed on pages 93 and 94. The arc process securing nitrogen from air for use in the manufacture of nitric acid and nitrate fertilizers requires by far the largest number of kilowatt hours per short ton of any electrochemical process. Since the original arc process plants were built in Norway, however, less costly methods of nitrogen fixation have been developed; nitric acid is made

by the oxidation of ammonia in the United States. The arc process is now regarded as uneconomical and new arc plants will probably not be built.

10. *Aluminum*.—But even in Europe, as in the United States, the largest total power load in electrochemical industries is carried by aluminum. In 1929 in this country, over 2,500,000,000 kilowatt-hours were consumed in the electrolytic reduction of aluminum from its oxide, alumina. This reduction also requires more power per ton than any other product manufactured in the United States, or from 19,000 to 25,200 kilowatt-hours per short ton. Latest developments in aluminum plants, here and abroad, indicate that power requirements of aluminum plants will be increased. Whereas the oxide of aluminum has been extracted from the ore bauxite by chemical methods until a year or two ago, new plants are extracting the oxide by electrothermal processes requiring 4,000 kilowatt-hours of current and more. Furnace electrodes and furnace linings are also being produced electrothermally at newly constructed aluminum plants. Mechanical operations are all electrified. Wherever it is feasible to install rolling mills at aluminum reduction works, the power load is further increased by electrically heated melting furnaces and heat treatment ovens as well as by the additional mechanical load.

11. *Ferro-alloys*.—The ferro-alloys rank second in importance among electrochemical products in total energy demands. Ferro-silicon containing 12 percent or more silicon, ferro-tungsten, ferro-chromium, ferro-molybdenum, and other alloys of these substances required by the steel industry are smelted only electrothermally. Ferro-vanadium is produced in the electric furnace and also by the thermit process. Ferro-manganese, alone of all the alloys which serve as scavengers in removing undesirable elements from steel or which improve the properties of steel, is not produced electrothermally in this country although it is so manufactured in Canada and Norway by American capital. The total energy consumed in ferro-alloy furnace smelting in 1929 was in excess of 1,260,000,000 kilowatt-hours. Almost 1,000,000,000 kilowatt-hours were consumed in ferro-silicon smelting, each ton requiring about 5,000 kilowatt-hours of current. Power forms from 13 to 14 percent of the market price of this alloy. Other ferro-alloys consume from 6,000 to 10,000 kilowatt-hours of electricity per ton but production is small; it is increasing, however.

12. *Newsprint paper*.—The newsprint paper industry in the United States including therein the mechanical and sulphite pulp manufactured at such paper mills, consumed almost 2,000,000,000 kilowatt-hours of electrical energy in 1929. Largest consumption occurs in the manufacture of mechanical pulp, approximately, 1,280 kilowatt-hours of current being essential to reduce pulp wood to 1 ton mechanical pulp. When considered in terms of newsprint paper, the electric requirements for mechanical operations per ton of newsprint averages 1,340 kilowatt-hours. Such paper also requires from 8,000 to 14,000 pounds of low steam pressure per ton which is still secured by fuels except in plants where hydraulic turbines drive the main electric generator. But electrical costs alone form over 11 percent of the cost of manufacturing newsprint paper, and 10 percent of the price at which newsprint paper is marketed. While the unit electric requirements per ton of newsprint paper are much lower than the unit current

requirements of many electrochemical products, the larger tonnage of newsprint paper, the regular daily demand for paper, the long contracts entered into between newsprint paper mills and newspaper publishers, make a modern newsprint mill manufacturing its mechanical pulp almost as constant a power load as are the major electrochemical factories.

13. *Caustic soda and chlorine.*—In spite of the fact that less than a third of caustic soda consumed in the United States is manufactured by the electrolysis of brines, approximately 660,000,000 kilowatt-hours of energy were consumed in such production in 1929. The passage of 2,328 kilowatt-hours or more current through purified brine solutions produces simultaneously 1 ton caustic soda, approximately nine-tenths ton chlorine, and approximately 8,100 cubic feet hydrogen. If power costs are charged against caustic soda alone, they form 14 percent or more of the market price of soda; but if they are divided proportionately with chlorine, power costs are reduced to 8 percent of the combined marketable yield.

14. *Other brine products.*—In 1930, all metallic magnesium manufactured in the United States was secured from the magnesium chloride extracted from well brines before such brines were electrolyzed into caustic soda and chlorine. Metallic magnesium is exceeded only by aluminum in the amount of current required per ton produced. It is still manufactured in pounds, however, rather than in tons, so that total power consumption in 1929 was but approximately 11,000,000 kilowatt-hours. Metallic sodium, also produced at electrochemical caustic soda plants, requires 13,000 kilowatt-hours of energy per ton. This, together with such sodium hypochlorite and such sodium chlorate as may be produced by electrolysis at electrochemical caustic soda and chlorine plants increases the power consumption of these plants. Separate industries have not been developed in the United States for the electrolytic manufacture of these three sodium products.

15. *Calcium carbide.*—The production of calcium carbide, the basic material for acetylene and for calcium cyanamide, required almost 750,000,000 kilowatt-hours of electricity in 1929. Unit consumption varies from 2,600 kilowatt-hours to 3,200 kilowatt-hours in different furnaces. All calcium carbide manufactured in the United States is for acetylene, the acetylene being used for welding and cutting, for lighting, and as a basic chemical for acetic acid and other synthetic organic chemicals. Calcium carbide for calcium cyanide, used in fertilizer and other chemical production, is manufactured in Canada and in Europe. Had the cyanamide shipped to the United States been manufactured here, an additional 85,000,000 kilowatt-hours of energy would have been required for its production in this country.

16. *Zinc and cadmium.*—Zinc is the principal metal secured from its ores by electrolysis. Although 70 percent of marketed zinc is still extracted by retort distillation, the zinc content of complex ores in the Northwest has been made available only through flotation and electrolytic processing. Zinc precipitation already ranks fifth among electrochemical processes in total amount of current consumed. In 1929, more than 507,000,000 kilowatt-hours were consumed in zinc electrolytic precipitation, from 2,206 to 3,200 kilowatt-hours being required per ton at electrolytic tanks.

17. The power load at zinc plants is being increased by a recent demand for cadmium as a protective coating for other metals. Cadmium must be removed from zinc concentrates before zinc can be secured. Consequently, its electrolysis from zinc concentrate residue adds a valuable byproduct to electrolytic zinc production. Cadmium production required almost 3,000,000 kilowatt-hours of current in 1929.

18. *Copper.*—The electrolytic refining of copper dates from 1885. Such refinement was essential for the recovery of valuable metals such as gold and silver and for the removal of objectionable metals such as bismuth and antimony from western copper. Today, all copper, save a small tonnage from the Lake Superior peninsula in Michigan, is refined electrolytically. As such refinement requires only from 141 kilowatt-hours to 233 kilowatt-hours of electricity per ton, power is not a large item in the unit cost of copper refining. However, copper tonnage is sufficiently large to give copper refinement sixth place in total power consumption among electrolytic and electrothermal processes.

19. A more promising power load is being developed in the Southwest by leaching and electrolytic precipitation of copper from oxide and mixed copper ores. Such precipitation requires from 1,700 to 2,625 kilowatt-hours per ton. In 1929, two American plants that have adopted this method consumed almost 63,000,000 kilowatt-hours of electricity.

20. *Lead, gold, and silver.*—Lead electrolytic refining required over 6,000,000 kilowatt-hours. Such refining competes with pyrometallurgical and chemical refining processes but has the advantage of removing bismuth which may be electrolytically refined for pharmaceutical purposes.

21. Four fifths of all silver and one fourth of all gold is secured through the refining of copper, lead, or zinc ores. The precious metals are cast into anodes to be electrolytically refined chiefly at a few large copper or lead refineries, and at United States mints. While the refining of silver and gold requires more kilowatt-hours per ton than the refining of copper or lead, gold and silver are produced by the fine ounce. As far as it is possible to determine, together, their refinement required but a million and a third kilowatt-hours of energy in 1929.

22. *Copper alloy rolling mills and foundries.*—The power consumption in brass, bronze, and other copper alloy rolling mills has approximated that required in copper refineries and is increasing. Until 1917, all melting and heat-treatment of copper and copper alloys was done in fuel-fired furnaces or ovens. Today, almost all brass and bronze melting in rolling mills and much in foundries is done in electric furnaces, the energy required varying with the alloy made from 195 kilowatt-hours to 300 kilowatt-hours per ton alloy melted. Such melting operations required in excess of 220,000,000 kilowatt-hours of electricity per year. Pure copper ingot is only melted in electric furnaces to a limited extent as present electric furnace lining life is short with metal containing more than 90 percent copper.

23. In the process of drawing, rolling, or piercing copper and copper alloys into wire, tubes, and sheets, the semi-finished product must be softened by annealing. In products such as hard-drawn wire and tubing, careful temperature control is essential and electric annealing furnaces are displacing wood-fired muffles. Such annealing furnaces

consume from 50 to 100 kilowatt-hours per ton of copper-alloy handled. While data concerning the actual number of installations of electric annealing ovens is not available, it is obvious that any general adoption of electric annealing furnaces would bring about a heavy increase in the power load of copper alloy rolling mills.

24. *Steel*.—Blast furnaces, steel works, and rolling mills outrank all other industries in installed horsepower, only three fourths of which is electric horsepower. This ranking position is due to the fact that iron and steel tonnage exceeds all other metal, chemical, or paper tonnage by many millions, rather than to unit power requirements of iron and steel products. But electrification of steel works and rolling mills is proceeding rapidly not only for mechanical operations but for heating processes. In 1929, 1 percent of steel ingots were refined in electrically heated furnaces requiring approximately 210 kilowatt-hours per ton molten charge. Such electric refinement consumed 125,000,000 kilowatt-hours of energy. Twenty-six percent of steel castings were melted in electric furnaces, consuming from 500 to 760 kilowatt-hours per ton cold charge. An increasing number of electric furnaces are employed in the heat-treatment of alloy steels and carbon steels, specific operation requiring from 50 to 500 kilowatt-hours of current. Electro-galvanizing, electrozincing, and electroplating are also increasing. Probably the best measurement of the part all power, regardless of source, plays in steel works and rolling mills today and the part which electrical power and heat may play in the future is gained by a comparison of the present cost of fuels and electricity in steel works and rolling mills and the market value of all manufactures. Electricity and fuels form 6.6 percent of the total market value of products today.

25. *Artificial abrasives and refractories*.—Closely associated with the development of hard alloy steels is the manufacture in electric furnaces of fused alumina and of silicon carbide, the latter being second only to the diamond in hardness. Both serve to grind metals and other substances and as refractories where high temperatures and difficult heating conditions must be met by furnace linings and equipment. Silicon carbide requires from 6,666 to 8,333 kilowatt-hours of energy per ton and fused alumina from 2,000 to 2,540 kilowatt-hours. American firms manufacture both abrasives in plants located in the United States and in Canada. While the crude materials are converted into marketable abrasives in this country, electrothermal processes are carried on more extensively in Canada than in the United States. Crude silicon carbide and fused alumina produced in electric furnaces in the United States in 1929 required less than 70,000,000 kilowatt-hours of energy whereas crude abrasives produced in both countries and consumed largely in the United States required 380,000,000 kilowatt-hours. Silicon, requiring approximately 12,000 kilowatt-hours per ton, is produced in small quantities at silicon carbide plants.

26. *Graphite*.—Crystalline graphite in powdered and electrode form requires approximately 7,600 kilowatt-hours of electricity per ton. Although manufactured by one firm only until recently, firms engaged in the manufacture of other electric furnace products are now offering it for sale, while firms requiring graphite electrodes in quantity for electrochemical production are manufacturing their own electrodes where petroleum coke is easily available.

27. *Phosphoric acid and phosphorus*.—Although phosphoric acid has been manufactured electrothermally for only 10 years chiefly for food and chemical industries, it already ranks eleventh among electrochemical industries in the total amount of electricity consumed. Current consumption totaled approximately 81,000,000 kilowatt-hours in 1929, while unit consumption averaged 5,400 kilowatt-hours. Electrothermal phosphoric acid production will have to compete with blast furnace phosphoric acid in markets requiring a pure acid, while chemical phosphoric acid still controls the fertilizer market. Phosphorus has been made in an electric furnace for many years. While power consumption is heavy, quantities produced are small.

28. *Industrial gases and synthetic ammonia*.—The electrolysis of water produces approximately 2 parts of hydrogen and 1 part oxygen, 1,000 cubic feet of hydrogen requiring 140 kilowatt-hours and 1,000 cubic feet of oxygen about 250 kilowatt-hours of electricity. These gases may each be manufactured by other methods. As manufacturing plants requiring large amounts of either gas produce their own gases, such production is not recorded and any electricity consumed is reported along with total power consumption of the specific product manufactured. We know only that about a sixth of the oxygen offered for sale was produced electrolytically and that such production consumed more than 50,000,000 kilowatt-hours of electricity, and that synthetic ammonia made from electrolytic hydrogen at ammonia plants in the United States consumed over 13,000,000 kilowatt-hours of energy.

29. *Potassium compounds*.—Potassium hydroxide used in the manufacture of soft soaps, dyes, and other potassium compounds required over 2,000 kilowatt-hours of electricity to produce by electrolysis. Total power consumption in its manufacture exceeded 15,000,000 kilowatt-hours. Potassium chlorate requires approximately 1,350 kilowatt-hours per ton. Potassium permanganate and potassium persulphate are also produced electrolytically in this country but in small quantities.

30. *Carbon bisulphide*.—Carbon bisulphide manufacture consumed approximately 36,000,000 kilowatt-hours of current in 1929. This chemical is used as an insecticide, as a solvent of caoutchouc and fats and also in the extraction of essential oils.

31. *Rare or minor electrochemical products*.—Fused quartz is finding extended application not only in equipment that must resist acids and sudden heat, but also in the manufacture of telescope and photograph lenses and in window glass which transmits ultra-violet and infra-red rays. Its production required from 10,000 to 16,000 kilowatt-hours per ton. Production is still on a poundage basis, however.

32. Demand for materials reduced only at high temperatures and employment of high pressures in chemical industries have brought into the market several new electric furnace refractories. Mullite, electrically sintered magnesite, and other electrically combined substances, are being tried out in industry.

33. Pure tungsten, for electric lamp filaments and for ignition contact points, also requires large amounts of power per unit and hydrogen atmosphere furnaces, but production is still in small quantities. Molybdenum, tantalum, and barium, are finding application in radio-tube manufacture. Cobalt is being alloyed with other metals to

produce machine tools and acid-resistant equipment. Beryllium, cerium, and lithium are also alloyed with other metals. Each product is manufactured electrochemically with high unit-current consumption. But each product is manufactured in small quantities today and has only potential significance in the development of the Nation's water power.

Power requirements of electrochemical processes and consumption of electricity by such processes in the United States in 1929¹

Material	Process	Kilowatt-hours required per short ton	Total kilowatt-hours consumed in 1929 in United States	Principal competing processes in United States or other countries
1. Nitric acid.....	Arc.....	61,000	None	Oxidation of ammonia.
2. Aluminum.....	Electrothermal reduction of bauxite to alumina.	4,082-?	None	Alkali reduction of bauxite to alumina.
3.	Electrolytic reduction of alumina to aluminum.	19,000-25,200	2,519,375,000	None.
4. Metallic magnesium.	Electrolysis of magnesium chloride in brine.	16,000	10,640,000	Electrolysis of magnesium chloride from mineral magnesite plus chlorine requiring 17,000 kilowatt-hours.
5. Metallic sodium....	Electrolysis of fused caustic soda.	13,000	(²)	Electrolysis of fused sodium chloride.
6. Synthetic ammonia.	Electrolytic hydrogen; pressure synthesis.	12,055	13,140,000	Water-gas hydrogen; coke-oven gas hydrogen; by-product hydrogen.
7. Fused quartz.....	Electrothermal fusion....	10,000-16,000	(³)	None.
8. Silicon.....	Electrothermal reduction..	12,000	(³)	Do.
9. Phosphorus.....	do.....	9,000	⁴ 1,250,000	Do.
10. Crystalline graphite.	do.....	7,600	⁴ 91,200,000	Do.
11. Ferro-tungsten...	Electrothermal smelting and refining.	7,600	26,395,000	Do.
12. Silicon carbide...	Electrothermal reduction..	6,666-8,833	⁵ 23,655,000	Do.
13. Ferro-molybdenum 70 percent.	Electrothermal smelting...	8,000-9,000		
14. Ferro-uranium....	do.....	6,000-10,000	⁶ 228,258,000	Do.
15. Ferro-chromium 60 percent.	do.....	6,000		
16. Ferro-vanadium 30 percent-35 percent.	do.....	6,800	⁴ 13,035,800	Thermit reduction.
17. Phosphoric acid...	Electrothermal reduction..	5,400	81,000,000	Sulphuric acid process.
18. Ferro-silicon 50 percent.	Electrothermal smelting..	5,000	994,011,000	Blast-furnace reduction. Byproduct fused alumina production; less than 12 percent silicon blast-furnace reduction.
19. Ferro-manganese 80 percent.	Electrothermal reduction..	4,400	None	Blast-furnace reduction.
20. Calcium carbide...	do.....	2,600-3,200	720,000,000	None.
21. Calcium cyanamide.	do.....	2,830	⁷ None	Do.
22. Zinc.....	Electrolytic precipitation..	2,206-3,200	⁸ 507,115,192	Retort distillation.
23. Copper.....	Copper precipitation from oxide and mixed ore.	1,700-2,625	62,848,806	Flotation and reverberatory smelting.
24. Caustic soda.....	Electrolytic reduction of Chlorine.....	⁹ 2,328-2,984	660,000,000	Lime-soda ash process.
25. Cadmium.....	Electrolytic precipitation of zinc residuum.	2,000-2,500	2,730,200	None.
26. Fused alumina....	Electrothermal fusion....	2,000-2,540	¹⁰ 43,318,000	Do.
27. Potassium hydroxide.	Electrolysis of potassium chloride.	2,100-2,300	15,831,000	Chemical process.

¹ Does not include 15 rare metals or chemicals, the production of which is still on a very small scale.

² United States production not officially recorded. Estimated world electricity consumption in manufacture of metallic sodium in 1927 was 375,000,000 kilowatt-hours.

³ United States production too small to be officially recorded.

⁴ Estimated.

⁵ Canadian and United States consumption in 1929 was 227,000,000 kilowatt-hours.

⁶ Includes minor quantities of other ferro-alloys.

⁷ The amount shipped to the United States in 1929 required 84,900,000 kilowatt-hours.

⁸ Includes power required in operations immediately essential to electrolytic precipitation.

⁹ Per ton caustic soda.

¹⁰ Canadian and United States consumption in 1929 was 152,489,000 kilowatt-hours.

Power requirements of electrochemical processes and consumption of electricity by such processes in the United States in 1929—Continued

Material	Process	Kilowatt-hours required per short ton	Total kilowatt-hours consumed in 1929 in United States	Principal competing processes in United States or other countries
28. Iron.....	Magnetite ore reduction in arc furnace.	2,000-2,500	None	Blast furnace. Electrodeposition.
29. Potassium chlorate.	Electrolysis of potassium chloride.	1,350	(3)	Chemical process.
30. Iron.....	Electrodeposition from ore.	900	None	Blast furnace. Electric furnace reduction.
31. Carbon bisulphide.	Electrothermal fusion.....	850	30,170,250	None.
32. Sponge iron.....	Electrothermal low temperature ore reduction.	400	(3)	Oil or gas low temperature reduction.
33. Steel castings.....	Electric melting solid charge.	500-760	4 281,594,000	Open-hearth furnace. Bessemer furnace. Crucible furnace.
34. Steel ingot.....	Electric melting or refining or superrefining of molten charge.	210	125,218,590	Do.
35. Steel.....	Electric annealing or hardening.	182-286	-----	Fuel-fired furnace.
36.	Electric galvanizing or electrozincing.	101-230	-----	Fuel hot process.
37. Iron castings.....	Electric melting: Duplex system.....	115	(3)	Fuel-fired cupola melting.
	Continuous.....	550		
38. Copper.....	Electrolytic refining.....	141-233	309,351,900	None—Lake copper is not refined.
39. Copper ingot.....	Melting.....	310	-----	Fuel-fired ovens.
40. Copper alloy.....	Electric furnace melting.....	200-300	11 220,000,000	Fuel-fired pit furnaces.
41.	Annealing.....	50-100	-----	Fuel-fired ovens.
42. Silver.....	Electrolytic refining.....	316-714	1,283,460	Sulphuric acid process.
43. Gold.....	do.....	266	45,300	Do.
44. Lead.....	do.....	95-111	6,180,000	-----
45. Oxygen, compressed.	Electrolytic reduction of water.	12 250	50,575,000	Liquefaction process.
46. Hydrogen.....		12 140	12	Water-gas. Iron contact processes.

³ United States production too small to be officially recorded.

⁴ Estimated.

¹¹ Figures are for 1927.

¹² Kilowatt-hours per 1,000 cubic feet.

¹³ Process employed chiefly in plants where hydrogen is consumed in major manufacturing processes.

PRESENT LOCATION AND STATUS OF MAJOR POWER CONSUMING INDUSTRIES

34. The most favorable location for any large power-consuming industry is one in which power site is within easy access of essential raw materials and in close proximity to consuming markets. As all new plants in power-consuming industries control mechanical operations electrically, such industries are no longer dependent upon a labor supply trained through years of actual experience for specific processes. The general levelling of wage rates in the industrial East and West has narrowed the differences in labor cost in all sections of the United States save in the South.

35. In the past, power supply, sources of raw materials, and available labor have determined plant locations in Eastern and Central States. In a period such as the present, when manufacturing capacity in many industries exceeds market demands, markets stand out as one of the most important factors in determining locations of new or branch plants. The advantages to be obtained through easy contact with customer industries, the lessened risk involved where companies are not entirely dependent upon conditions in one locality, and the

wisdom of distributed investments is tending more and more to the establishment of branch factories in consuming areas. The heaviest markets for electrochemical and paper products are in East Central and Lake States. The general movement of population westward brings with it an increase in service industries. But the development of basic industries in a given locality due to a dependence on bulky low-cost raw materials has tended to bring related industries to specific sections. Even so, production costs of manufactured products are seldom sufficiently low to offset heavy freight charges from western raw-material sources to eastern markets. Manufacturing costs are being lowered, however, by the integration of a number of related industries so that present waste is eliminated and overhead costs greatly reduced.

36. In the following pages are outlined briefly, factors entering into the establishment of existing major electrochemical and paper plants, present sources of raw materials, possible future sources, as well as conditions affecting prevailing markets and industrial control.

THE ALUMINUM INDUSTRY

37. *Plant location.*—Aluminum manufacture as practiced in the United States involves two processes, the chemical extraction of aluminum oxide from the ore bauxite and the electrolytic reduction of the oxides to metallic aluminum. When hydroelectric service was first available at Niagara Falls, aluminum-reduction works were put into operation at the Falls. The chemical-extraction plant was placed at East St. Louis, Ill., near coal fields and where bauxite could be shipped via water from Arkansas bauxite mines to it. As markets for aluminum expanded, additional reduction works were constructed at Massena, N.Y., where power is secured from waters of the St. Lawrence River; at Shawinigan Falls, Quebec, on the St. Maurice River; at Badin, N.C., where power is gotten from the Yadkin River; at Alcoa, Tenn., which is served by power from a number of developments in the Great Smokey Mountains of Tennessee; and in 1926 construction was started at Arvida, Quebec, on the Saguenay River. The Massena reduction works is the largest plant in the United States. Plans for developments at Arvida, Canada, contemplate a capacity almost equal to present total production in the United States.

38. Until 1928, aluminum oxide for all North American reduction works was supplied by the East St. Louis factory. By 1929, the Arvida plant had succeeded in meeting almost all its own needs by the electrochemical extraction of aluminum oxide from bauxite shipped to it from the British and Dutch Guianas. Should electrothermal reduction of bauxite be able to compete with the long-established chemical reduction which resulted in locating one unit of aluminum production near coal fields, all processes in the manufacture of aluminum from its ores can be carried on at power sites.

39. While present power developments along the Saguenay River will provide 500,000 horsepower at Arvida, completed construction will make available 1,000,000 horsepower. The Aluminum Company of America, sole producer of virgin aluminum in the United States and in Canada since 1886, holds riparian rights near Long Sault Rapids in the St. Lawrence River which it has not been able to develop

due to lack of coordinate legislation on the part of the United States and Canada, the State of New York, and the Province of Ontario. It also has undeveloped power sites in the Great Smoky Mountains of Tennessee.

40. *Expanding markets.*—Continuous research has brought about an expanding market for aluminum. Not only has it held well established markets in cooking utensil and electrical conductor industries, but strong aluminum alloys have found large markets in transportation industries and in electrical apparatus manufacture while beginnings have been made in structural fields. With the exception of post war years, aluminum production has increased steadily in the United States. The very rapid expansion since 1923 is shown on Graph I.⁷

41. *Control of production.*—World aluminum production is also increasing. Such production is controlled by two groups, the Aluminum Company of America with Canadian and other foreign holdings operated by Aluminum Limited and the International Aluminum Cartel made up of four principal producing companies in France, Germany, Great Britain, and Switzerland. In 1929, the Aluminum Company of America produced 51 percent of the world's supply of aluminum, 38 percent being manufactured in the United States. Germany produced 13 percent of the world's supply, France 11 percent.

42. *Sources of raw materials.*—Bauxite, a hydrated oxide of aluminum containing 50 percent to 60 percent aluminum oxide, is the source of all commercial aluminum today. It is mined principally in southeastern United States, in British Guiana and Dutch Guiana, in France, Hungary, Italy, and Yugoslavia. Extensive deposits are believed to exist in Africa and India. As the large world aluminum manufacturers control extensive bauxite deposits, it is not believed that the very abundant aluminous clays containing lesser amounts of aluminum oxide will be used in aluminum production for many years.

43. However, Italy is experimenting with the commercial production of aluminum oxide and potash from leucite ores containing both minerals. This experiment is of importance to Wyoming where geologists estimate 2,000,000,000 tons of leucite ore containing 200,000,000 tons of aluminum oxide and a like amount of potash are available.

PHOSPHORIC ACID, NITROGEN, AND POTASH PRODUCTION

44. *Sources of potash and phosphates.*—The undeveloped potash resources of Wyoming call sharply to attention the research that is being carried on by two Federal departments to develop methods of making available to agriculture and industry the potash resources of the country. The American farmer applies approximately 343,000 tons of pure potash to farm lands each year along with 345,000 tons of nitrogen and 808,000 tons of phosphoric acid. The phosphoric acid was produced in the United States from native phosphate rock; 53 percent of available nitrogen was manufactured in the United States; while but 16 percent of available potash was American production.

45. The Wyoming potash in leucite rock is not water soluble as is German and French potash and, therefore, must be chemically

⁷ Not printed.

treated before it is available as plant food. As yet, no process has been developed which will permit potash so treated to meet foreign fertilizer prices unless the aluminum contained in the ore is also marketed. Development of this potash along with nearby phosphate deposits for baking powder and chemical industries has just begun. Experiments are also under way using this potash silicate as a flux in electrothermal phosphoric acid manufacture. Government geologists and metallurgists, however, are working at present with potash from well deposits in Texas and New Mexico. As the Wyoming deposits of potash are believed to be the largest in the United States and as the largest known world deposits of high grade phosphate rock are located in Idaho, Wyoming, Utah and Montana, the Nation will eventually depend upon these States to supply much of its phosphate and potash requirements.

46. At present, Florida supplies the largest amount of phosphate rock; Tennessee ranks second in production, while but a small amount is mined in Idaho, Wyoming, and Montana.

47. *The fertilizer market.*—More than 90 percent of phosphate rock sold enters the fertilizer trade. This rock is manufactured into phosphatic fertilizer, not at the mines, but in fertilizer consuming centers. The reason is obvious. The prevailing phosphatic fertilizer, superphosphate, is made by mixing one part of phosphate rock with one part of sulphuric acid producing a product containing 16 to 18 percent phosphoric acid and a large quantity of gypsum. The original phosphate rock from which this fertilizer was produced contained 30 to 34 percent phosphoric acid. As value is based on phosphoric acid content rather than on bulk, it is cheaper to ship rock containing over 30 percent phosphoric acid to fertilizer consuming districts than to manufacture the fertilizer at the mine and ship the finished product containing only 16 to 18 percent phosphoric acid.

48. Fertilizer manufacturing located in the South, as cotton fields consume 31 percent of all fertilizer, and also near corn, potato, wheat, and tobacco regions. Such manufacturing involved the production of superphosphate and mixing it with foreign potash and, until recent years, with foreign nitrogen materials. In this mixed fertilizer the farmer paid not only for 17 percent available plant food but the cost of bagging, handling, and hauling the other 83 percent almost valueless filler. Obviously, Rocky Mountain phosphate rock or Rocky Mountain superphosphate could not be shipped profitably to southern and central fertilizer markets.

49. *Transitional period.*—The costliness of such practices, as well as the waste involved in diluting phosphate rock with sulphuric acid and the danger of permitting the country's agricultural development to be largely dependent upon foreign sources of nitrogen and potash is nationally recognized. Fertilizer manufacture and the production of the three chemicals entering into such manufacture are passing through a transitional period in the United States.

50. The percentage of plant food in fertilizer increased from 14 percent in 1920 to 17.6 percent in 1929. Some phosphate rock is being treated with phosphoric acid in place of sulphuric acid in order that both rock and reagent may furnish plant food. This product, known as double superphosphate, contains from 45 to 50 percent plant food as against 14 to 18 percent in regular superphosphate. Phosphoric

acid is also used as the carrier of nitrate ammonia fertilizer, thereby creating a 2-plant food fertilizer. Instead of forcing the producer of ammonia to manufacture ammonium sulphate with its useless sulphate radical for the fertilizer market, this practice permits anhydrous or aqua ammonia to be shipped to fertilizer plants to be combined directly with phosphoric acid fertilizer.

51. *Competition between phosphoric acid manufacturing processes.*—But this phosphoric acid is still produced mainly by the sulphuric acid process. Electrothermal phosphoric acid manufacture began in 1920, blast furnace phosphoric acid manufacture in 1929. As these methods produce a pure acid more easily than the sulphuric acid process, pyrolytic phosphoric acid has served the baking powder, pharmaceutical, and other industries in which a pure acid is essential. The pure acid required by these markets brings a price of \$170 to \$180 per ton whereas the phosphoric acid in superphosphate fertilizer is worth only \$50 a ton of acid. It is obvious why pyrolytic producers of phosphoric acid have given first attention to markets other than the fertilizer market.

52. But as the industrial market is small, normal growth will force pyrolytic phosphoric acid into the fertilizer market. All furnace processes have advantages over the sulphuric acid process. Low-grade ores may be treated along with high-grade ores making unnecessary the washing and screening of ores essential for the chemical process. Much present waste of phosphate rock is avoided. Again, any degree of concentration of phosphoric acid may be obtained directly by furnace methods so that the expense involved in the sulphuric-acid process of evaporating weak solutions is eliminated.

53. In regions where a market must be found for waste sulphur fumes, as near sulphide ore smelters, sulphuric acid may be a very cheap reagent. More labor is required by this chemical process than by other processes. Where coke is cheaply available, blast-furnace reduction may prove to be more economical, whereas an abundance of electrical power may make the electrothermal process more advantageous.

54. *Chemical nitrogen production.*—Other technical developments which may lead to the production of high-analysis fertilizers and thereby permit a development of western phosphate and potash deposits, are also of recent date in the United States. The direct synthetic ammonia process for nitrogen fixation was first put into operation at Syracuse, N.Y., in 1921. In 1929 a sixth of the available nitrogen supply was secured from air nitrogen fixation plants, this production representing a 350 percent increase in 2 years. Building of additional plants during 1929 and 1930 will bring the direct synthetic ammonia plant capacity of the United States close to 200,000 tons.

55. *Ammonia plant location.*—Largest present production takes place at Hopewell, Va., and at Belle, W.Va., where water-gas is employed as the hydrogen source. Near Seattle, Wash., electrolytic hydrogen is employed. Recently, an electrolytic plant has been erected at Trail, British Columbia, for the pressure synthesis. A plant building at Brose, Calif., will secure its hydrogen from natural gas. Four electrolytic caustic soda plants are manufacturing by-product hydrogen into ammonia. In Europe, coke-oven hydrogen has proved a cheap source of supply.

56. As shown on graph II,⁸ by far the larger amount of domestic nitrogen was secured as a by-product of coke production. As coke is sold primarily to iron and steel mills, any production of ammonia at coke ovens depends on the demands of iron and steel mills for coke rather than upon the market demand for ammonia. Chilean nitrate, until 1926 our prevailing nitrogen source, still ranks second as a source of supply. Ten percent of our available nitrogen was imported from Canada in the form of calcium cyanamide and cyanide. Much of the cyanamide imported is manufactured into ammonia and ammonium phosphate.

57. *Competitive conditions.*—Successful competition of the several nitrogen compounds depends not only on the cost of differing manufacturing methods at particular plant locations, but upon the derivatives obtainable from the initial nitrogen products and upon the markets for by-products. In the electrolytic-hydrogen ammonia process, power is the major operating cost. As 1 part of oxygen is produced with every 2 parts of hydrogen, a profitable market for this oxygen, such as the oxidation of ammonia to nitric acid, reduces the cost of manufacture materially. Then, too, electrolytic hydrogen costs would be reduced if such manufacture were carried on with off-peak power as the electrolytic hydrogen cells operate efficiently under great load variations. The cyanamide process requires large amounts of power per ton of nitrogen fixed as well as coal, coke, and limestone. The cyanamide is not only converted into ammonia and all ammonia compounds, but into the fertilizer area containing 45 percent nitrogen, into calcium cyanide for metallurgical reductions, into hydrocyanic acid for plant fumigation, and into ferrocyanide used in dye manufacture. Methanol used in the production of formaldehyde, insolvents and in other chemicals is the principal by-product of water-gas ammonia.

58. *Industrial control.*—The two largest producers of direct synthetic ammonia are the Atmospheric Nitrogen Corporation, a subsidiary of the Allied Chemical & Dye Corporation, and the E. I. du Pont de Nemours & Co. The latter company oxidizes much of its ammonia to nitric acid for use in the explosives, nitrate plastics, and nitrocellulose lacquers it manufactures. The American Cyanamide Co., producing cyanamide at Niagara Falls, Canada, phosphoric acid at Tampa, Fla., and ammonium phosphate and other chemicals in New Jersey, owns controlling cyanamide patents.

59. All nitrate-producing countries save the United States have entered into an agreement concerning production quotas, export quotas, and prices, such agreement becoming effective in August 1930.

FERRO-ALLOYS AND THE IRON AND STEEL INDUSTRY

60. *Ferro-alloy plant Location.*—Original plants for the electrothermal manufacture of ferrosilicon and ferrochromium were located at Holcomb Rock, Va., and at Kanawha Falls, W.Va., during and immediately after the Spanish American War. Ten years later production began at Niagara Falls. But foreign competition hindered extensive development of all ferro-alloy manufacture until the outbreak of the European war. The demand for alloy steels, the employment of ferrosilicon to supply hydrogen for aircraft, caused

⁸Not printed.

the United States Government to encourage the building of ferro-alloy plants in States where alloying minerals were available. Under this stimulus, plants were built in Washington, Oregon, California, Montana, Colorado, Alabama, Tennessee, as well as in Iowa, Pennsylvania, Maryland, and New York. From 1915 to 1917, production of ferro-alloys increased 184 percent. With the cessation of hostilities, all far-western plants were forced to close down. But the ferro-alloy industry had been firmly established in this country. Ferrosilicon production was 88 percent more in 1929 than in 1919. From 1928 to 1929 it increased 12 percent while production of the rarer alloys such as ferrochromium, ferrovandium, ferrotungsten, and ferromolybdenum increased 24 percent.

61. The largest manufacturer of electrothermal ferro-alloys in the United States is the Electro-Metallurgical Co., a unit of the Union Carbide & Carbon Corporation. This company has a large factory at Niagara Falls where a number of ferro-alloys are manufactured. It produces ferrovandium in Ohio and operates the original ferrosilicon and ferrochromium plants in Virginia and West Virginia. It is completing the construction of a hydroelectric power plant on the New River, W.Va., which will furnish 80,000 horsepower to a new unit of the company erected at Boncar, W.Va. The Union Carbide & Carbon Corporation manufactures ferromanganese electrothermally in Norway.

62. The Vanadium Corporation of America is especially interested in the manufacture of ferrovandium and the rarer alloys, although it also manufactures ferrosilicon and ferrochromium at Niagara Falls. Other electrothermal ferrosilicon plants are located at Keokuk, Iowa, and near Chattanooga, Tenn. A small amount of this alloy is produced as a by-product of artificial abrasive manufacture. Several smaller plants are making a specialty of specific rare ferro-alloys and are located near consuming markets.

63. *Sources of alloy materials.*—Although the United States has achieved virtual independence in the manufacture of ferro-alloys, imports being chiefly of electrothermal ferromanganese from Canada and Norway, it is still largely dependent on foreign countries for all alloying minerals save silicon and molybdenum. Manganese ore is imported principally 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. Reserves of chromium, tungsten, uranium, and vanadium are located in Pacific Coast or Rocky Mountain States. Reserves of high-grade manganese are not extensive in the United States but large reserves of low-grade ores are found in these Western States and in Minnesota. Efforts to concentrate these ores to the purity demanded by steel manufacturers have reached the trial commercial plant stage.

64. *Ferro-alloy markets and location of iron and steel industry.*—At present, largest markets for ferro-alloys are in Pennsylvania and Ohio where almost 60 percent of all steel is produced. Indiana and Illinois manufacture about 20 percent of all steel. The iron and steel industry is located in coking coal regions because it is less costly to bring iron ore to coal than coal to iron. Only in Alabama do coking coals and iron ore occur in adjacent fields.

65. *Iron ore supply.*—Seven eighths of all iron ore consumed in the United States comes from the Lake Superior region. As the estimated life of these deposits is drawing to a visible end at present consumption rates, radical changes may occur in the iron and steel industry in another quarter century. A large iron and steel firm has already secured control of some iron-ore deposits in South America. Some experts believe China will export iron ore to this country. Others believe that the exhaustion of hematite ores in the United States will bring with it the abandonment of the blast furnace and the adoption of low-temperature reduction furnaces operated by gas, oil, or electricity on magnetite iron ores of far Western and Eastern States. If any one of these predictions prove correct, the iron and steel industry will tend to move to locations that can be reached by ocean shipment. Under existing conditions, it is gradually moving westward.

66. *Increased use of electricity in iron and steel.*—Electric-furnace production of iron from its ores is carried on in Norway, Sweden, and Italy. While iron and steel of high quality has also been produced in this country, there is so small a market for the product that manufacture has not been able to proceed on a commercially profitable scale.

67. The increased production of alloy steel is, however, bringing with it new installations of electric melting and refining furnaces as well as expanding ferro-alloy manufacture. The relationship between alloy-steel production and ferro-alloy production is clearly shown on graph III. Although only 1 percent of steel ingots produced in 1929 was melted or refined in the electric furnace, this constituted a 17 percent increase in electric furnace ingots in 1 year. Electric furnace iron and steel castings formed 26 percent of castings produced. Approximately seven tenths of all alloy steel is consumed by the automobile industry.

68. *Markets.*—The building and construction industry vies with the automotive industry for first place in steel consumption. Railroads afford the third largest outlet for rolled products. These three industries absorb approximately 50 percent of all rolled steel. Oil, gas, and water companies are heaviest consumers of pipe and rank second 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.

69. While major consuming markets are in the East and Middle West, the purchase of Pacific coast iron and steel mills in 1929 by the two largest steel corporations is indicative of the increasing demand for steel on the Pacific coast. Only a sixth of Pacific coast steel market needs are met by existing Pacific coast States. One fifth of all tin plate produced in the United States is consumed by canning industries on the Pacific coast, while but 10 percent of these needs are supplied by local mills. None of the pipe and seamless tubing, rail, and plate requirements of this region are met by Pacific coast plants.

70. Exports of iron and steel are chiefly in the form of finished rolled products; tinplate, terneplate, and structural shapes exceed all other forms. Tinplate and terneplate are shipped principally to Japan and Canada, to China, Argentina, Mexico, British India, Siam, Cuba, and South American countries. Structural

shapes go chiefly to Canada. Plates and sheets go in largest measure to Canada, Japan, and the Philippine Islands.

71. *Control.*—More than 80 percent of the steel ingot capacity in the United States is controlled by 11 steel companies. The United States Steel Corporation produced 41.6 percent of the iron ore of the country, 29 percent of the coke, and 39 percent of our steel ingots and castings.

ZINC AND CADMIUM REDUCTION

72. *Plant location.*—The location of zinc reduction plants in the United States has been determined by the character of ore treated and the specific reduction process employed. As fuel is essential to zinc distillation, zinc retort plants are located in coal mining or in natural gas regions. Zinc-lead ores of Oklahoma, Kansas, and Missouri are smelted at natural gas fields in Oklahoma and Kansas or are shipped to Arkansas gas fields or to Illinois coal fields. One electrolytic plant is located in Illinois near a large steam power plant. Zinc oxide ores of New Jersey are sent for distillation to Pennsylvania coal fields. Southern States ship to either middlewestern or Pennsylvania smelters, although new construction is taking place in West Virginia coal fields. Complex ores of the Rocky Mountain region are reduced by flotation and electrolysis near zinc mines as abundant power is obtainable near largest zinc mining regions.

73. *Production and consumption.*—In 1929 there were four electrolytic zinc plants, producing 23 percent of the zinc, and 21 operating retort smelters. Zinc production in 1929 was the largest in the history of the industry, although smelters were operating at less than 60 percent capacity. The apparent consumption in 1929 was approximately 15 percent less than production. In 1930 production fell to its lowest level since 1922.

74. Forty-six percent of zinc consumed in the United States is used in galvanizing sheets, tubes, and other iron and steel products. Twenty-nine percent is mixed with copper to produce brass. Eleven percent is rolled into zinc sheets or strips for roofings, boilerplate, electrotype, and dry batteries. Pigments, paints, and rubber consumed less than 10 percent. Die castings made of a zinc-tin-aluminum-copper alloy are finding a market in the automobile hardware industry. Efforts are being made to introduce this alloy into building hardware manufacture and to find new markets for zinc. Exports of zinc are small.

75. *Industrial control.*—The largest production of metallic zinc in 1929 occurred at the two electrolytic plants of the Anaconda Copper Mining Co. in Montana. This company has also operated since 1929 large zinc properties in upper Silesia, ceded to Poland by the Treaty of Versailles. Here zinc is not only mined, smelted, and manufactured into finished products, but pig lead and lead products, sulphuric acid, superphosphate, and mixed fertilizers, as well as coal, brick, lumber, porcelain, paper, and explosives are produced.

76. The New Jersey Zinc Co. not only mines and distills zinc, but produces finished products and sulphuric acid. Subsidiaries of the United States Steel Co. produce zinc ore in the Tri-State District and in Tennessee. The Grasselli Chemical Co., a subsidiary of E. I. du Pont de Nemours & Co., operates two zinc plants and is also producing sulphuric acid from zinc fumes. A number of other com-

panies operate in the Tri-State District. The only other western zinc electrolytic plant is located at Kellogg, Idaho, and is operated by the Sullivan Mining Co.

77. *Competitive processes.*—Supplies of zinc in the United States and in other countries are abundant. The existing plant capacities in the United States and in Europe exceed demands. Sharp competition between zinc companies has resulted.

78. The electrolytic process has marked advantages over the old retort distillation methods. Not only is a zinc of higher quality produced, and a higher extraction of zinc secured, but elements lost in distillation operations are saved. Gold and silver are recovered in a lead concentrate and are shipped to lead smelters and refineries; residue copper is sent to copper refineries. Cadmium, used to electroplate ferrous materials and as a primary wash for automobile parts that are to be chromium or nickel plated, is necessarily precipitated before the electrolysis of zinc. It also is recovered by electrolysis. Cobalt, now alloyed with tungsten carbide in high-speed machine tools, and with chromium and tungsten for acid and heat resistant equipment, is a recoverable byproduct. Cobalt is secured for its oxide, electrothermally. Arsenic, thallium, and other elements are recoverable whenever a market is found for these substances. Sulphur dioxide fumes may be collected from either electrolytic or distillation processes wherever a market exists for sulphuric acid. This acid is now consumed principally in fertilizer manufacture and in petroleum refining (in which fields it is meeting competition from other acids or by new production methods), in chemicals, metallurgical reduction, paints, pigments, explosives, paper, rayon, and textiles.

Improvements are being made in retort distillation methods, however, and several new processes are being tested.

CAUSTIC SODA AND CHLORINE PRODUCTION

79. *Plant location.*—The cost involved in evaporating dilute solutions of caustic soda to concentrated form for shipment only to be diluted again in actual application, the difficulty, only recently overcome, of shipping corrosive chlorine, has caused caustic soda and chlorine plants to be established close to consuming markets. In fact, manufacturers requiring large amounts of chlorine have frequently established their own electrolytic chlorine plants, while others requiring caustic soda, only have installed equipment to manufacture the caustic from sodium carbonate.

80. The electrolytic branch of the industry has been fortunate in finding its largest markets close to power supplies and to brine sources. Five plants are located at Niagara Falls, near brine wells and near New York pulp and paper plants and other consuming industries. Michigan electrolytic plants are located above brine wells and serve principally Michigan and Wisconsin pulp and paper industries. West Virginia plants are near organic chemical factories, the California plant sells to petroleum refineries and soap industries, while Washington electrolytic plants were established to serve the pulp and paper industry of the Pacific Northwest. While there are 19 electrolytic caustic soda and chlorine plants serving all markets, 17 other plants are operated at paper mills by paper companies.

81. *Consuming markets.*—It is estimated almost two thirds of all chlorine produced enters the pulp and paper industry. Whether in liquid or gaseous form, as a hypochlorite or in bleaching powder, some form of chlorine is used in paper manufacture to remove impurities left by all pulping processes. Twenty percent enters into textile production. Amounts of chlorine used for purifying drinking water and bathing beaches, and for other sanitary purposes are increasing. Aluminum chloride enters into oil refining. Chlorine is used to detin tin-plate scrap. It is also the basic ingredient of almost every one of modern chemical warfare agents. But the largest recent increased demand for chlorine has come from the synthetic organic chemical industry.

82. Electrolytic production of caustic soda has been hindered by lack of market for chlorine. The extended use of chlorine in synthetic organic and chemical production or expansion in industries already served will increase the demand for chlorine and at the same time increase the consumption of electrolytic caustic soda. Unless part of the cost of electrolytic production of caustic soda is borne by the chlorine produced simultaneously, such caustic cannot compete with caustic soda produced by the lime-soda process. The largest markets for caustic soda are offered, at present, by the rayon, the chemical, the petroleum, and the soap industries, each of which purchases 15 percent or more of the total amount marketed. Soda pulp for fine papers, rubber reclaiming and textiles are also products which require caustic soda. Exporting markets are in Japan, the Philippines, Mexico, Cuba, Canada, and South America, where our products come in competition with those of Great Britain, which at present supplies about three fourths of the market.

83. *Diversification of products.*—Manufacturers of electrolytic caustic soda and chlorine do not confine themselves to the production of these two chemicals. As caustic soda and chlorine are raw materials for a number of other chemicals, each electrolytic producer for the general market manufactures such sodium and chlorine compounds as his market demands. Recently other constituents of brine than sodium chloride have been utilized. Well brines containing magnesium chloride supply all metal magnesium now manufactured in the United States. Bromine and calcium chloride may also be secured by electrolytic methods. Such utilization of brine and the manufacture of related chemicals so diversifies consuming markets and so divides overhead expense as to fortify electrolytic caustic soda and chlorine production against competition from lime-caustic soda.

PULP AND PAPER AND OTHER CELLULOSE INDUSTRIES

84. The pulp and paper industry not only affords chlorine its largest market, but caustic soda, soda ash, sulphur, lime, sodium sulphate, aluminum sulphate, casein, clays, and rosins find extensive demand in the several types of pulp and many kinds of paper made. Then, too, the quantity and quality of water supply is a matter of vital importance to pulp and paper manufacture.

85. *Location of industry.*—From earliest times, pulp and paper mills located on the banks of streams where a clear, abundant water supply was available near forests supplying the pulpwood. As such locations were plentiful in New York, New England, and Pennsylvania, early paper mills were established fairly close to consuming centers. With

the westward movement of population, spruce forests of Wisconsin, Michigan, and Minnesota were cut for newsprint paper and the hardwoods of Ohio and Indiana added to the book paper pulpwood supply; paper mills were established near these sources of supply. In 1909, three fifths of all pulp and paper was produced in New England, New York, and Pennsylvania, and about one fourth in Lake States.

86. This over-centralization, combined with the heedless felling of trees, developed a shortage in the supply of spruce in these States. Paper mills turned to Canadian forests for a part of their supply. In 1910, the Government of Quebec prohibited the exportation of any wood cut from crown lands. This policy was followed by other provinces until pulpwood could only be shipped into the United States from freehold lands comprising about one tenth of Canadian pulpwood lands. Since 1911, standard newsprint paper and pulp has entered this country duty free.

87. *Imports.*—The effect of these two policies is reflected on graph VI.¹ While our imports of pulpwood have not changed, proportionately, in 20 years, our imports of wood pulp and paper have increased materially. When all paper and wood pulp imported into this country are reduced to their pulpwood content, about 60 percent of the forest material for paper used in the United States comes from outside our country. These imports are chiefly of newsprint paper or of pulp and wood for such paper, and of pulp for wrapping paper.

88. *Pulpwood reserves.*—One half the Nation's spruce reserves are in Washington and Oregon. One fourth of our pines, available for wrapping paper, are on the Pacific coast. These States possess the same natural advantages for newsprint pulp and paper manufacture as does eastern Canada; that is, extensive forests and cheap hydroelectric power. These States have demonstrated that they can produce the chemicals necessary for paper or rayon manufacture. Yet Washington State produced but 8 percent of the Nation's wood pulp and 3 percent of the Nation's paper requirements, while Oregon and California produced but 5 percent of the wood pulp and 3.7 percent of the paper requirements.

89. By correlating the lumber industry with the pulp industry, Northwestern States have been able to produce mechanical and sulphite pulp for newsprint paper more cheaply than can be done in Eastern States, but not cheaply enough to meet competition in eastern markets of Canadian and Scandinavian pulp. Sweden has been able to meet Canadian competition in American markets by so integrating her lumbering, sawmill, planing mill, and pulp-mill activities that almost all her pulp is manufactured from logging and sawmill waste. The extensive lumber industry of Washington and Oregon make similar correlation possible in these States.

90. *Consuming markets.*—Paper mills which purchase wood pulp from distant sections are located principally in New York State, Pennsylvania, Ohio, and Michigan. Massachusetts, Connecticut, New Jersey, Maryland, Indiana, and Illinois also purchase some pulp along with much waste paper and waste textiles.

91. The market for final paper product whether it be newsprint or magazine paper, paper boxes or wrapping paper, building boards or fine stationery, is dependent upon the size and character of specific

¹ Not printed.

retail purchasing markets. The New York City metropolitan area consumes far more paper than any other section. Illinois ranks second in printing and publishing of all types; Pennsylvania third, and Ohio fourth. Massachusetts and California follow.

92. Pacific coast paper mills supply paper needs of Pacific coast and Rocky Mountain States. A British Columbia paper mill ships newsprint paper via the Panama Canal to Texas, Louisiana, Oklahoma, New Mexico, Arkansas, Nebraska, and Kansas. Gulf ports and lower Mississippi ports can be reached more cheaply from Seattle than from New York, but large middle western consuming cities are served more cheaply by Lake State paper mills.

93. Paper and pulp exports are small. Export trade is chiefly with the Philippines, China, and Mexico.

94. *Newsprint paper purchasers.*—Four publishers in the United States purchase about 30 percent of all newsprint paper available in the United States. The Hearst papers require almost 15 percent, the Scripps-Howard, the Patterson-McCormick, and the Ochs papers purchasing the remaining 15 percent. Over three fourths the newsprint paper is purchased for large daily papers. These papers contract for their paper supply from 1 to 10 years. The hundreds of small daily papers and thousands of weekly papers buy through jobbers or through cooperative associations in small lots.

95. *Control of paper and pulp industry.*—Twenty-one firms operating mills in the United States and Canada have daily capacities of 500 tons or over finished paper. The largest of these, the International Paper Co., manufactures all kinds of wood pulp and many kinds of paper. It produces the larger part of its newsprint paper in Canada where it has timber rights to an extensive acreage and owns hydroelectric power systems. The Canada Power & Paper Corporation has the second largest productive capacity. The Crown Zellerbach Corporation, of Washington, Oregon, and Canada, ranks third in pulp and paper production. The next two largest companies are Canadian companies. The largest producer of newsprint paper in the United States is the Great Northern Paper Co. of Maine. The largest book paper manufacturer is the West Virginia Pulp & Paper Co. with mills in New York, Pennsylvania, Maryland, and Virginia.

96. All Canadian newsprint mills in the Provinces of Ontario and Quebec are members of the Newsprint Institute of Canada, organized through the efforts of the Prime Ministers of these provinces to bring about a more even distribution of available business.

97. *Rayon, cellulose plastics, and cellulose lacquers industries.*—The rayon, cellulose plastic, and cellulose lacquer industries are not large consumers of power in themselves although the rayon industry requires a 24-hour supply. Only when they are considered as markets for electrolytic chemicals do these cellulose industries become of interest in power development. Each ton of viscose rayon requires 2 tons of high-quality caustic soda. All rayon pulp and rayon skeins are bleached with chlorine compounds. The cellulose acetate rayon and plastics require acetic anhydride in the manufacture of which chlorine compounds are essential. The cellulose nitrate plastics and lacquers require nitric acid now made by the oxidation of ammonia, the hydrogen content of which may be obtained from the electrolytic production of caustic soda and chlorine.

98. *Sources of raw materials.*—About 80 percent of the world's rayon is manufactured from spruce pulp. American rayon mills do

not buy the spruce but purchase sulphite pulp made from it. The Canadian International Paper Co. at Temis-Kaning, Quebec, is the largest manufacturer of bleached sulphite pulp for rayon. The only large producer of such pulp in the United States is the Brown Co., of Berlin, N.H. The Rainier Pulp & Paper Co., of Shelton, Wash., is now manufacturing rayon pulp from hemlock.

99. Cotton linters, obtained from a second ginning of cotton after the staple cotton has been removed in the first ginning, also serve as a raw material for some rayon and for a number of the cellulose plastics.

100. *Plant location.*—Large American rayon factories not only produce rayon skeins but they carry on such textile operations as render the threads in condition for the knit goods manufacturer or the weaver. European firms ship rayon skeins to “converters” in this country, who dye, twist, and wind the threads in a manner desired by knitting and weaving customers. Because textile operations are a part of rayon production in this country, labor costs form from 40 to 50 percent of total costs, while engineering and administrative services add another 10 percent to the pay roll. Labor requirements have caused large rayon mills to be built in sections where no other industry is competing for semiskilled man and woman labor, woman labor forming approximately half the total amount required.

101. *Industrial control.*—It is claimed that 80 to 85 percent of the world's rayon production is controlled directly or indirectly by three companies: Courtalds, Limited, of England; Snia Viscosia of Italy, and Vereinigte Glanzstoff-Fabriken of Germany. The English company operates as the Viscose Co. in the United States and is by far the largest producer of rayon in this country. The German company operates two plants in Tennessee. The Italian company no longer operates any American plants, although a second Italian company operates one plant. The E. I. du Pont de Nemours & Co. is associated in rayon production with the leading French rayon producer.

102. While the rayon industry in the United States has been built up largely by foreign companies operating under foreign patents, the cellulose plastics industry has developed as an American industry. The E. I. du Pont de Nemours & Co. is the largest producer of cellulose nitrate and manufactures the cellulose into numerous plastic forms and into lacquers. The Eastman Kodak Co. is the largest producer of cellulose acetate plastic, its plant being located at Kingsport, Tenn.

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