POWER IN ZINC AND LEAD PRODUCTION

TABLE OF CONTENTS

Power in Zinc and Lead Production

The electrolytic treatment of zinc has made available zinc found in abundance in the complex ores of Idaho, Montana, northwestern Washington, Utah, and Colorado. Zinc and lead occur in the same deposits in these States. Lead smelters were erected in districts in which lead was the dominant mineral; electrolytic zinc plants are being erected in districts in which zinc is the principal mineral. The companies operating zinc- and lead-reduction plants are usually identical, each company shipping all zinc recovered from its lead concentration and smelting plants to its electrolytic zinc units, and all lead recoveries from zinc concentration and refining plants to its lead smelters.

A steady current is essential for the electrolysis of zinc which requires from 2,500 to 3,350 kilowatt-hours of energy per ton of zinc produced. The capacity of plants in the United States totals 645 tons electrolytic zinc daily. British Columbia has a 380-ton electrolytic plant, while the world's total electrolytic zinc plant daily capacity is approximately 2,000 tons.

Electrolytic zinc competes with zinc distilled in retorts. Not only is the cost of electrolysis less, but electrolysis produces a zinc of higher quality, secures a higher extraction of zinc, and recovers other elements lost in distillation operations. The gold and silver recovered during electrolytic processes are shipped in lead concentrates to lead smelters and refineries; residue copper is sent to copper refineries, while cadmium is produced electrolytically at some zinc electrolytic plants. Other elements such as cobalt, arsenic, thallium, indium, gallium, and germanium are recoverable wherever a market is found for these byproducts. Sulphur dioxide can be recovered from electrolytic plants as well as from retort plants.

The productive capacity of electrolytic and retort plants already built exceeds present zinc consumption in the United States. The same situation prevails throughout the world. The major problem of the industry is, therefore, to increase the outlets for zinc so that the abundant resources in the United States, Canada, Australia, Africa, Mexico, and Poland may be adequately developed.

A minor market for electricity in zinc application is being developed in the galvanizing of iron and steel. From 100 to 230 kilowatt-hours of energy is consumed per ton of metal galvanized, dependent upon the quantity galvanized at one heat and upon the period of plant operation.

Lead is smelted and refined so easily and cheaply by pyrometallurgical methods that electrolytic refinement is employed only to produce the highest quality lead, free of bismuth, an outlet for which is found in the white lead pigment industries. In the pigment industry electrolytic lead competes with the electrolytic production of pigment for impure furnace-refined lead. Approximately 95 to 110 kilowatt-hours of energy are required for the electrolytic refinement of lead. Byproduct bismuth is also refined electrolytically. Gold and silver in the residue may be parted chemically or electrolytically.

DEVELOPMENT OF THE ZINC INDUSTRY IN THE UNITED STATES

1. The expansion of the zinc industry in the United States parallels the adoption of ore treatment and reduction methods that have made

metallic zinc available from ores containing differing minerals. Zinc does not occur as a metal in nature but is found as a sulphide, an oxide, or as a carbonate. Some zinc ores are almost free of other metallic elements, others are associated with iron, lead, or copper, and others are combined with a number of metals.

2. *Zinc oxide deposits developed.*—In New Jersey only are located large deposits of zinc oxide ores free of other metals or combined with some iron or with silica. Small deposits of carbonate ores were found in Pennsylvania and Wisconsin. As calcining was sufficient treatment for zinc oxide and carbonate ores, these deposits were the first to be developed. They supplied the brass industry of Connecticut with zinc in the early nineteenth century. The zinc oxide mines of New Jersey have been continuous producers, New Jersey ranking third in zinc mining in 1929.

3. *Zinc-lead sulphide mining.*—Lead miners in Missouri discovered zinc sulphide in lead mines. At the close of the Civil War zinc mining was successfully developed in this State, thus causing zinc-lead mines located in neighboring States to become zinc producers. For a time Missouri was the largest zinc-producing State in the Union, but as lead proved to be the more abundant mineral, Missouri's position as a zinc producer of importance was lost. But the two adjoining States of Oklahoma and Kansas continued to increase zinc production until Oklahoma held first place in zinc mining and Kansas, second position.

4. Desultory mining of zinc sulphide ore without lead was carried on from time to time in Tennessee and Virginia. Rocky Mountain lead smelters penalized miners who delivered lead ores containing more than a specified percent of zinc because zinc was detrimental in lead blast furnace operation. Middle western retort plants would not purchase concentrates containing less than 40 percent zinc. Consequently only a few zinc mines could be developed in the Rocky Mountains, although much zinc was found in combination with other metals.

5. In 1871 there were 7 zinc smelters producing 6,900 tons of zinc; in 1880 there were 13 smelters producing 25,100 tons.[71] Or, in this 10-year period, 152,700 tons of metallic zinc was produced in United States smelters. In the next 10 years zinc production almost trebled. Production increased to meet national demands until a maximum of 346,676 tons were smelted in 1913.

6. *Complex zinc ores made available.*—The zinc industry had become well established in Germany, Belgium, France, and Great Britain long before it began in this country; consequently, European markets were supplied by European zinc smelters. With the beginning of the World War, the German and Belgium zinc industry was demoralized. Zinc was essential for the manufacture of brass cartridge metal. United States zinc mines increased their output in all zinc-producing States, and smelter capacities doubled. In 1917, 669,573 tons of metallic zinc were produced.

7. This sharp demand gave impetus to the commercialization of the electrolytic treatment of complex zinc ores of Montana, Idaho, and Colorado. The development of the electrolytic zinc process brought about the application of selective flotation to complex zinc ores. Not only was a greater recovery of zinc made possible, but lead, silver,

[71] Siebenthal, C. E. Zinc Production in the United States Before 1882.

gold, cadmium, and other metals were recovered, thereby lessening the cost of zinc production. The zinc produced was also of great purity. The low cost of production in the Rocky Mountains forced tri-State miners to adopt flotation where ores had valuable byproducts and forced smelters to consider new methods of concentrate reduction.

8. *Lead ores a source of zinc.*—In 1925 the big lead smelters of Utah constructed lead-zinc flotation plants where lead-zinc ores of their own and other mines were concentrated. These ores usually contain less than 10 percent zinc. Instead of being penalized for this zinc, the miner is now paid for it.

9. More recently any zinc that is not segregated from lead by selective flotation is removed from lead furnace slags and recovered as a fume containing 70 percent metallic zinc.

10. *Reorganization of the industry.*—The tri-State mining district had been built up by many small miners selling their ores to smelters located outside the mining fields. But with the growth of the zinc industry, firms originally operating as smelters only acquired zinc mines. Firms consuming zinc in galvanizing, in paints, or in chemicals have built zinc smelters and purchased or leased zinc mining properties. The New Jersey ores have been mined and reduced by one company. The electrolytic treatment of ores has been developed in large units by firms mining their own ores but also purchasing some concentrate. But even today, in the tri-State region and in Colorado and other Rocky Mountain States, there are still a number of small mines in operation.

11. Not only, therefore, are there zinc producers only interested in the zinc industry, but lead, copper, steel, and chemical firms are also zinc manufacturers and miners. The Mining Congress Journal of November 1930 states that there are 92 zinc mines, representing an investment of $200,000,000. There are 4 electrolytic zinc plants and 21 operating retort smelters.

12. *Present-day conditions.*—The expansion in zinc production in the United States, stimulated by war's demands and made possible by electrolysis and flotation, has outstripped the market demands for zinc. Before the war had closed, the American Zinc Institute was organized to bring about better relationships between miner, smelter, and galvanizer and to stimulate the use of zinc. In 1929, 624,520 tons of primary zinc were produced in this country and 47,348 tons of secondary zinc were redistilled, making a total of 671,868 tons. This production was attained with smelters operating at less than 60 percent capacity. The apparent consumption given by the Bureau of Mines was but 564,049 short tons.[72] Output of primary zinc fell to 498,045 tons in 1930, while production of redistilled secondary zinc was 34,849 tons, giving an available supply of but 532,894 short tons in the last year.

13. Zinc slab prices at St. Louis were $0.04266 in November of 1930, as compared with $0.06242 in November 1929 and $0.08568 in November of 1925. In the Rocky Mountain regions where complex ores are mined, zinc has been regarded as somewhat of a byproduct, adding value to the silver, lead, and copper marketed. The low prices prevailing in 1930 on all four ores caused small mines in the West as well as in the Middle West and East to close down.

[72] U.S. Bureau of Mines. Production of Slab Zinc and Rolled Zinc in 1929. U.S. Bureau of Mines Production of Slab Zinc and Rolled Zinc in 1930.

TABLE I.—*Types of zinc and lead ore mined in each State in 1928* [1]

[In short tons]

State	Zinc-lead, lead-zinc, and complex ores				Zinc-oxide or sulphide ores		Lead-sulphide ore	
	Zinc content	Value	Lead content	Value	Zinc content	Value	Lead content	Value
Total	551, 125	$67, 237, 300	607, 052	$70, 302, 227	144, 045	$19, 516, 228	20, 082	$2, 329, 246
Arizona	639	77, 997	1, 640	190, 347			5, 550	643, 749
Arkansas	86	10, 492	38	4, 408				
California							946	109, 680
Colorado	35, 731	4, 359, 182	21, 861	2, 419, 914			5, 890	683, 186
Idaho	31, 263	3, 814, 126	142, 354	16, 513, 042			2, 969	344, 420
Illinois	17	2, 074	385	44, 660				
Kansas	107, 251	13, 084, 622	25, 276	2, 932, 016				
Kentucky	92	11, 224	39	4, 524				
Missouri	12, 974	1, 582, 828	195, 393	22, 665, 588				
Montana	82, 830	10, 105, 270	16, 221	1, 881, 631			659	76, 428
Nevada	3, 398	414, 599	4, 278	496, 174			3, 596	417, 178
New Jersey					99, 871	$14, 127, 000		
New Mexico	31, 203	3, 806, 766	7, 795	904, 270			10	1, 139
New York					11, 257	1, 373, 354		
Oklahoma	180, 252	21, 990, 744	43, 687	5, 067, 692				
Oregon							7	768
South Dakota							37	4, 292
Tennessee	(2)	(2)			[2] 32, 917	4, 015, 874		
Texas							348	40, 343
Utah	46, 929	5, 725, 298	145, 845	16, 918, 078			70	8, 063
Virginia	(2)	(2)	(3)	(3)				
Washington	43	5, 204	542	62, 915				
Wisconsin	18, 417	2, 246, 874	1, 698	196, 968				

[1] Compiled from reports of U.S. Bureau of Mines.
[2] Includes zinc content of ores mined in Virginia.
[3] Lead content of Virginia ores not available.

PRODUCTION OF ZINC AND LEAD ORES IN THE SEVERAL STATES

14. *Washington.*—In the northeast corner of Washington, in Pend Oreille and Stevens Counties, are located zinc carbonate, lead-zinc ores, lead ores, and copper-lead ores. One thousand tons of zinc and 508 tons of lead were produced in 1929. The only year in which a greater amount of zinc was produced was in 1923, when a total of 1,512 tons was reached. The lead-zinc ores contain some silver and a little gold. The zinc ore averages about 8.6 percent recoverable zinc and the lead-zinc ore about 7 percent. Recently a "zinc rush" to the Metaline district led to the establishment of a number of claims by individual miners in this district. It has been reported that the Pend Oreille Lead & Zinc Co., with mines and flotation plant near Metaline Falls, and the Reeves McDonald properties in British Columbia have been taken over by the Pend Oreille Mines & Metals Co. It is believed this company is contemplating the establishment of an electrolytic plant for reduction of both Canadian and American ores in Washington State.[73] In 1929 zinc concentrate from the Grandview Mill was shipped to the new electrolytic zinc plant near Kellogg, Idaho. Lead-zinc ore from the Great Western project was shipped to Mineral Point, Wis.

15. *Idaho.*—Zinc is found in largest quantity in the lead-zinc ores in Idaho. While 60 percent of the lead mined in the State and 51 percent of the silver is gotten from lead ores, 98 percent of the zinc is concentrated from lead-zinc ores containing silver, a little gold, and

[73] Senate hearings. Tariff Act of 1929. Vol. III.

some copper. The Coeur d'Alene district in Shoshone County is by far the largest producing district, but Blaine County mined about 2,500 tons in 1929, and small amounts were mined in Valley and Bonner Counties. Custer County produced zinc in 1928.

16. The State mined 5.5 percent of the total zinc in the United States in 1929, 22.9 percent of the lead, and 15.4 percent of the total silver mined. The erection of the electrolytic zinc plant near Kellogg by the Bunker Hill & Sullivan Mining & Concentrating Co. and the Hecla Mining Co. to treat zinc ores of the Couer d'Alene district will serve to stimulate the mining of complex ores in northern Idaho when market conditions warrant. Much Idaho ore is still sent to Great Falls and Anaconda electrolytic plants.

17. *Montana.*—Until the adoption of selective flotation, zinc was largely a waste product of silver mines in Montana. Although some lead occurs with the zinc, lead is distinctly a by-product of zinc concentration, rather than zinc a by-product of lead concentration, as in Idaho.

18. Almost four fifths of the zinc produced in 1929 came from the Butte region in Silver Bow County. Some was recovered from the fuming plant at the East Helena lead smelter of the American Smelting & Refining Co. Zinc ore in relatively small amounts was produced in Lewis and Clark, Judith Basin, Granite, Jefferson, Cascade, Broadwater, Lincoln, Madison, Mineral, and Sanders Counties. The total State production of zinc in 1929 was 54,900 tons, forming 8 percent of the total national production. In addition, 19,607 tons of lead and 12,716,977 fine ounces of silver were produced. In 1928 zinc production totaled 82,830 tons, the highest achieved to date.

19. The electrolytic plants at Great Falls and Anaconda treat all ores mined by the Anaconda Copper Co. and custom ores from Montana, Colorado, Utah, and Idaho. A rough estimate states that about half the concentrate treated originates in Montana, about a third in Colorado and Utah, and about 17 percent in Idaho. This mixed concentrate contains approximately 53 percent zinc and 3.6 percent lead.

20. *Colorado.*—Colorado has a large number of relatively small complex ore bodies containing lead, zinc, or copper, gold, and silver. The principal zinc-producing counties are Lake, San Juan, and Dolores Counties, although some zinc is produced in Summit, Pitkin, Hinsdale, Gunnison, Eagle, and Clear Creek Counties. Total production in 1929 was 23,600 tons or 3.4 percent of the United States total. In 1928 it was 35,731 tons. This is less than the average annual production from 1911 to 1920. With the increased zinc production in other mountain States, Colorado miners have found competition keen. The smallness of the mines, their individual ownership, and the relatively low-grade ore do not permit the establishment of smelters or electrolytic plants. Consequently, concentrate is shipped to Illinois, Texas, or Montana for smelting or electrolytic treatment, and must bear transportation costs. Colorado produced 24,445 tons of lead, 4,397,377 fine ounces of silver, and $4,417,358 in gold.

21. *Utah.*—Until 1925 Utah produced but little zinc. Most of its lead-zinc ores contain less than 10 percent zinc. They were smelted for their lead and silver content, and zinc was not recovered. Ores containing more than this amount of zinc incurred a zinc penalty

at the lead smelters and yet had not sufficient zinc content to warrant shipment to zinc smelters. The adoption of selective flotation by the Tooele lead concentrator of the International Refining & Smelting Co. in November 1924 and by the United States Smelting & Refining Co. caused the production of zinc in Utah to jump from 9,281 to 26,306 tons in 1 year. Other companies later installed selective flotation units, so that Utah's zinc production reached 49,593 tons in 1928 and 46,929 tons in 1929, in which year it formed 9 percent of the total United States zinc production. The lead production of Utah in 1929 was 149,377 tons, the silver, including placer production, 17,592,396 fine ounces, and the gold, 240,419 fine ounces. The principal zinc-mining counties are Salt Lake and Wasatch. Summit, Tooele, Beaver, Juab, Sevier, and Utah Counties also produced zinc in 1929.

22. *Other Rocky Mountain States.*—Nevada produced 3,398 tons of zinc in 1928 and 1,200 tons in 1929, chiefly as a byproduct of lead concentration. Lincoln County was the chief zinc and lead mining center, while some zinc was produced in Nye, Clark, Elko, Eureka, and Mineral Counties. Nye County was the principal silver-producing county.

23. Arizona produced its maximum amount of zinc in 1926 when, from ores mined, 6,473 tons of zinc were obtained. In 1929 production was but 1,000 tons. The production is chiefly from lead-zinc ores in Santa Cruz County. Concentrate is shipped to the Amarillo and El Paso, Tex., smelters.

24. New Mexico produced 35,100 tons of zinc in 1929, or 5 percent of the United States total. Zinc is found in complex sulphide ore containing lead, iron, and sometimes copper and gold and silver. The largest producing mine is the Pecos Mine of the American Metal Co., in San Miguel County. Grant and Socorro Counties also produced some zinc. Lead production totaled 11,130 tons, and silver 1,121,546 fine ounces.

25. *Other Pacific Coast States.*—California mined ore having 10,217 tons zinc content in 1926, but has not produced any zinc in 1928 or in 1929. In the copper region of Shasta County some ores have higher zinc than copper content. Lead-zinc sulphide ore was reported from Plumas County in 1915. Zinc sulphide has also been found in the foothill copper belt, extending from Nevada County to Madera County. Ingo County produced 670 tons of lead in 1929, while small amounts were produced in seven other counties.

26. Oregon produces some lead in the eastern part. It is not marketing any zinc, although the zinc occurs in complex lead-zinc deposits in western Oregon.

TABLE II.—*Mine production of recoverable zinc in the United States* [1]

State	1925 (short tons)	1926 (short tons)	1927 (short tons)	1928 (short tons)	1929	
					Short tons	Percent
Total	710,847	774,563	718,541	695,170	695,000	100.0
Arizona	3,666	6,473	1,134	639	1,000	.1
Arkansas	43	87	128	86		
California	5,745	10,217	4,031			
Colorado	30,811	32,500	35,865	35,731	23,600	3.4
Idaho	15,619	26,307	26,778	31,263	38,300	5.5
Illinois	2,724	2,577	521	17		
Kansas	118,778	126,307	109,427	107,251	106,000	15.3
Kentucky	429	1,838	860	92		
Missouri	14,794	26,018	18,737	12,974	9,300	1.3
Montana	57,658	73,701	80,231	82,830	54,900	7.9
Nevada	7,411	5,409	3,172	3,398	1,200	.2
New Jersey	89,261	80,629	95,695	99,871	102,000	14.7
New Mexico	9,246	12,052	29,802	31,203	35,100	5.1
New York	5,158	5,041	3,750	11,257	(2)	
Oklahoma	283,371	272,567	206,611	180,252	197,000	28.3
Tennessee	16,256	12,098	10,400	[3] 32,917	47,000	6.8
Utah	26,306	47,590	49,593	46,929	61,600	8.9
Virginia	2,732	5,830	8,325	(3)	(3)	
Washington	609	522	640	43	1,000	.1
Wisconsin	20,230	26,800	32,841	18,417	17,000	2.4

[1] Compiled from U.S. Bureau of Mines: Zinc in 1928, p. 376, and Mineral Industry, 1929, p. 665.
[2] Included with Tennessee total.
[3] Figures for Virginia not available; included with total for Tennessee.

27. *The Tri-State District.*—At the junction of Oklahoma, Kansas, and Missouri lies the largest zinc producing district in the United States. Oklahoma produced 197,000 tons of zinc in 1929, or 28.3 percent of the United States production; Kansas produced 15 percent, and Missouri 1.3 percent. Highest production was achieved by Oklahoma in 1925, when the zinc content of ores mined was 283,371 tons. Prior to 1915 Missouri was the principal zinc-producing State in the district, but since that date Oklahoma and Kansas have been by far the more important producers of zinc, and Missouri the leading lead-producing State in the Union. Oklahoma zinc is mined in Ottawa County, Kansas zinc in Cherokee County, Missouri zinc in Jasper, Newton, and Lawrence Counties, and also in St. Francois County, in the southeastern part of the State, where lead forms the principal mineral mined and zinc is a byproduct.

28. Surface deposits were found rich in zinc. Deeper mines contain disseminated ores. Both sulphide and carbonate zinc ores occur, the zinc ore being usually associated with lead ore. In Oklahoma the metal content of crude ore is 2.42 percent zinc and 0.42 percent lead. In Kansas it averages 2.4 percent zinc and 0.5 percent lead. In southwestern Missouri the ores contain 2.26 percent zinc and 0.25 percent lead, whereas in southeastern Missouri they contain 0.06 percent zinc and 3.13 percent lead. In addition to new ore mined, a quantity of old tailings and slimes are treated in Kansas and Oklahoma. Less than a third of the lead and zinc concentrates were produced by flotation in 1929. Thirty-two companies produced more than 5,000 tons of zinc concentrate in 1929, the largest operating company being the Commerce Mining & Royalty Co.

29. *Wisconsin.*—Wisconsin ore is similar in character to the zinc-lead ores of the Tri-State district but it contains 3.53 percent zinc and but 0.26 percent lead. Zinc has been mined in Wisconsin for many years and production played a greater part in the national markets

prior to 1920 than it does today. In 1929, 17,000 tons of zinc were produced, forming 2.4 percent of United States mined ore zinc content. Between 1916 and 1920, Wisconsin mined about 7 percent of the country's total production. Mining is done in Iowa, Granite, and Lafayette Counties. Lead production is small.

EASTERN STATES

30. New Jersey is the third largest zinc producing State in the Union. Sussex County contains zinc oxide ores known as franklinite, zincite, and willemite, ores found nowhere else in any quantity. In 1929 ore having 102,000 tons zinc content was mined by the one producing company, the New Jersey Zinc Co., which owns both mines and smelters. The franklinite concentrate is used to produce zinc oxide and the willemite concentrates for metallic zinc.

31. Pennsylvania has small deposits of zinc and lead ores in Lehigh County and in Blain County which are operated occasionally. The principal zinc producing area in New York is operated by the St. Joseph Lead Co., near Edwards in St. Lawrence County. The ore is chiefly sulphide and iron sulphide and is fine grained.

32. Some mining has taken place in Tennessee for many years. Recently, developments have proceeded on a large scale. Sulphide zinc ores are produced at Mascot in Knox County by the American Zinc Co. Carbonate ores are produced by the Mineral Exploration Co. (a United States Steel subsidiary) and two other companies operating near Jefferson City, Jefferson County, and in Embreeville, Washington County. In addition, the Tennessee Copper Co. separates zinc from its copper ores through selective flotation.

33. The Universal Exploration Co. has developed not only a large reserve of carbonate ores now shipped to zinc oxide manufacturers, but also has large high-grade sulphide ore reserves. Mill equipment to treat 25,000 tons zinc concentrate per year is now installed and provision made to triple this capacity when market conditions are favorable.

34. Tennessee and Virginia produced 6.8 percent of the Nation's zinc in 1929, or 47,000 tons. This is more than twice as much as the State's 1927 production. The New Jersey Zinc Co. was the sole producer of zinc in Virginia in 1929. It operated zinc-lead-sulphide mines near Austinville in Wythe County. Tri-State companies are developing tracts near Wytheville and prospecting in other sections of the State is taking place.

35. Several other States have small zinc deposits that might be developed were the demand for zinc very great. However, the country's resources are so large that small deposits will have value only when very cheaply mined or when located close to consuming markets.

Production of Metallic Zinc and Zinc Oxide From Ore

36. *Location of reduction plants.*—As fuel is essential to zinc distillation, zinc smelters were established in coal-mining regions or in natural-gas regions. The natural gas found in Oklahoma and Kansas was responsible for the erection of zinc smelters in these States to smelt zinc ores from the Tri-State district. The gradual depletion of the gas supply caused a number of companies to move to, or erect new plants in, Illinois coal fields or in Arkansas gas fields. New Jersey

ships its ore for distillation to Palmerton, Pa., while mines in the Southern States ship to Middle Western or Pennsylvania smelters. New construction is taking place in West Virginia coal fields. Texas smelters care for Arizona and New Mexico zinc.

Electrolytic plants are located near abundant power sources, whether such power is generated from water or from coal.

TABLE III.—*Zinc distillation and electrolytic plants operating in 1929* [1]

Location	Operating company	Zinc capacity (short tons)	Products other than slab zinc manufactured at plant
Arkansas:			
Fort Smith	Athletic Mining & Smelting Co	40,000	
Van Buren	Van Buren Zinc Co.[2]	40,000	
Idaho: Kellogg	Sullivan Mining Co	[3] 23,725	Manganese dioxide.
Illinois:			
Danville	Hegeler Zinc Co	64,000	Rolled zinc, sulphuric acid.
Depue	Mineral Point Zinc Co	100,000	Lithopone, sulphuric acid.
East St. Louis	American Zinc Co. of Illinois	46,000	Sulphuric acid.
Do	Evans-Wallower Zinc Co	[3] 20,075	Cadmium. Sulphur dioxide made into acid at neighboring plant.
La Salle	Matthiessen & Hegler Zinc Co	31,000	Rolled zinc, sulphuric acid.
Peru	Illinois Zinc Co	42,000	Do.
Indiana: Terre Haute	Grasselli Chemical Co	48,300	Sulphur dioxide shipped to Grasselli, Ind., plant.
Kansas:			
Caney	Weir Smelting Co	18,000	
Cherryvale	Edgar Zinc Co	51,000	
Montana:			
Great Falls	Anaconda Copper Mining Co	[3] 127,750	Cadmium.
Anaconda	do	[3] 63,875	Do.
Oklahoma:			
Bartlesville	National Zinc Co	60,000	Sulphuric acid.
Blackwell	American Metal Co., Ltd	74,000	
Henryetta	Eagle-Picher Lead Co	64,000	
Kusa	Kusa Spelter Co	35,000	
Quinton	Quinton Spelter Co	40,800	
Pennsylvania:			
Donora	Donora Zinc Co	100,000	Sulphuric acid.
Langeloth	American Metal Co., Ltd	64,000	Sulphuric acid, zinc salts.
Palmerton	New Jersey Zinc Co	110,000	Rolled zinc, zinc oxide, sulphuric acid, lithopone, zinc dust, die casting alloy.
Texas: Amarillo	U.S. Zinc Co	96,000	
West Virginia:			
Meadowbrook	Grasselli Chemical Co	79,900	Zinc dust, sulphur dioxide shipped to other plants.
Moundsville	United Zinc Smelting Corporation.	31,000	Sulphuric acid.

[1] Compiled from The Mineral Industry During 1929, p. 665, and Zinc in 1928, U.S. Bureau of Mines.
[2] Idle part of year.
[3] Electrolytic zinc.

37. In 1929, the largest amount of primary zinc, or zinc manufactured from zinc concentrates and ores, was produced by the two electrolytic plants in Montana. Almost equal proportions were distilled in Oklahoma, Illinois, and Pennsylvania. Distilled zinc was also produced in Kansas, Arkansas, West Virginia, Indiana, and Texas, while electrolytic zinc production had gotten underway in Idaho and, in September 1929, in Illinois.

TABLE IV.—*Primary zinc produced in each State* [1]

State	1925	1926	1927	1928	1929	
	Short tons	Short tons	Short tons	Short tons	Short tons	Percent
Total	572,946	618,422	592,516	602,581	624,520	100.0
Arkansas	27,145	32,712	26,317	20,505	17,923	2.9
Idaho				1,939	16,582	2.7
Illinois	109,672	110,381	102,768	103,765	110,007	17.6
Kansas	25,765	33,671	33,144	33,923	37,795	6.0
Montana	79,004	111,596	112,629	158,221	[2] 139,510	22.3
Oklahoma	138,906	136,560	120,801	106,557	111,683	17.9
Pennsylvania	99,899	100,538	106,099	108,802	108,167	17.3
Other States	92,555	92,964	90,758	68,869	82,853	13.3

[1] Compiled from U.S. Bureau of Mines: Zinc in 1928, p. 366, and Preliminary Report of May 28, 1930, p. 2.

[2] Electrolytic includes a small quantity from Illinois.

38. *Slab zinc production.*—The primary zinc production totaled 624,520 short tons. Of this 13,311 tons was from Mexican ore, all other production being from domestic ore. In addition, 47,348 tons was smeltered from secondary metal secured from galvanizers' dross, ashes, and scrap metal. The total amount of slab zinc available at zinc reduction plants in 1929 was, therefore, 671,868 short, tons. This is the largest amount of metallic zinc produced to date in the United States.

39. In spite of this fact, the 21 zinc smelters in operation were using less than 60 percent of their capacity at the end of the year. The total number of retorts reported was 107,500, whereas but 62,200 were in active operation. Table III lists the electrolytic and distillation plants and their capacities in 1929. Distillation capacity totaled 1,235,000 short tons. Electrolytic capacity, based on 365-day operating year, totaled 235,425 short tons.

40. *Zinc oxide production.*—Zinc oxide is produced chiefly from zinc ores although it may be manufactured from metallic zinc and secondary zinc. One hundred twenty-four thousand and ninety (124,090) short tons of ore is used in the production of zinc pigments. Of this 70 percent enters into the production of zinc oxide by the American process, 21 percent into lithopone, and only 9 percent into leaded zinc oxide. Metallic zinc, to the extent of 37,588 tons, entered into the manufacture of French process zinc oxide, whereas 25,353 tons of secondary material produced lithopone, leaded zinc oxide, and zinc salts.

41. Firms manufacturing zinc oxide and leaded zinc oxide from zinc ores are as follows:

Colorado: Canon City, Empire Zinc Co.
Florence, River Smelting & Refining Co.
Leadville, Western Zinc Oxide Co.

Illinois: Hillsboro, American Zinc Co. of Illinois (also produces sulphuric acid); Eagle Picher Lead Co. (also produces sulphuric acid).

Indiana: Grasselli, Grasselli Chemical Co. (also produces sulphuric acid and lithopone).

Kansas: Coffeyville, Ozark Smelting & Mining Co.

Ohio: Columbus, American Zinz Oxide Co. (disposes of sulphur dioxide gas to Farmer's Fertilizer Co.).

Pennsylvania: Palmerton, New Jersey Zinc Co.

Wisconsin: Mineral Point, Mineral Point Zinc Co. (also produces sulphuric acid).

42. Plants producing zinc oxide from metallic zinc are the International Lead Refining Co. of East Chicago, Ind., and Akron, Ohio, which receives electrolytic zinc from the Anaconda Copper Co., and the New Jersey Zinc Co. at its Freemansburg (Pa.) plant.

43. *Zinc-dust production.*—Zinc dust or "blue powder" results during the course of zinc distillation and is marketed by six companies for sherardizing small articles. The total sold was 9,172 tons in 1928. One company, the Alloys Co., of San Francisco, produces "atomized zinc dust" by ejecting molten metal from a nozzle under pressure. The electrolytic plants use their own atomized zinc dust in the process of purifying the zinc solution, whereas the larger number of distilleries distill their blue powder.

44. Smelters marketing zinc dust are the Grasselli Chemical Co., of Meadowbrook, W.Va., and the New Jersey Zinc Co., at Palmerton, Pa. Other firms specializing in zinc-dust production are the Alloys Co. and the John Finn Metal Works, of San Francisco; the Federated Metals Works, of Trenton; and the United States Zinc Co., of Sand Springs, Okla.

45. *Byproduct sulphuric acid.*—Wherever zinc sulphide ores are roasted sulphur dioxide is given off. This is manufactured into sulphuric acid by some zinc distillation plants and some zinc oxide plants, or it may be shipped to nearby acid plants or acid plants near acid markets. The gases, when converted to acid in zinc factories, are usually supplemented with sulphur to utilize acid-plant capacities to the fullest. Twenty-one zinc roasting plants manufactured sulphuric acid in 1928, producing 1,056,725 short tons of acid. While some of this was consumed at the plant, acid sold had a value of over $11,000,000. This byproduct manufacture formed about 19 percent of the country's total output of sulphuric acid, although only 10 percent was produced from byproduct gases, the remaining amount being derived from sulphur purchased. The zinc smelters that produced sulphuric acid or shipped it to other plants are indicated on table III. The Evans-Wallower Zinc Co. was the only electrolytic plant marketing its sulphur fumes. These were transferred directly to the neighboring plant of the Monsanto Chemical Co.

Zinc-Reduction Processes

46. The larger amount of zinc carbonate ores are calcined and zinc sulphide ores roasted before being distilled in retort furnaces, while complex ores are leached by sulphuric acid and precipitated electrolytically. At the present date, only one firm treating zinc-lead sulphide ore is employing the electrolytic process, although the process as now developed is applicable to all sulphide ores. Table V indicates the growth in the application of the electrolytic method in the last 5 years. Almost a fourth of all metallic zinc manufactured today is produced by electrolysis.

47. The zinc produced by electrolytic precipitation has different characteristics from high-grade retort zinc. It is easily drawn, stamped and extruded and may be rolled and beaten into thin sheets, whereas retort zinc is a harder metal.

TABLE V.—*Methods of primary and secondary zinc reduction in the United States*[1]

Reduction method	1925		1926		1927		1928		1929	
	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent	Short tons	Percent
Total	612, 127	100.0	659, 221	100.0	635, 300	100.0	651, 247	100.0	671, 868	100.0
Electrolytic	79, 004	12.9	111, 596	16.9	112, 629	17.7	160, 160	24.6	156, 092	23.2
Distilled primary	493, 942	80.7	506, 826	76.9	479, 887	75.6	442, 421	67.9	468, 428	69.7
Redistilled secondary	39, 181	6.4	40, 799	6.2	42, 784	6.7	48, 666	7.5	47, 348	7.1

[1] Compiled from U.S. Bureau of Mines: Zinc in 1928 and Preliminary Report for 1929, p. 2.

48. *Reduction by electrolysis.*—Gravity concentration has given way almost entirely to selective flotation in the treatment of complex zinc ores. Only through such flotation is a concentrate produced suitable for the production of metallic zinc by electrolytic precipitation

49. *Selective flotation.*—Although the essentials of selective flotation are the same for complex zinc ores as for copper ores, the details of the process vary, due to the wide differences in the two ores. Galena (lead sulphide) and sphalerite (zinc sulphide) do not separate until crushing has been carried to minus 200 mesh. Consequently, fine grinding after crushing is essential. This is usually done in Hardinge ball mills in closed circuit with Dorr classifiers. The overflow from the classifiers passes to the rougher flotation machines of the mineral separations type. This machine consists of a number of cells arranged in series, the pulp flowing from one cell to the next cell, while the froth, carrying mineral, is floated off as it appears. Each cell has a vertical shaft stirrer to agitate the pulp and beat air into it. In the Fahrenwald machine, which is coming into use, rotation of the impeller draws air from the atmosphere, thus functioning as a stirrer and a blower. As the pulp falls upon the top of the rotating impeller it is forced vigorously into the body of the pulp in the cell. The flotation reagents used vary somewhat with the character of the ore treated. For an ore analyzing 13 percent zinc, 9 percent sulphur, 2 percent lead, iron, and lime each, 5 percent aluminum, gold, and silver, and 56 percent silica, sodium ethyl xanthate is used as a collector of the sphalerite and galena, copper sulphate for activation of the sphalerite, calcium cyanide as a depressant of pyrite; burnt lime is employed for alkalinity. These reagents, together with pine oil as a primary frother and coal-tar oil as a froth stabilizer, cause the sphalerite and galena to float while the pyrite and gangue fall to the cell bottom.

50. The bulk concentrate is often cleaned in a Callow or pneumatic type of flotation machine, in which air is introduced below a porous bottom to agitate the pulp and provide air for flotation. The cleaned concentrate is thickened to 50 percent solids and is then agitated with zinc sulphate and calcium cyanide which depress the sphalerite while floating off the galena. The tailing is a relatively high-grade zinc concentrate.

51. In other plants two circuits are operated—a lead circuit and a zinc circuit. Thiocarbanilid is used as the basic lead collector, sodium cyanide as the lead accelerator, and zinc iron as the depressant in the mineral separation subaeration machines. The lead concentrate floated passes through Callow pneumatic cells to Dorr thickeners and filters, while the middlings and Callow cleaner tailings pass through the rougher cells a second time. After lead is removed, the

lead rougher tailings are heated to 30° and pass through Dorr thickeners to the zinc circuit, where aerofloat or phosphocresylic acid is the basic collector and frother and copper sulphate the accelerator. The zinc concentrate passes to thickeners and filters, while the remaining pulp passes through an iron circuit in which the Callow cell is used as both rougher and cleaner flotation machines to float off iron.

52. *Electrolytic zinc processes.*—Two processes for producing electrolytic zinc have been developed in the United States. That used at the Great Falls and Anaconda plants of the Anaconda Copper Mining Co. is known as the Anaconda process and that employed at the Sullivan plant, Idaho, and at the Evans-Wallower plant, Ill., is the Tainton process. The principles underlying both processes are the same. Zinc concentrates are roasted to convert the zinc sulphide into soluble oxide or zinc sulphate. This calcine is leached with dilute sulpuhric acid to dissolve out the zinc content and is purified. The zinc is precipitated from the resulting solution by electrolysis. The chief differences in the two methods lie in the fact that in the Tainton process the plant is designed to make use of a high-acid process and high-current density, while Anaconda employs low-current density and low-acid content.

53. A description of the Tainton process, as carried on in Idaho, will be given and the major differences in other plant procedure will be noted later.

54. *Roasting and leaching.*—The concentrate, after being disintegrated by rolls, passes to modified wedge roasters having seven roasting hearths and a top hearth for drying the feed. Water or air cooled arms revolved from the center shaft carry the concentrate from circumference to center on the drying hearth, from which it dumps through holes to the next hearth, and so on down through the furnace. A Mahr oil burner is provided to maintain sufficiently high temperatures to insure a good roast. The calcine drops to a chain conveyor and is delivered to a leaching screen, while the gases rise upward and are cleaned by a Cottrell treater. The oversize from this screen is crushed in a ball mill and returned to the roaster. The calcine that passes through the screen goes to two magnetic separators which take out from 30 to 50 percent of the magnetic material present in the concentrate—that is, the zinc and copper ferrites and the zinc sulphide. This passes to ferrite bins, while the nonmagnetic calcine goes to oxide bins. These bins, together with a third manganese ore bin and weighers, are located above each leach agitator. Agitator tanks are made of wood lined with lead, the stirring mechanism being driven by a 15-horsepower motor equipped with reducing gears. Return electrolyte heated to 60° C. and containing 28 to 30 percent free acid is pumped into the primary agitators. A charge of ferrite is dumped in and agitated, decomposing most of the relatively insoluble zinc compounds. Crushed manganese dioxide ore is added to oxidize the dissolved iron. The zinc oxide is then added until all iron is precipitated. As the pulp reaches the boiling point, water is evaporated. The pulp is passed through Burt filters to mechanical purification agitators, where the solution which contains dissolved zinc, cadmium, copper, cobalt, and nickel is treated with zinc dust, which precipitates all the metals except zinc. When precipitation is complete, the solution goes through Shriver filter presses and is ready for the electrolytic cells.

55. *Byproducts.*—The residue from the leaching tanks contains lead, silver, gold, iron, and silica. It is thickened, filtered, and dried for shipment to lead smelters. The residue from the Shriver filter press passes to storage tanks in the cadmium plant. This copper-cadmium cake is treated in agitator tanks until the cadmium is in solution. It is filtered, separating out the high-grade undissolved copper, which is shipped to the smelter. The cadmium solution goes to an electrolytic cell, where it is precipitated. The cadmium cathode is melted down and cast into slabs. These are recast, frequently under molten caustic soda, into balls of 2-inch diameter for use in the plating industry, or into other marketable forms.

56. *Electrolytic precipitation according to Tainton process.*—At the Idaho plant the cell room contains 2 circuits of 150 cells, each cell containing 10 cathodes and 20 anodes. At the East St. Louis plant the cell room contains 190 cells in series, each containing 12 cathodes and 24 anodes. The cathodes are of aluminum sheet, with aluminum conductor bars welded at the upper end. The anodes are a silver-lead alloy perforated to permit free circulation of the electrolyte and to decrease terminal voltage. The cathodes slide into grooved wooden guides fixed in the cell with a wooden framework so that the framework also holds two anodes at definite spacing between each cathode. The solution, containing about 20 percent zinc and 22 percent sulphuric acid, is fed to the center of each cell through hard-rubber pipes and is circulated in parallel through the cells down to sumps. From the sumps it flows through a thickener that recovers manganese dioxide to storage tanks. Before returning to the cells it is cooled by passing through water-cooled coils to launders. A colloid, such as gum arabic, is added to the electrolyte for the smooth deposition of zinc.

57. The current is led into the conductor bars through spring chips at the side of the cell. It is supplied by motor generator sets having an efficiency of 91 percent.[74] At Kellogg 8,000 amperes at 500 volts can be delivered to each circuit, the motors each having a capacity of 4,000 kilowatts. At East St. Louis the motor has a 6,500-kilowatt capacity and can deliver 10,000 amperes at 600 volts.

58. Zinc is deposited at a current density of 100 amperes per square foot and is stripped from the cathodes at intervals of 12 to 16 hours. According to Mr. F. S. Elfred, of the Evans-Wallower Zinc Co., only 1,760 kilowatt-hours of energy are required, theoretically, to produce 1 ton of zinc.[75] The current efficiency in the tank averages 85 percent, according to E. R. Fosdick, which would only bring the tank consumption of energy per ton of zinc to 2,024 kilowatt-hours with this current density. With a 9 percent additional loss at transformers and other points, 2,206 kilowatt-hours energy would be essential for the deposition of 1 ton of zinc. Almost 10 percent additional power is necessary for compressed air, roasters, and other plant operations, bringing the total consumption to about 2,426 kilowatt-hours direct current.

59. A steady current is one of the essentials for the electrolytic deposition of zinc. For although zinc remains undissolved in sulphuric acid while electric current is passing through it, deposited zinc will be redissolved into the acid whenever current is off.

---

[74] Fosdick, E. R. Journal American Institute of Electrical Engineers. 1928. 77. P. 808.
[75] Elfred, F. S. Address Before American Die Casting Institute. January 1930.

60. The Kellogg plant secures its power from the Washington Water Power Co., whose generating station is 100 or more miles distant from the plant. The East St. Louis plant's power is supplied at 13,200 volts through an underground cable directly from the switchboard of the Cahokia power generating plant of the Union Light & Electric Co. This station is a large steam-power unit located within half a mile of the zinc reduction plant.

Zinc sheets are melted in either gas- or oil-fired furnaces, and the molten metal is cast into slabs. The zinc is 99.99 percent pure.

COMPARISON WITH THE ANACONDA PROCESS

61. At Great Falls the roasters are fired by natural gas having heat value of 930 B.t.u., 2,400 cubic feet being required per ton of new furnace feed as compared with 14 gallons of oil of 18,500 B.t.u. heat value and 0.92 specific gravity used per ton of feed at the Anaconda roaster.

62. In place of batch leaching of the calcine, continuous leaching is employed. To the spent electrolyte containing 10 to 15 percent free acid scrap iron is added. This is oxidized with manganese dioxide to ferric sulphate before calcine is added. The excess zinc oxide causes the oxidized iron to form insoluble salts with arsenic and antimony, which are precipitated. Because the recovery of zinc is low in this first or "neutral" leach, about half of the spent electrolyte is added to the second or "acid" leach to recover practically all acid-soluble zinc. The copper and cadmium in this solution are precipitated by agitating with finely divided particles of metallic zinc. This sludge is roasted and leached with sulphuric acid to recover the zinc and cadmium and precipitate the copper. The zinc cadmium solution is heated and circulated slowly through tanks in which zinc slabs are suspended to precipitate the cadmium as a spongy deposit on the zinc slabs.

63. The Great Falls electrolytic division is divided into 8 circuits each containing 144 cells arranged in cascades of 6 cells each, each cell containing 28 lead anodes and 27 aluminum cathodes. In addition there are 12 reserve cells. Rotary converters having a capacity of 10,000 amperes at 580 volts supply the current to each circuit. They have a conversion efficiency of about 93 percent. The Anaconda plant has four such units, but they are connected to motor-generator sets. Current density is approximately 30 amperes per square foot of cathode area in both plants, and the zinc deposited on both sides of the cathodes is recovered every 24 hours. The power required averages 3,200 kilowatt-hours per ton zinc produced. The other processes in the plant require an additional 5 percent power, so that the total number of kilowatt-hours used is about 3,350 per ton of zinc produced. The two zinc plants require approximately 75,000 kilowatts of electric energy daily.

64. The Great Falls zinc substation receives power at 110,000 volts which are stepped down to 406 volts through 9 water-cooled transformers. The Montana Power Co. furnishes power to the zinc plant at Anaconda over a 100,000-volt, 3-phase, 60-cycle transmission line to an outdoor high-tension bus.

REDUCTION BY DISTILLATION

65. *Concentration.*—Sulphide-zinc ores and much carbonate ore must undergo some concentration before shipment to smelters. For many years jigging following a coarse crushing was the usual form of concentration. In the jigs used water is forced through a screen by action of a piston causing particles to be sorted under the influence of the rising column of water. These fixed-sieve jigs have a number of cells per unit with a separate piston or plunger for each cell. The lessening of the amount of coarsely crystallized ore made up of zinc sulphide, lead sulphide, and waste, all having varying specific gravities, together with the sharp competition from complex ores, are gradually bringing about new methods of concentration. Electrostatic separation, causing the sulphides to be repelled from a charged table, has had much application. Flotation has been adopted for fine ores containing residue of some value. Mills continuing a mechanical concentration are grinding the ore after crushing for a more complete segregation of the minerals from the waste. Bendelaire diaphragm jigs are being introduced. Classifying before tabling has been found effective.

66. *Distillation.*—Distillation operations are also undergoing change in the effort to secure greater metal recovery at less cost. It is still standard practice to dry and crush the coarse milled zinc-lead sulphide concentrates and roast them in kilns until they contain but one half of 1 per cent sulphur. This calcine is a finished product ready for the regenerative furnaces. Carbonate ores are crushed and slightly calcined to drive off water and impurities. Zinc-sulphide flotation concentrates are roasted in hearth furnaces having water-cooled rabble arms until sulphur is reduced to approximately 3 or 4 percent. After screening and cooling, this calcine is carried in uniform thin layers through a wind box sintering machine from which it emerges as a porous cake with less than 1 percent sulphur. This is crushed and screened ready for the mixing room.

67. In the mixing room approximately 35 percent reduction fuel made up of coke, bituminous coal, and a little salt is added to the roasted concentrates. This is charged in retorts which are placed in rows in a regenerative furnace, usually about 400 per side. Gas and preheated air are introduced through ports under the retort rows. In burning, the flames rise and descend between the retorts. The direction of the gas current is reversed at intervals of 30 minutes. As the temperature is gradually increased the carbon first reduces the metallic oxides other than zinc. These, together with hydrocarbons, are driven off. At a higher temperature zinc vapors rise from the retorts and are cooled as they circle around the interior surface of a condenser. Vapors condense and are collected at the base of the furnace. Distillation requires about 19 hours and setting up the furnace, 5 hours.

68. In a plant using a Neurenther Siemens regenerative furnace 1 ton of coal is required as furnace fuel per ton of roasted Tri-State ore; and one half ton is required for power and steam. In a Hegeler furnace 1.6 tons of furnace fuel and one tenth ton of coal for power and steam are consumed. In the natural gas districts gas is used in place of coal, approximately 40,000 cubic feet being used to distill a ton roasted zinc sulphide. Waste gas from byproduct coke ovens is used

by one American zinc company in Mexico where there is no more immediate market for gas.[76]

69. Zinc distilleries manufacture their own retorts, as the average life of a retort is about 37 days. Clay, dug in Missouri, mixed with a little coke, is used chiefly in the Tri-State district.

After passing through a hammering machine and a hydraulic press the retorts are fired in gas kilns.

70. *Zinc oxide manufacture.*—When zinc oxide is desired, instead of condensing the zinc vapors they may be burned and the zinc oxide fume collected by filtration through bags or settlement in chambers.

71. But the larger amount of zinc oxide is produced by the Wetherill or American process. Zinc ore and coal, mixed in almost equal proportions, are spread thinly on grates in a furnace. The zinc is reduced and volatilized. This is immediately oxidized by the carbon dioxide and burned by excess air. The gas passes through settling chambers and then is drawn through long cooling flues and collected in a bag house where zinc oxide is filtered in woolen flues. By the French process, which is employed on metallic zinc, air only is used for oxidizing the distilled zinc, the air being blown through pipes in a central shaft of a Wedge roaster.

72. *New processes.*—Only 60 to 70 percent of the zinc in the concentrate is condensed as metallic zinc in the ordinary distillation furnace. While some of the remainder is secured by the redistribution of samplings, ladle skim, and other between products known as "blue powder", the old methods are not as successful in zinc recovery as is the electrolytic process. The amount of fuel consumed also adds greatly to the cost of these methods. Consequently, efforts are being made to secure greater metal recovery at less cost.

73. An English company is trying out the Coley process, in which liquid hydrocarbon is used as the reducer. The screened raw ore is fed to a preheater and passed through a vertical shaft to the main furnace rotating tube. Surrounding this tube is a regenerative system for burning producer gas to maintain the necessary high temperature. The ore, turned to zinc oxide, passes from the tube to the reduction section of the furnace, where heavy cold oil is sprayed over it. The zinc is liberated and volatilizes, passes to the condenser, and emerges as metallic zinc. It is claimed that 95 percent of the zinc is recovered by this process, that the cost of the plant is one fourth that of the ordinary distillation plant, and that the labor required is less than one third as much.

74. *Electrothermal process.*—The school of mines and metallurgy of the University of Missouri, at Rolla, has erected a modern experimental plant for electrothermic-dry distillation. A briquetted mixture of 100 parts roasted Tri-State zinc concentrate, 70 parts crushed coke, and 25 parts of hard coal is made. These small blocks are piled in a column upon the furnace hearth. A non-heat-conducting cylinder is dropped over the column so that it is gas-tight except for its connection with the condenser. The current is passed through the column of charge and volatilized zinc passes to the condenser and is turned into molten zinc. Any residue is easily removed from the column when distillation is complete. Dr. Charles H. Fulton, the inventor of this process, states that 2,500 kilowatt-hours of power are required

[76] Ingalls, W. R. I. Metallurgy of Zinc and Cadmium. Handbook of Non-Ferrous Metallurgy, pp. 1207–1208.

per ton of zinc. He believes that the electrothermal process for zinc connected with a coke plant will give economical results. This process had not been put into commercial operation in this country.

75. The St. Joseph Lead Co. has been experimenting with the Gaskill process, which is similar to the Fulton process, except that it is a continuous process, for the manufacture of zinc oxide. A small electrothermal plant is in operation in Scandinavia.

BYPRODUCTS

76. *Sulphuric acid.*—Wherever a market exists for sulphuric acid, the sulphur-dioxide fumes driven off from zinc-sulphide ores, whether zinc is produced by distillation or by the electrolytic process, are collected. The gases from roasting furnaces passes through lined steel flues in which part of dust settles. As they are cooled to 400° C. they enter Cottrell treaters for final cleaning. The precipitated dust is shaken out and the gas passes to chambers for sulphuric acid manufacture. When sintering machines are used, the Schmiedel process of collection and cleaning is employed. The gas passes through lead boxes containing a bath of nitrated acid. The sulphur dioxide is converted into trioxide and passed to a series of towers similar to the ordinary chamber process.

77. *Cadmium.*—Cadmium is being used to electroplate ferrous materials and to provide a primary wash for automobile parts that are later to be chromium or nickel plated. As it is only produced as a byproduct of zinc or lead, its extended use will unquestionably lead to greater recovery. As stated on page 258, cadmium is necessarily precipitated before the electro-deposition of zinc. The cadmium is recovered from this precipitation by electrolysis. Cadmium could also be recovered from the roaster flue dusts, zinc dust, or blue powder from zinc distillation. It has also become a byproduct of electrolytic-lead refining or of lead furnaces. In 1929, 1,241 tons were recovered by the Anaconda Copper Mining Co., the Grasselli Chemical Co., New Jersey Zinc Co., American Smelting & Refining Co. in Colorado, and the United States Smelting, Refining & Mining Co., of Midvale, Utah.

78. *Lead and other metals.*—The lead, copper, silver, and gold recovered in selective flotation and from leaching before electrolysis are usually shipped to lead or copper smelters for separation. Other metals could be recovered from zinc sulphide and complex ores if there was a market for them. Such metals are gallium, thallin, germanium, and indium.

ZINC REFINING

79. Ordinarily there is little need for zinc refining. The high-grade zinc produced electrolytically and high-grade distilled zinc more than meet the requirements of the brass-making, zinc oxide, die-casting, and other markets for 99.9 percent pure zinc. Prime Western, which may contain some lead, iron, and cadmium is a harder metal and is used to advantage in galvanizing iron and steel and for rolling into sheets.

80. During the World War, however, the demand for high-grade zinc for brass cartridges led to the refining of crude zinc. This was done at smelters by drawing off the product distilled at lowest tem-

perature and, consequently, low in lead, and shipping this to brass makers, while later draws were sent to galvanizers. Or crude smelter was redistilled or refined by electrolysis. Today these distilling furnaces which permit lead to be tapped from the lower end, while the zinc vapor passes out of the upper end into condensers, are used only for scrap and galvanizers' dross.

81. *Production costs.*—That an electrolytic zinc plant can operate in the Northwest zinc regions, pay freight on slab zinc, and compete with Middle Western retort zinc in the eastern market has been amply demonstrated in the last 10 years. That electrolytic zinc can press prime western zinc hard, is seen by the recent efforts of Tri-State producers to improve methods of concentration and distillation. How much of this commercial success has been due to real differences in cost of producing electrolytic zinc and retort zinc, and how much to the fact that manufacturing costs are partially distributed over recovered lead or copper, gold and silver, and cadmium, is difficult to state. There is no fixed apportionment of costs between the several products resulting from the electrolytic production of zinc. A high price for any byproduct, makes zinc production possible at a lower figure.

82. *Concentration costs.*—This difficulty in cost distribution begins with the production of flotation concentrates from complex ores. Take, for example, the concentrate produced at one western mine. The mill feed contained 5.15 percent lead, 4.5 percent zinc, 8.53 ounces of silver, and 0.024 ounce of gold, and other metals. A 2-circuit flotation system produced two concentrates: A zinc concentrate assaying 46.57 percent zinc, 2.71 percent lead, 11.8 percent iron, 28 percent sulphur, 13.65 ounces silver, and 0.03 ounce gold; and a lead concentrate containing 62.72 percent lead, 3.5 percent zinc, 7 percent iron, 0.2 ounce gold, 90.43 ounces silver, 15.3 percent sulphur, 1.4 percent arsenic, 1 percent antimony. The cost of concentration per ton of ore milled was $1.282, 26 kilowatt-hours of power costing $0.318; supplies, $0.554; labor, $0.244; and other manufacturing and general mill costs being $0.166. What was the cost of the zinc concentrate? The zinc-electrolytic plant and the lead smelter will pay for the various metals in each concentrate in accordance with their respective prevailing market prices and the miner will expect to make a profit on his entire operations.

83. The Tri-State Zinc and Lead Ores Producers Association reports costs of producing zinc-lead concentrates as follows:

Cost item	Cost per ton of ore hoisted	Cost per ton of concentrate
Power, all classes	$0.1993	$2.9458
Labor	.9081	13.4197
Explosives	.1456	2.1519
Other supplies and repairs	.2637	3.8967
Management	.1142	1.6873
Insurance	.0955	1.4104
Taxes	.0157	.2315
Miscellaneous	.1813	2.6785
Total operating costs	1.9234	28.4218
Depletion and depreciation		6.0601
Royalty		4.6800
Total		39.1619

84. It is obvious that a distillation plant not recovering any precious metals will be paying proportionately more for these zinc-lead concentrates than will the electrolytic plant in which large percentages of metals are recovered.

85. *Electrolysis and distillation.*—The same difficulty is found in comparing the electrolytic and the retort zinc process costs where comparisons are further complicated by the manufacture of sulphuric acid at retort plants. These difficulties are enhanced by the reticence of zinc producers concerning costs of production. Comparisons, therefore, can be based on rough estimates only, and will not take into consideration byproduct recovery.

86. *Plant costs.*—It is claimed by several engineers that the first cost of a 200-ton daily capacity retort and electrolytic zinc plant will be approximate; that with smaller capacities the retort plant will have the advantage. Frederick Laist and Russel B. Caples, of the Anaconda Copper Co., stated in 1926 that the first cost of a 200- to 250-ton electrolytic zinc plant using the Anaconda process would be from $25,000 to $40,000 per ton of daily zinc capacity, while a plant of half the capacity would cost from $30,000 to $35,000. Published cost figures of the two plants employing the Tainton process and having less than 100 tons daily capacity would indicate that plant costs were $20,000 per ton daily zinc capacity. The electrolytic plant has higher salvage value than the retort plant.

87. *Power costs.*—The Anaconda Copper Co. has an arrangement with the Montana Power Co. to purchase power for zinc production on a sliding scale. When zinc sells at $0.06 per pound or over the charge is $25 per horsepower-year; when zinc is priced at lower levels, the cost of power is reduced until it reaches $17.50 per horsepower-year with zinc at about $0.045 per pound.

TABLE VI.—*Estimated cost of producing 1 ton electrolytic zinc and 1 ton retort zinc in plant having capacity of 100 tons daily* [1]

[Byproduct values not considered]

Cost item	Electrolytic zinc	Retort zinc
Capital cost per ton-year	$60.00-$100.00	$50.00-$75.00
Amortization, interest, taxes charged:		
At 15 percent	9.00- 15.00	
At 16½ percent		8.25- 12.38
Power consumption, 2,500 kilowatt-hours to 3,350 kilowatt-hours, at $0.003	7.50- 10.05	
Fuel:		
20 gallons oil or 3,400 cubic feet gas	.52- .65	
1½ tons coal, at $2 or 40,000 cubic feet gas, at $0.13		3.00- 5.20
Labor:		
1.5 to 2 man-days, at $4.75	7.13- 9.50	
4 men, at $4.50		18.00
Supplies, repairs, and miscellaneous items	12.00	3.00
Cost of concentrates	47.00	56.78
	83.00- 94.00	89.00- 95.00
Freight rate to—		
New York from Black Eagle, Mont., Hillsboro, Ill	12.50	7.00
	95.50- 106.50	96.00-102.00
East St. Louis from Black Eagle, Mont., Henryetta, Okla	8.50	3.80
	91.50- 102.50	92.80- 98.80

[1] Estimated from data given by: Laist, Frederick, and Caples, Russel B., The Electrolytic Zinc Process; Ingalls, W. R. I., Pyrometallurgy of Zinc in Handbook of Non-ferrous Metallurgy; Ralston, Olive, Electrolytic Deposition and Hydrometallurgy of Zinc; and from individual plant data.

88. The estimates given on page 264 not only do not give credit for high recovery of metals other than zinc or for byproduct manufacture, but they do not take into consideration the percentage of zinc recovered by each process. As has been stated, the average retort recovers 5 or 6 percent less zinc in the concentrate than does electrolysis. There can be no question, therefore, but that, when all factors are taken into consideration, electrolytic zinc from complex ores can be produced for sufficiently less than retort zinc to be able to bear freight rates to central and eastern markets. Unfortunately, no data are available concerning the cost of production of the New Jersey Zinc Co. from zinc oxide ores; but as its plant contributes but 8 percent to the country's total metallic zinc capacity, its costs cannot affect market prices.

Zinc Consumption

89. Forty-six percent of the zinc consumed in the United States is used in galvanizing sheets, tubes, wire, wire cloth, and miscellaneous articles. Twenty-nine percent is mixed with copper to produce brass. Eleven percent is rolled into sheets or strips. A third of the remainder, or about 30,000 tons, is consumed in die casting. French zinc oxide, lithopone, and atomized zinc dust produced from slab zinc consumed less than 10 percent of zinc produced.

90. What is known as "Prime Western" zinc, or zinc containing 1.6 percent lead and 0.08 percent cadmium and iron, is consumed in the "hot process" galvanizing industry. While "Brass Special" is still a recognized grade of zinc, the increased production of high-grade electrolytic zinc has so decreased the premium formerly paid for high-grade zinc that much of it is being purchased by brass and other zinc-alloy manufacturers. High-grade metal is also used in die-casting alloy manufacture.

TABLE VII.—*Estimated consumption of zinc in the United States in 1929,*[1] *by principal uses*

Item	Short tons	Percent
Total consumption	628,300	100.0
Galvanizing	----------	46.1
Sheets	142,800	22.7
Tubes	52,200	8.3
Wire	39,000	6.2
Wire cloth	10,800	1.7
Shapes	45,200	7.2
Brassmaking	180,000	28.7
Sheet zinc	68,300	10.9
Other uses [2]	90,000	14.3

[1] Estimate by American Bureau of Metal Statistics. These estimates exceed the consumption figures given by the Bureau of Mines by 64,000 tons.
[2] Includes slab zinc used in French oxide, lithopone, atomized zinc dust, die castings, slush castings, and for desilveration of lead.

91. *Galvanizing.*—Galvanizing is accomplished by three methods: the well-known hot process, electrozincking, and sherardizing.

92. *Hot process.*—Iron or steel that has been cleaned and pickled in a sulphuric acid bath is immersed in molten zinc, in the "hot" process. The heat for this process may be supplied by fuel or by electricity. The Southern California Edison Co. reports savings in the substitution of electrical heat for gas. A tank 3 by 5 by 3 feet was equipped with 70 kilowatts in 3-phase, 220-volt, heaters. The

material to be galvanized consisted of braces, angle irons, and small castings. During the working period 164 kilowatt-hours were consumed per ton of material galvanized. Radiation losses over night brought the total energy consumption to 230 kilowatt-hours per ton. At a rate of $0.0125 per kilowatt-hour, the electrothermal galvanizing cost $25.375 per ton whereas a gas-fired tank had cost $55 per ton. This saving resulted from a cut in the immersion period to 45 seconds in the electric tank as compared with a 2-minute immersion in the gas-fired tank. [77]

93. A much larger electric tank is used for galvanizing by a firm fabricating transmission-line towers. This tank is 30.5 feet long by 4 feet wide by 1 foot 10 inches deep, holding 45 tons of molten zinc. The heating element is continuous and is laid over the insulating supports which are a part of the brick lining. The capacity of the tank is 4 tons galvanized steel per hour consuming 405 kilowatt-hours of energy or 101 kilowatt-hours per ton. The tank temperature is maintained 24 hours per day.

94. *Electrozincking.*—Or iron and steel may be coated with zinc by the deposition of zinc from zinc anodes suspended in an electrolyte. The anodes are connected to the negative pole of the generator, the positive pole being the object to be zincked. It is claimed that electrozincking produces a superior product than does the "hot process." At the present time its use seems to be confined to objects that are difficult to make rustproof by other methods. Wire has been electroplated with zinc by use of an electrolyte containing zinc sulphate, ammonium, and sodium sulphates, and boric acid.

95. *Sherardizing.*—Small objects—such as screws, nuts, and bolts—are frequently galvanized in sealed containers. The objects to be coated and zinc dust are placed in the container which is heated to a given temperature.

96. Although there are a large number of firms that do contract galvanizing, the major consumption of zinc for galvanizing is in the large iron and steel sheet and tube mills located in Ohio, Pennsylvania, Illinois, and Indiana.

97. *Brass.*—The manufacture of brass and other copper alloys in which zinc plays an important part is discussed on pages 238 and 239 of "Power in Copper and Copper-Alloy Production." Such consumption of zinc occurs chiefly in Connecticut, New York, and Michigan, although Illinois, Pennsylvania, and Ohio are also large brass-producing States.

98. *Sheet zinc.*—The ductility of zinc permits it to be easily rolled into sheets, boiler plates, and strips, or to be drawn through disks. Approximately 68,300 tons of zinc was rolled in 1929 to be used later for roofing, valleys, flashings, boiler plates, electrotype, and in dry batteries. The adoption of socket-power radio receivers has caused a lessened local market for dry cells.

99. Four zinc-distillation plants roll zinc while five other firms purchase slab zinc for rolling. Zinc rolling mills at zinc distillation plants are:

Hegeler Zinc Co., Danville, Ill.
Illinois Zinc Co., Peru, Ill.
Matthiessen & Hegeler Zinc Co., La Salle, Ill.
New Jersey Zinc Co., Palmerton, Pa.

---

[77] Electrical World. Aug. 24, 1929.

The rolling mills purchasing slab zinc are:

The Platt Bros. & Co., Waterbury, Conn.
American Zinc Products Co., Greencastle, Ind.
Ball Bros. Co., Muncie, Ind.
Edes Manufacturing Co., Plymouth, Mass.
Hazel-Atlas Glass Co., Wheeling, W.Va.

100. *Die casting.*—The demands of the automobile industry for hardware that could be used in mass production led to the introduction of die castings made of zinc to which tin, aluminum, and copper or other metals are added. Only 6,000 tons of zinc were used for this purpose in 1921, whereas in 1929, consumption totaled 30,000 tons. The American Zinc Institute is endeavoring to increase the uses of die-cast zinc in building hardware.

101. *Zinc dust.*—As has been stated, zinc dust is sold for sherardizing. It is also used as a precipitating agent for gold in the cyanide process, as a reducing agent in the dye industry, and as a special paint pigment.

102. *Zinc oxide.*—As has been stated on page 254, while much more zinc oxide is made directly from zinc ores, 37,588 tons of metallic zinc is vaporized and oxidized by air to zinc oxide (french process). Zinc oxide is mixed with white lead to add a hard surface to the soft lead paint. It is used in lacquers to stabilize the nitrocellulose. French-process oxide adds brilliancy to enamels. In rubber, zinc oxide speeds up the curing and vulcanizing process and toughens the rubber. Zinc oxide is also used as a flux in vitreous enamel.

103. In addition to the plants manufacturing zinc oxide from the ore and, therefore, listed under zinc-reduction plants, the International Lead Refining Co. has plants at Akron, Ohio, and East Chicago, Ind., in which zinc oxide is made from electrolytic zinc. The New Jersey Zinc Co. also produces french zinc oxide at Freemansburg, Pa.

104. The location of rubber factories in Ohio and of paint and varnish factories in Ohio, Illinois, and New Jersey, is responsible for the location of zinc-oxide plants in or near these States.

105. *Lithopone.*—Lithopone is made up of 30 percent zinc sulphate and 70 percent barium sulphate. It is a dense white pigment used in the manufacture of paints and enamels. It is manufactured by the E. I. du Pont de Nemours Co.; by the Glidden Co. at Oakland, Calif., Collinsville, Ill., and St. Helena, Md.; by the Sherwin-Williams Co. at Chicago; by the Eagle-Picher Lead Co. at Argo, Ill.; the Mineral Point Zinc Co. at Depue, Ill.; at both plants of the New Jersey Zinc Co.; by the Grasselli Chemical Co. at Grasselli, N.J., and by a few other paint manufacturers.

106. *Zinc salts.*—Zinc chloride is produced by the action of hydrochloric acid upon zinc. It is a disinfectant and germicide and is used for medical purposes and in dentistry. Some is consumed in petroleum refining and in textiles. Zinc sulphate is used in lithopone manufacture, in cotton printing, in glue manufacture, and in medicine. Zinc salts are produced by several chemical companies in New Jersey, Indiana, Illinois, Ohio, Pennsylvania, West Virginia, California, and Massachusetts.

107. Although the American Bureau of Metal Statistics estimates the amount of zinc consumed by the several industries, neither the amount consumed by firms located in the several States nor the ton-

nage or value of finished products by States is available from Census figures except in scattered instances. While it is feasible to determine the States which are the heaviest consumers of zinc, the States which consume zinc for a number of purposes, and the States requiring it for one or two large industries, it is not possible to draw lines of demarcation as to actual amount of zinc consumed in each State or as to the total value of manufactured product containing zinc.

108. Ohio, Illinois, and Pennsylvania are heavy consumers of zinc for galvanizing. In them are also manufactured zinc oxide or zinc-ozide-consuming rubbers, paints, and lacquers, zinc salts, and brass. Illinois and Pennsylvania have zinc-rolling mills. Indiana has large galvanizing plants, two rolling mills, a zinc-oxide plant, and chemical plants consuming zinc. New Jersey is a large producer of zinc paints and zinc salts. New York manufacturers consume zinc in a number of industries. As the largest brass-producing State, Connecticut buys large amounts of zinc; it also has a zinc-rolling mill. Michigan is a heavy producer of brass and zinc paints. Massachusetts, Missouri, California, and West Virginia have galvanizing plants or zinc-rolling mills, or manufacture zinc pigments or zinc chemicals.

109. *Zinc exports.*—Only a little metallic zinc is imported into the United States. Some exporting is done of slab zinc, rolled products, and zinc dust. Of the 14,000 tons of slab or pig zinc exported, less than 5,000 tons reached English ports and about 2,000 tons went directly to France. Only 1,255 short tons of zinc dust was exported, of which half went to Mexico. Finished zinc products exports totaled less than 6,000 short tons. This reached Canadian or English ports, principally (see table IX, page 269).

TABLE VIII.—*Imports of zinc into the United States in 1929, by country of origin* [1]

Country	Ore, zinc content		Blocks, pigs, old zinc, etc.		Dust and other manufactures
	Short tons	Value	Short tons	Value	Value
Total	14,412	$1,127,432	226	$21,522	$152,758
Austria					13,518
Belgium			224	21,157	28,319
Canada	849	62,219			839
Cuba			(2)	13	25
Czechoslovakia					444
France			1	126	52,278
Germany			1	219	36,780
Italy					1,119
Jamaica			(2)	7	
Japan					2,655
Java and Madura					37
Mexico	13,563	1,065,213			40
Norway					20
Sweden					220
United Kingdom					16,464
All others					

[1] Compiled from unpublished data, Bureau of Foreign and Domestic Commerce, Department of Commerce.

[2] Less than 1 short ton.

TABLE IX.—*Exports of zinc from the United States in 1929, by country of destination*[1]

Country	Ores and concentrates		Dross		Cast; in slabs, blocks, or pigs		Rolled; in sheets, plates, etc.		Zinc dust		Other manufactures	
	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value	Short tons	Value
Total	71	$2,434	3,490	$217,019	14,344	$1,870,705	5,264	$1,075,000	1,255	$250,447	622	$233,789
Belgium	----	----	960	45,841	420	100,480	----	----	----	----	1	737
British India	----	----	36	3,640	1,681	220,114	340	47,320	2	497	(2)	208
Canada	61	1,950	20	4,000	974	128,892	2,124	384,602	148	30,924	222	92,180
Chile	----	----	----	----	565	80,285	26	8,458	4	1,093	1	559
France	----	----	56	3,809	2,299	289,021	13	2,338	----	----	----	----
Germany	8	368	462	29,000	1,894	214,804	35	4,559	----	----	26	4,134
Japan	----	----	1,357	91,584	587	69,528	270	40,024	2	438	8	3,497
Mexico	----	----	(2)	91	22	3,965	149	31,919	689	140,861	74	29,200
Netherlands	----	----	36	2,150	554	64,491	58	8,435	----	----	3	1,793
New Zealand	----	----	----	----	----	----	18	5,712	11	2,070	100	25,921
Sweden	----	----	----	----	487	64,169	39	12,724	----	----	2	769
Union of South Africa	----	----	----	----	----	----	----	----	167	28,532	1	299
United Kingdom	----	----	562	36,855	4,716	613,235	1,592	367,664	52	8,013	49	24,476
All others	2	116	1	49	145	21,721	600	161,245	180	38,019	135	50,016

[1] Compiled from unpublished data, Bureau of Foreign and Domestic Commerce, Department of Commerce.
[2] Less than 1 short ton.

WORLD PRODUCTION AND CONSUMPTION

110. Metallic zinc was produced in Germany, Great Britain, Belgium, and Austria-Hungary many years before the industry gained a foothold in the United States. Production in Asia, Australasia, and Africa began only with the twentieth century. But in 1928 the United States mined by far the largest amount of zinc ore, it produced by far the largest amount of metallic zinc, and it was the largest zinc-consuming country. Mexico and Australia were the second largest zinc-ore-mining countries. While Australia reduced about one third of its ore, it consumed only a small proportion of the world's zinc. Other fairly large zinc-mining countries, in their order of importance, are Poland, Germany, and Canada.

111. The largest zinc-ore-reduction countries, following after the United States, are Belgium, Poland, Germany, France, Canada, and Great Britain. While the United States consumes 37 percent of the total metallic zinc produced, Germany consumes 14.3 percent, Great Britain 12.8 percent, France 8.8 percent, Belgium, 8.2 percent, and Japan 3.8 percent.

112. The importing countries for zinc ore are Belgium, France, Great Britain, and the Netherlands. The countries exporting zinc ore are Mexico, Australia, Italy, Spain, Austria, Algeria, British India, Indo China, Peru, and Canada. The countries which import finished zinc products are, principally, Germany and Great Britain, while the United States, Canada, Belgium, Poland, Australia, Northern Rhodesia, Sweden, and the Netherlands have finished zinc products to export.

113. *European zinc cartel.*—Attempts have been made since 1885 to maintain a good price for zinc by limiting production. Cartels have been formed by the principal metallic-zinc-producing countries and have been abandoned with changed conditions. The depression

of 1926 and 1927 brought about the formation of the present European zinc cartel with offices in Brussels. It aims to control production by reviewing the production and stocks on hand every 2 months. Agreements to curtail production have been entered into in an effort to stabilize the London market price at approximately £27. But new plants have developed near zinc mines and production has increased in spite of these agreements. The London price for zinc averaged £24 during 1929, having dropped as low as £19 during the year.

TABLE X.—*World zinc production and consumption in 1928*

Country	Mine production zinc content [1]		Primary zinc reduction [1]		Apparent consumption [2]	
	Metric tons	Percent	Metric tons	Percent	Metric tons	Percent
Total	[3] 1,498,022	100.0	1,410,728	100.0	1,433,300	100.0
North America	877,036	58.6	632,045	44.8	549,500	38.3
Canada	[4] 84,645	5.7	74,176	5.3	17,300	1.2
Mexico	161,747	10.8	11,220	.8		
United States	630,644	42.1	546,649	38.7	532,200	37.1
South America	30,400	2.1			10,800	.8
Argentina					10,800	.8
Bolivia (exports)	2,261	.2				
Peru	28,139	1.9				
Europe	353,978	23.5	695,804	49.3	789,600	55.2
Austria	1,818	.1			5,600	.4
Belgium	(5)		209,280	14.8	117,900	8.2
Czechoslovakia	291	(6)	8,039	.6	24,600	1.7
Finland	660	(6)				
France	(3)		96,873	6.9	125,700	8.8
Germany	116,979	7.8	98,256	7.0	204,300	14.3
Great Britain	720	(6)	56,284	4.0	184,100	12.8
Greece	4,476	.3				
Italy	84,840	5.7	10,564	.7	21,100	1.5
Netherlands			26,855	1.9	5,000	.4
Norway	22	(6)			[7] 6,000	.4
Poland	150,000	8.7	161,815	11.5		
Russia	(5)		4,300	.3	36,000	2.5
Spain	(3)		13,549	.9	9,500	.7
Sweden	14,172	.9	5,106	.4		
Yugoslavia	(3)		4,883	.3	4,300	.3
Other European countries	(5)				45,500	3.2
Asia	54,387	3.6	22,117	1.6	64,900	4.5
British India	32,901	2.2				
Indo China	21,486	1.4	3,000	.2		
Japan	(5)		19,117	1.4	54,900	3.8
Other Asia	(5)				10,000	.7
Africa	31,985	2.1	9,733	.7	3,500	.2
Algeria	15,098	1.0				
Northern Rhodesia	13,387	.9	9,733	.7		
Tunisia	3,500	.2				
Australia	150,236	10.0	51,029	3.6	15,000	1.0

1 Compiled from U.S. Bureau of Mines: "Zinc in 1928", pp. 382 and 384.
2 American Statistics Year Book. Compiled from reports of American Bureau of Metal Statistics and Metalgesellschaft.
3 Total, incomplete; does not include content of ores mined in France—zinc ore, 8,729 tons; zinc-lead ore, 36,760 tons. Spain—ore, 122,141 tons; Yugoslavia—ore, 1,153 tons.
4 Estimated smelter recoveries.
5 Not available.
6 Less than 0.1 percent.
7 Includes Sweden.

EUROPEAN MINING AND METALLIC-ZINC PRODUCTION

114. *Germany and Poland.*—Germany was the leading zinc producer of the nineteenth century. In Upper Silesia the large smelters obtained ore from local mines while in the Rhine Provinces ore imported from Austria-Hungary and other countries was smelted. The Treaty of Versailles ceded the Upper Silesian smelting area to Poland although some zinc mines are located in German Upper Silesia. As a consequence, Germany's contribution to the world's metallic zinc dropped from 30 percent during the decade ending 1910 to 7 percent in 1928. Production took place in Poland first in 1919. By 1928 Poland mined 8.7 percent of the world's zinc ore and smelted 11.5 percent.

115. The largest Polish zinc-mining, -smelting, and -manufacturing company, Giesche Spolka Akcyjna, has been operated by the Anaconda Copper Co. since 1926. In 1928, this company sold approximately 67,000 tons of slab zinc, 7,000 tons of pig lead, 2,976,000 tons of coal mined in the company's mines, 5,347,000 zinc battery cups, 16,000 tons of zinc sheet, 405 tons lead pipe, 406 tons lead shot, 4,536 tons of litharge and red lead, 25,000,000 brick, 103,590 tons of sulphuric acid, and 67,360 tons of superphosphate and mixed fertilizer. The company also controls large timbering activities, a porcelain plant, and has holdings in paper and explosive factories. As much of the ore is zinc carbonate, after flotation, the zinc carbonate is converted into zinc oxide and then sent to an electrolytic plant at Bernharde. Zinc-sulphide ore is treated in smelters. The power is supplied from generating plants located at the company's coal mines.[78]

116. Germany now secures her ores chiefly from Mexico, Italy, Russia, Algeria, and Bolivia. It is constructing an electrolytic plant at Magdeburg.

117. *Belgium.*—During Germany's supremacy as a zinc producer, Belgium ranked second in European metallic-zinc production. In 1928, she ranked first. All but a small proportion of zinc ores smelted are imported. The founding of the industry in Belgium before 1810 was due to a Belgian's discovery of a process for smelting zinc, together with the location of zinc ores, coal, and clay for retorts near Liege, at that time. Since 1856 zinc ore production has declined and Belgium has become the chief importer of zinc ores. Some ore comes from Italy, Spain, Australasia, and Mexico.

118. *France.*—France produces 7 percent of the world supply of metallic zinc. It has 6 smelters and 1 electrolytic plant. Only a small proportion is derived from ores mined in France but ore is secured from French colonies, Algeria and Tunisia.

119. *Austria, Czechoslovakia, Yugoslavia, and Italy.*—Prior to the World War, Austria-Hungary produced about 2 percent of the world's metallic zinc from zinc ores located within her boundaries. The northern zinc district in Galicia was ceded to Czechoslovakia and the southern zinc districts to Italy and Yugoslavia after the World War. Only a small amount of ore is still mined in Austria which is shipped to Czechoslovakia and Germany for smelting. Yugoslavia does some mining and smelting.

[78] Brooks, G. S., president, Giesche Spolka Akcyjna. The Polish Enterprise. Engineering and Mining Journal, Aug. 24, 1929.

120. In addition to the ores ceded to it in the north, Italy has produced much ore from Sardinian mines where deposits are extensive. These mines are controlled by American, Belgian, and French interests and all ore not smelted in Italy is shipped to Belgium and Great Britain for smelting. Electrolytic plants are located at Cotrone, Monteponi, and San Dalvazzo di Tenda.

121. *Spain.*—Spain has mined zinc ores for many years but the ore has low zinc content. It has produced as much as 18,000 tons metallic zinc but most of its ore has been shipped to Belgium and Germany.

122. *Great Britain.*—Great Britain has produced metallic zinc since 1740 but her own supply of zinc ore for smelting proved insufficient as early as 1860. Ores have been imported since that time but largely from British possessions. She produced 4 percent of the world's metallic zinc in 1828.

123. *Other European countries.*—While entirely dependent on foreign sources of ore, the Netherlands produces about 2 percent of the world's metallic zinc. Sweden mines zinc ore, treats some of it, and ships the remainder to Belgium. Norway produces a little ore but counts on foreign ores for its electrolytic reduction plants. A little mining and smelting is being carried on in Russia but little information as to zinc reserves is available.

124. *Asia.*—Japan mines and smelts zinc. Her ore is sufficient to meet local smelter demands, but Japan buys some ore from Indo-China and Korea, or from America and Mexico when prices are attractive. Chosen, a province of Japan on the mainland, produces some zinc ore.

125. China has exported zinc ores for many years and has also produced some metallic zinc. The industry is at a standstill at the present time. Indo-China produced a little over 1 percent of the world's ore, only a small amount being smelted, however. British India is a larger contributor to the zinc ore supply. The Burma Corporation, Ltd., is one of the world's important lead-zinc producers. Ore is high in both zinc, silver, and lead.

126. *Australasia.*—Australasia is the second largest zinc ore producing continent. Mining occurs at New South Wales where the Broken Hill Co. has vast reserves of lead-zinc ore, in Tasmania, and in Queensland. Prospecting is under way in New Zealand. In Queensland 20,000,000 tons of zinc-lead ore is blocked.

127. The completion of an electrolytic reduction plant at Risdon, Tasmania, increased the production of metallic zinc in Australasia until but two thirds of the ore concentrated is exported. A second electrolytic plant is being erected by the Electrolytic Zinc Co. of Australia.

128. *Africa.*—Both Algeria and Tunisia mine zinc ore which is shipped to France and other European markets.

129. Rhodesia became an important producer of zinc for the first time in 1928 when operations were begun at the electrolytic zinc plant of the Rhodesia Broken Hill Development Co., Ltd. Ore is reported to assay 30 percent zinc, 8 percent lead, and 0.9 percent vanadium oxide. The Base Metals Co. is shipping zinc ore averaging 47 percent to 48 percent zinc to Johannesburg.

130. *South America.*—Zinc ore has been produced in Bolivia and Peru. It is believed than zinc resources are abundant although lack of transportation facilities has retarded prospecting and development.

131. *North America.*—The complex ore belt which runs through the Rocky Mountain region in the United States extends into Canada and Mexico. Mexico mined approximately 11 percent of the world's zinc ores in 1928 and Canada 8 percent. Mexico has been an important but irregular source of the world's zinc ores for many years. Some of the smelting is done in the United States but more ore is shipped to Europe.

132. *Canada.*—The Consolidated Mining & Smelting Co. of British Columbia is one of the largest lead-zinc mining companies in the world. Reserves are extensive and ore is reported to contain 11 percent lead, 7.5 percent zinc, 40 percent iron, and 4.2 ounces of silver per ton.[79] This company has an electrolytic zinc plant at Trail with a capacity of 380 tons of zinc per day. The Reeves-McDonald property on the Pend Oreille River contains 2,000,000 tons of proved ore of 7 percent zinc content.

133. The Province of Quebec also produces zinc ore which is concentrated by flotation and shipped to Belgium. The Sudbury District of Ontario will also become an important producer of zinc in the near future. The Errington mine of the Treadwell Yukon Co. has developed 1,000,000 tons of ore above the 300 foot level and other companies are getting mines ready for operation. Manitoba is also the scene of much activity. The Flin Flon property has developed ore reserves of 18,000,000 tons above the 900-foot level. An electrolytic plant is planned to be located on the property. Nova Scotia mines report some reserves. The American Smelting & Refining Co. is operating a mine in Newfoundland having ore reserves of over 5,000,000 tons assaying 17.85 percent zinc, 7.65 percent lead, with some gold, silver, and copper.

Power in the Lead Industry

TREATMENT OF LEAD ORES AND CONCENTRATES

134. All lead ores and lead concentrates are smelted in blast furnaces to produce metallic lead. Little power is required for their beneficiation. When ores comparatively free of silver and base metals are used, the smelted lead is sufficiently pure for many purposes and is marketed as "soft lead." While much of the lead ores from the Mississippi Valley and Southern States is of this character, some is refined further either because of silver content or because smelting does not remove objectionable metals. All complex lead ores and concentrates of the Rocky Mountain Region (see pp. 248 to 251 for location of ores) yield an impure pig lead called "base bullion" which must be refined before consumption. Foreign ore entering the United States is first smelted into base bullion and then refined.

135. In 1929, out of a total production of 774,633 short tons of refined primary lead, 30 percent was soft lead, 7 percent was desilverized soft lead, almost 50 percent was refined domestic bullion, and about 13 percent refined foreign bullion. In addition, 25,669 tons of antimonial lead were produced as a byproduct of base bullion refining.

136. Soft lead, produced from ores of the Southeastern Missouri District and the Tri-State District, is known in the trade as chemical

[79] Engineering and Mining Journal, vol. 124. Oct. 1, 1927.

lead and used principally in the manufacture of cable, pipe, and sheets. High-grade lead is essential for white lead, litharge, red lead, and other pigments. Antimonial lead, as well as lead oxide, is consumed in the manufacture of storage batteries, while antimonial lead enters into bearing metal and type metal.

REFINING OF LEAD BULLION

137. Lead bullion is refined electrolytically or desilverized by pyrometallurgical or by chemical processes. The electrolytic process may be used to convert the lead bullion into common lead containing as much as 2 percent impurities or it may be employed to produce the highest grades of refined lead. It removes bismuth from the crude metal which is not done by pyrometallurgical processes. It is in operation at East Chicago, Ind., at the plant of the United States Smelting Lead Refinery, Inc., and at the Omaha, Nebr., plant of the American Smelting and Refining Co. The Consolidated Smelting and Refining Co., Ltd., of Trail, British Columbia, has employed electrolysis in lead refining since 1904. The Evans-Wallower Lead Co. has announced its intention to erect an electrolytic lead plant at the location of its electrolytic zinc plant at East Chicago for the recovery of lead values from residues of the zinc plant. About 60,000 tons of crude metal is refined electrolytically.

138. Most of the plants refining lead by furnace and chemical processes have previously smelted led ores or concentrates. The exception is the International Lead Refining Co. at East Chicago which refines led bullion shipped to it from the International Smelting Co., at Tooele, Utah, and from the American Smelting & Refining Co. at East Helena, Mont. Plants refining lead by furnace processes are as follows:

California, Selby, American Smelting & Refining Co.
Idaho, Kellogg, Bunker Hill and Sullivan Mining & Concentrating Co.
Illinois, Collinsville, St. Louis Smelting & Refining Works of National Lead Co.
Indiana, East Chicago, International Lead Refining Co. (refinery only).
Missouri, Herculaneum, St. Joseph Lead Co.
New Jersey, Newark, U.S. Metals Refining Co.
New Jersey, Perth Amboy, American Smelting & Refining Co.
Pennsylvania, Carnegie, Pennsylvania Smelting Co.

139. *Electrolytic refining of lead bullion.*—The "Betts" process is the only process developed commercially for the refining of lead bullion While in principle it is similar to the multiple system of refining copper, the details of operation are different.

140. *Electrolyte manufacture.*—The electrolyte employed is lead fluosilicate. This is manufactured at the process plants. Ground high-grade fluorspar (2.5 pounds approximately) is mixed with 3 pounds of 66° B. sulphuric acid. This is heated gradually in a retort until hydrofluoric acid passes as a gas to condensers where it is absorbed by water. This hydrofluoric acid is fed slowly to tanks filled with pure silica sand. It percolates up through the bed of silica and the overflow passes through a cascade of tanks. The resulting product is hydrofluosilicic acid. This is converted into lead fluosilicate either by electrolysis of the acid with lead anodes and cathodes separated by a diaphragm or by adding white lead or basic lead carbonate to the hydrofluosilicic acid.

141. The electrolyte as used usually carries 6 percent lead and 8 percent hydrofluosilicic acid. After the electrolyte is in the cells, dissolved glue is added. Each ton of lead produced requires 1.5 pounds of glue.[80] The temperature of the electrolyte is kept at 38° to 40° C.

142. *Electrolytic cells.*—Concrete tanks with impervious asphalt linings are preferred although wooden tanks are still in use. The tanks are arranged either according to the Walker system of four tanks to a section or in cascades, or double rows of 5, 7, or 11 tanks. Hard rubber and soft rubber connections and feed lines are used between tanks and the centrifugal pumps are of copper. The electrolyte passes through the 4-tank sections at the rate of 2.5 to 4 gallons per minute to launders, from which it is pumped to cooling tanks and then returned to the cells. In the cascade system it flows through each tank by gravity to collecting launders and from there is pumped back to the gravity feed tank.

143. Smelters cast lead bullion to be used in the electrolytic process into anodes with a pair of lugs attached to support the anodes in tanks and to make the electrical contact. Anodes are about 24 inches by 36 inches in size and about 1.25 inches thick at the top, tapering toward the end. They weigh from 364 pounds to 460 pounds in different plants.

144. Cathodes are made by pouring molten lead over inclined cast-iron plates, thereby forming a thin sheet of lead about 0.025 inch thick and weighing 10 or 15 pounds. These sheets are folded over copper bars which act as supports and also conduct the current to the next cell. As these sheets have sufficient strength to hold the deposited lead, no starting sheet is necessary such as is essential in copper refining.

145. Cathodes are placed in the cells by hand and must be hand straightened. Anodes are lowered by cranes into position approximately 4⅜ inches center to center. One set of anode lugs rests on the positive bus bar or triangle of the cell and the other rests on the wooden heavy strip on the opposite side. Two sets of cathodes are usually drawn from each set of anodes. The cathodes are removed by cranes to wash tanks. They are then melted and cast as refined lead.

146. *Power consumed.*—The current density varies from 16 amperes per square foot of cathode surface to 18 amperes in the several plants. The initial cell potential of 0.35 volt gradually increases as sponge adheres to the anode surface until it reaches 0.44 volt. The lead deposited per kilowatt-hour will vary, with the current efficiency and the resistance, from 18 to 21 pounds. Or from 95 kilowatt-hours to 111 kilowatt-hours energy is required to refine 1 ton of lead.

147. *Slimes.*—About a fifth of the anode weight is left after two cathodes are produced from it. The larger amount of slime formed during electrolysis has adhered to the anode. The scrap anode is, therefore, removed and brushed mechanically. The washed scrap anodes, after melting and casting, are used again for anodes. The anode slime, together with tank slime, is filtered and washed free of any electrolyte or soluble lead. It is then dried by compressed air and in gas chambers. The dried slime is melted in a reverberatory furnace. After the lead-antimony slag is tapped off, silver, gold,

[80] Fingland, J. J. "The Betts Electrolytic Lead Refining Process in Practice." Paper before American Electrochemical Society, May 1930.

copper, tellurium, and bismuth are oxidized. The three last-named metals are oxidized as slag in a second reverberatory furnace, leaving a gold-silver alloy which is refined by air and niter to doré. The doré is cast into plates ready for parting at the lead refinery or special silver and gold refineries.

148. The bismuth, copper, and tellurium slags are retreated for the recovery of each metal. Bismuth is recovered electrolytically. The lead-antimony slag is reduced to antimonial lead in a blast furnace. Any metals that are volatilized during the furnace processes are collected in a bag house and by Cottrell treaters and are returned to the furnaces.

149. *Lead refining by furnace processes.*—Lead bullion for furnace refining is cast into slabs or bars at smelters for shipment to refineries. At refineries it goes to coal-fired drossing kettles in which it is melted. From there it is pumped to coal-fired reverberatory furnaces called "softeners." By alternative heating and cooling, metals held in solution in the bullion rise to the surface of the molten metal and are solidified. They are skimmed off every 6 or 8 hours. A charge of 250 tons requires a 48-hour softening.[81]

150. From the softening furnaces, the metal goes to desilvering, coal-fired kettles. Zinc is added here which causes nearly all the silver and gold to rise. The metal then passes to refining furnaces similar to the softeners. Steam is introduced for oxidation of the zinc. The dross formed is skimmed off until all traces of zinc, antimony, and other impurities are removed. The lead metal goes to a melting furnace from which it is poured into molds.

151. Zinc is recovered in retorts to be used again. Cupellation is employed for the separation of precious metals. This consists of melting the retort bullion in a reverberatory furnace and oxiding base metals with air blasts. The base metals are slagged off as litharge, while the silver and gold remain in metallic state. The doré is cast into bars and shipped to silver and gold refineries.

152. Skims from the softening furnaces, litharge from the cupels, and copper dross is charged to reverberatory furnaces with sufficient galena to form a matte. A lead antimoniate slag is produced which is remelted in the blast furnace to antimonial lead. Copper matte is shipped to copper smelters.

153. *Harris process.*—A chemical process to remove such impurities as arsenic, antimony, and tin from base bullion and zinc from desilverized lead is coming into use. Caustic alkali and alkali chloride are brought into contact with the bullion at a temperature beyond the melting point. They effect a clean separation of the lead from these base metals which are collected as oxide or oxysalts in the chemicals. By the wet process, these metals are recovered in marketable form.

154. Other chemical processes are also used to remove other base metal impurities and to simplify the kettle lead refining. At the Bunker Hill smelter in Idaho, a gold crust is obtained first in desilvering kettles which is retorted, cupelled, and parted with sulphuric acid. The silver crust is gotten after the gold crust has been removed. This is liquidated to remove lead and retorted to a bullion. The silver is cupelled and finally melted.

[81] Johnson, G. E., superintendent, International Lead Refining Co. Western Lead Refined at East Chicago by Parkes Process. August 1929.

155. The Bunker Hill process requires about 200 pounds of coal for each ton of metal produced, the coal consumption including that used for byproduct as well as lead production. The labor required is but 1-man-day per 4.2 ton refined lead.[82]

156. *Comparison of processes.*—The heaviest market demand is for common lead which can be produced so cheaply by pyrometallurgical processes as to preclude competition from electorlytic processes. In high-grade lead, the electrolytic process has the advantage of removing bismuth, which is objectionable in some industries. The bismuth, itself electrolytically refined, may be sold to the pharmaceutical manufacturer or for use in low melting-point alloys.

157. The demand for high-grade lead comes chiefly from manufacturers of white lead pigment. One eighth of the lead produced is manufactured into white lead or basic lead carbonate. As even small amounts of silver or other nitrates affect the whiteness of the pigment, a pure lead is essential. While white lead used in oil paints is manufactured more generally by the laborious old Dutch process or by the faster Carter process, one producer of such pigments uses furnace refined impure lead anodes for the electrolytic production of white lead. This process is as follows:

158. *Production of white lead by electrolysis.*—At the Anaconda Lead Products Co. at East Chicago, Ind., the Sperry electrolytic process is in use. The plant has a daily capacity of 28 tons of dry white lead.

159. Cells are arranged in series, each containing 18 lead anodes, 21 inches by 30.5 inches in size and 1 inch thick, and weighing 250 pounds. The anodes need not be pure lead as lead only is dissolved. The cathodes are thin sheets of steel. Each is enclosed in a heavy linen duck diaphragm.

160. The catholyte contains a relatively large amount of sodium carbonate in a sodium acetate solution. This is fed to each cathode frame by a separate feed tube and overflows through a spout at the top. In passing through the cell it gives the required carbonate to the anolyte and then passes out of the cell to an absorption tower for restoration. The anolyte solution contains the exact amount of carbonate necessary to precipitate the lead compound. It enters the cell, and circulates about the anode which dissolves. The lead is precipitated as basic carbonate in suspension in the anolyte. The discharge from the cell goes to thickeners, to filters, to washers, and to driers. When thoroughly dried, the lead carbonate is pulverized and packed in barrels.

LEAD PRODUCING AND CONSUMING UNITS

161. *Location of mines.*—Table XI shows the production of lead ore by States in 1929. Three States, Missouri, Utah, and Idaho produced more than three fourths of the lead in domestic ores in 1929. Missouri produced nearly 31 percent, Utah nearly 23 percent, and Idaho approximately 22 percent of the lead in domestic ores. The only other States of importance in lead ore mining were Oklahoma, Kansas, Montana, and Colorado.

162. *Location of smelters.*—Utah ranked first in lead smelting having the three largest lead smelters in the country, namely, the Murray plant of the American Smelting & Refining Co., the International

[82] Beasley, A. F., superintendent of the Bunker Hill & Sullivan Mining & Concentrating Co., in an address before American Institute of Mining Engineers at Spokane, Wash., June 1930.

Smelting Co. (subsidiary of Anaconda Copper Mining Co.), and the United States Smelting, Refining & Mining Co. The capacity of Utah smelters totals 1,714,000 tons. Idaho has a smelter capacity of 450,000 tons, Montana of 360,000 tons, Texas and Illinois each of 350,000 tons, Colorado of 300,000 tons, with 1 or 2 smelters of smaller capacities in Missouri, New Jersey, California, Arizona, Kansas, and Nebraska. It is obvious that western ores are smelted near lead mining regions, but that Missouri lead is smelted in Illinois as well as in Missouri and Kansas and other Central States.

163. *Location of refineries.*—As is shown in table XI, with the exception of Idaho and California, all lead bullion refining is carried on in Central or Eastern States. The freight rate on lead bullion from Utah smelters to St. Louis is $9, to New York $12.50; from East Chicago, the pig lead rate to St. Louis is $2.10. The freight rate on soft lead from Illinois and Missouri smelters to St. Louis varies from $0.25 to $3.50 and from $5 to $8.50 to New York.

TABLE XI.—*Sources of lead ore smelted and refined in United States in 1929* [1]

Source of lead ore, United States and Alaska	Amount smelted or refined		Source of lead ore, United States and Alaska	Amount smelted or refined	
	Short tons	Percent		Short tons	Percent
Total, domestic ores	685,992	100.0	Utah	157,085	22.9
Alaska	1,266	.2	Washington	447	.1
Arizona	8,153	1.2	Wisconsin	1,729	.3
California	1,459	.2	Undistributed	5,624	.8
Colorado	23,675	3.5	Zinc residues	1,903	.3
Idaho	147,595	21.5	Total, foreign ores	102,135	100.0
Illinois	777	.1			
Kentucky	303	(2)	Canada	9,499	9.3
Missouri	211,345	30.8	Europe	28	(2)
Montana	26,795	3.9	Mexico	16,807	16.5
Nevada	13,256	1.9	South America	3,285	3.2
New Mexico	12,249	1.8	Other foreign	56	.1
Oklahoma and Kansas	71,757	10.5	Foreign base bullion:		
Oregon	15	(2)	Mexico	51,295	50.2
Texas	559	.1	Peru	21,165	20.7

[1] Compiled from Bureau of Mines preliminary report, Lead in 1929.
[2] Less than 0.05 percent.

164. *Large producing units.*—The largest lead smelter and refiner in the United States is the American Smelting & Refining Co. producing more than 50 percent of the country's pig lead. It has 2 lead-silver smelters in Colorado, 1 at East Helena, Mont., its largest smelter at Murray, Utah, and a smelter at El Paso, and 1 at Federal, Ill.; it has smelters and furnace refineries in California and New Jersey; it has a smelter and electrolytic refinery at Omaha. The capacity of its plants in the United States totals 2,203,000 short tons of lead. In addition, this company operates 2 smelters and 1 smelter and refinery in Mexico. The company, through subsidiaries, operates mines in the Coeur d'Alene and tri-State districts and in other countries.

165. The St. Joseph Lead Co. is the largest lead producer in southeastern Missouri; only a part of the ores mined are smelted in its own furnaces. The Bunker Hill and Sullivan Mining & Concentrating Co.'s lead smelter in Idaho has a capacity of 450,000 tons.

166. *Ore and bullion imports.*—United States smelters and refineries treated 102,135 tons of foreign ore and bullion in 1929. Seventy-three percent of this was shipped in from Mexico and 20 percent came from Peru and other South American countries. Much of this is refined in bond and subsequently exported. Consequently, of the 72,261 short tons of pig lead exported, 53,003 tons or 73 percent was smelted from foreign ore.

167. *Secondary lead.*—Smelters also recovered about 70,000 tons of lead from secondary lead, while plants that treat only scrap and drosses recovered 244,400 short tons. Or, more than a third of all lead produced in the United States was manufactured from secondary metal.

168. *Consumption of lead.*—Industries demanding the largest amounts of lead are the storage battery and the lead-covered cable industries. Each requires from a fifth to a fourth of all lead produced. With continued growth of the automobile industry the demand for lead in storage batteries will increase. With continued use of underground cables for electrical transmission the demand for cable lead will increase. Common lead and antimonial leads are used by these markets.

169. Lead pigments are an outlet for 15 percent of lead refined. White lead is being hard pressed by the use of zinc-oxide pigments. This is offset somewhat by the use of red lead for protective coating of iron and steel framework. White lead produced in 1929 totaled 147,031 tons, litharge 87,916 tons, red lead 43,021 tons, and orange mineral 678 tons. A new pigment for spraying has been put on the market which is finely divided lead suboxide suspended in linseed oil.

170. The States manufacturing the largest amount of lead pigment are Illinois, Ohio, Missouri, New York, Pennsylvania, and New Jersey. California has several paint factories of size. The same States afford largest outlets for lead for other purposes.

BIBLIOGRAPHY

Year	Author	Title
1929	American Bureau of Metal Statistics	American Statistics Yearbook.
1930	Beasley, A. F., superintendent, Bunker Hill & Sullivan Mining & Concentrating Co.	Address Before American Institute of Mining Engineers at Spokane, Wash.
1929	Brooks, G. S., president, Giesche Spolka Akcyjna.	The Polish Enterprise, Engineering and Mining Journal. Aug. 24.
1929	Case, F. O.	French Process Modernized by Anaconda Production of Zinc Oxide at East Chicago, Engineering and Mining Journal. Aug. 24.
1930	Elfred, F. S., Evans-Wallower Zinc Co.	Address Before American Die-Casting Institute. January.
1929		Electrical World. Aug. 24.
1927		Engineering and Mining Journal. Vol. 124. Oct. 1.
	Fahrenwald, A. W.	Flotation Practice in the Coeur d'Alene District, Idaho. Technical Publication No. 1, American Institute of Mining and Metallurgical Engineers.
1930	Fingland, J. J.	The Betts Electrolytic Lead Refining Process in Practice. Paper presented before American Electrochemical Society, June 1.
	Fosdick, E. R.	Power in Zinc Production, Journal American Institute of Electrical Engineers. Vol. 77.
1918	Hansen, C. A.	Electrolytic Zinc, A.I.M.E.
	Hoffman, H. O.	Metallurgy of Zinc and Cadmium.
1926	Ingalls, W. R. I.	Metallurgy of Zinc and Cadmium, Handbook of Non-Ferrous Metallurgy.
1926	do.	Pyrometallurgy of Zinc, Handbook of Non-Ferrous Metallurgy.

BIBLIOGRAPHY—Continued

Year	Author	Title
1929	Johnson, G. E., superintendent, International Lead Refining Co., East Chicago, Ind.	Western Lead Refined at East Chicago by Parkes Process, Engineering and Mining Journal. Aug. 24.
	Laist, Frederick, and Caples, Russell B.	The Electrolytic Zinc Process, Handbook of Non-Ferrous Metallurgy.
1930	Moody, John, Inc.	Moody's Industrials.
		Thomas Register.
1929	Pehrson, Elmer W., U.S. Bureau of Mines.	Flow of Lead into World Trade in 1928, Mining Congress Journal, November.
1920	Ralston, Oliver E.	Electrolytic Deposition and Hydrometallurgy of Zinc.
1926	Riddell, C. C.	Lead, in Handbook of Non-Ferrous Metallurgy.
1929	Roosevelt, Ralph M.	Use of Lead in Industry.
1930	Roush, G. E.	The Mineral Industry During 1929.
1929	U.S. Senate	Hearings on Tariff Act of 1929. Vol. III.
1927	Sheet Steel Trade Extension Committee.	5,000 Sheet Steel Products and Who Make Them.
	Siebenthal, C. E.	Zinc Production Before 1882.
1926	Smith, Walter C.	Electrolytic Refining of Lead, in Handbook of Non-Ferrous Metallurgy.
1926	do	Treatment of Electrolytic Slimes and Zinc Crust, Handbook of Non-Ferrous Metallurgy.
1929	Tainton, U. G., and Bosqui, David	The Electrolytic Zinc Plant of the Evans-Wallower Co. at East St. Louis, Ill. American Electrochemical Society.
1929	Tri-State Zinc & Lead Ores Producers Association.	Reports.
1927	U.S. Bureau of the Census	Biennial Census of Manufactures.
1929	U.S. Bureau of Mines	Lead in 1928. (General report.)
1929	do	Preliminary Reports for Lead.
1930	do	Preliminary Report on Zinc Production in 1929. May 28.
1930	do	Production of Slab and Rolled Zinc in 1929, and other reports.
1930	do	Reports of State Production of Metals.
1929	do	Zinc in 1928.
1915	U.S. Geological Survey	Zinc and Cadmium in 1915.
1929	Wiggin, Albert E., and Caples, Russell B.	Electrolytic Zinc Practice at Great Falls and Anaconda, Engineering and Mining Journal. Aug. 24.

POWER IN THE MANUFACTURE OF CHEMICALS AND METALS FROM BRINE

CONTENTS