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FUSED QUARTZ

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ELECTRIC REDUCTION OF GOLD AND SILVER AND RARE OR MINOR METALS

CONTENTS

Gold and Silver

The production of gold and silver is affected vitally by the fact that monetary uses constitute so important a market. Particularly is this true of gold, for while certain populous countries like China make silver the money standard of half the people of the world, yet gold is the standard of the majority of all important nations, measured by political influence and by financial and commercial importance. Furthermore, the price of gold in the United States is fixed

at $20.67 a fine ounce and the world's supply of gold is sharply limited The price of silver varies in this as in other countries with fluctuations in supply and demand.

The United States produces approximately 11 percent of the world's gold and consumes 57 percent of the gold supply. It mines 23 percent of the world's silver and consumes 15 percent of the world's silver supply. Electrolytic processes are employed only in the refinement of these precious metals. The United States mints have become the larger refineries of new gold, although private refineries refine the largest proportion of silver. Although the unit consumption of electricity for such electrolytic refinement is relatively high, production in fine ounces is so small in the United States that only about 45,000 kilowatt-hours of energy are consumed in gold refining and approximately 1,280,000 kilowatt-hours in silver refining annually.

Sources of Gold and Silver

1. *Occurrences of metals in the United States.*—Gold is usually found in nature as an alloy with silver. These precious metals are associated with quartz in dry and siliceous ores or in gravel, or they are found in complex ores which have value because of their copper, lead, or zinc content as well as for their silver and gold content. Gold is found in greater quantity in siliceous ores than in complex ores, while the latter are the principal source of silver. Approximately 56 percent of all gold mined is secured from dry and siliceous ores, 19 percent from placer gravels, while but 25 percent is obtained from refining complex ores. On the other hand, four fifths of all silver was secured through the refining of lead, copper, or zinc ores and only one fifth was recovered from dry and siliceous ores.

Table I.—*Gold and silver produced in the United States by sources of ore* [1]

GOLD

Year	Total (fine ounces)	Placers	Dry and siliceous ore	Copper ore	Lead ore	Zinc ore	Copper-lead and copper-lead-zinc ores	Lead-zinc ore
1928:								
Amount	2,148,064	416,832	1,195,804	414,771	35,959	130	6,973	77,595
Percent	100.0	19.4	55.7	19.3	1.7		0.3	3.6
1927	2,107,032	451,215	1,162,404	367,639	41,504	1,563	2,631	80,076
1926	2,232,526	457,717	1,295,570	365,223	45,724	1,194	3,335	63,763
1925	2,307,374	436,251	1,414,446	348,025	50,378	375	5,515	52,384
1919	2,753,282	704,377	1,780,567	186,701	41,945	86	1,043	38,563
1915	4,754,475	1,077,432	3,212,298	343,226	84,449	4,975	2,496	29,599
1913	4,311,103	1,075,784	2,864,901	275,634	73,880	896	4,697	15,311

SILVER

Year	Total (fine ounces)	Placers	Dry and siliceous ore	Copper ore	Lead ore	Zinc ore	Copper-lead and copper-lead-zinc ores	Lead-zinc ore
1928:								
Amount	57,872,443	46,276	11,140,496	14,733,852	13,416,396	117,532	2,207,200	16,210,691
Percent	100.0		19.3	25.5	23.2	0.2	3.8	28.0
1927	59,625,682	49,829	11,775,384	14,556,572	15,762,197	1,685,764	2,171,792	13,624,144
1926	62,487,219	49,890	13,567,095	17,039,546	15,528,454	313,119	1,415,699	14,573,416
1925	66,710,080	50,303	17,099,876	18,051,937	18,777,853	181,886	970,370	11,577,855
1919	51,899,460	78,401	19,043,515	12,880,624	14,351,293	39,480	232,157	5,273,990
1915	72,353,730	154,968	25,709,505	18,781,365	19,828,533	1,136,220	234,047	6,509,092
1913	71,187,228	123,739	28,010,875	18,250,253	18,629,246	86,432	752,563	5,334,120

[1] Compiled from U.S. Department of Commerce, Bureau of Mines, Gold and Silver in 1928, and U.S. Department of the Interior, Geological Survey, Mineral Resources of the United States, Part 1, for 1913 and 1915.

2. *Gold mining in the several States.*—The largest gold mining States and Territories are California, Alaska, South Dakota, Utah, Colorado, Arizona, and Nevada. The Homestake Mining Co. of South Dakota is the biggest single producer, followed by the Alaska Juneau Gold Mining Co., the Golden Cycle Mining and Reduction Co. of Cripple Creek, Colo., the Yuba Consolidated Goldfields of Marysville, Calif., and the Utah Copper Co., of West Mountain, Utah.

3. In California, 32 counties reported gold production. Yuba County, the largest producing county, and Sacramento County, fourth in rank, obtained most of their gold by dredging. Nevada County, the second county in quantity of gold mined in California, produced gold from the siliceous ores of the Grass Valley district. Amador County ranked third in gold production. Almost one half the gold production in Alaska occurs in southeastern Alaska and more than one fourth in the Yukon River Basin. Lawrence County, S.Dak., mines about 14 percent of the entire gold mined in the United States.

4. In Utah, Salt Lake County is the principal gold-mining county, while Cripple Creek in Teller County, Colo., produces more than half of Colorado's gold. The larger amount of Arizona's gold was secured from copper mining. Maricopa and Cochise Counties produced two thirds of the State's gold. In Nevada, while more gold is secured from siliceous ores than from copper and lead ores, considerable amounts are secured from complex ores. Here, too, gold production is heavily concentrated in one county, for White Pine County produced 40 percent of all Nevada's gold although Esmeralda County mined 20 percent.

5. The 20,337 fine ounces of gold mined in Idaho came principally from placer and dry and siliceous mining in Boise and Custer Counties. The larger part of Montana's gold was secured from copper ores in Silver Bow County. Oregon mines gold in Grant, Jackson, Baker, Coos, Curry, Josephine, and Malheur Counties. Washington's gold came chiefly from Ferry County.

TABLE II.—*Mining of gold in the several States in 1929* [1]

State	Total	Lode mines		Placer mines			
				Dredges		All other	
		Ounces	Percent of total	Ounces	Percent of total	Ounces	Percent of total
	Ounces						
Total	2,059,085	1,650,742	80.2	330,556	16.0	77,787	3.8
Alabama	10					10	100.0
Alaska	375,437	176,278	46.9	141,835	37.8	57,324	15.3
Arizona	202,318	202,045	99.9			273	.1
California	412,477	225,237	54.6	173,630	42.1	13,610	3.3
Colorado	213,690	211,472	98.9	1,862	.9	356	.2
Georgia	125	32	25.6			93	74.4
Idaho	20,337	16,117	79.2	2,999	14.8	1,221	6.0
Montana	54,753	54,161	98.9			592	1.1
Nevada	163,711	161,594	98.7			2,117	1.3
New Mexico	35,177	35,097	99.8			80	.2
North Carolina	244	192	78.7			52	21.3
Oregon	17,092	5,145	30.1	9,939	58.2	2,008	11.7
Pennsylvania	836	836	100.0				
South Dakota	316,837	316,837	100.0				
Tennessee	565	565	100.0				
Texas	1,279	1,279	100.0				
Utah	240,419	240,373	99.9			46	(2)
Washington	3,730	3,434	92.1	291	7.8	5	.1
Wyoming	48	48	100.0				

[1] Compiled from U.S. Treasury Department, Annual Report of the Director of the Mint for the fiscal year ended June 30, 1930.

[2] Less than 0.1 percent.

6. *Silver mining in the several States.*—Utah and Montana outrank all other States in production of silver in 1929. In Utah, three fourths of all silver is gained from copper ores, while in Montana 57 percent is taken from copper ores and 33 percent from lead ores. Consequently, Utah silver comes from the same counties that produce large amounts of lead or Juab, Utah, Wasatch, and Salt Lake Counties. Eighty-eight percent of Montana's silver is from Silver Bow County's mines. The Anaconda Copper Co. is the largest single producer of silver.

7. Idaho produced over 9,000,000 ounces of silver in 1929 almost entirely as a byproduct of lead mining in Shoshone County. Arizona ranked third in silver production, seven eighths of the silver being secured in the course of copper concentration. Cochise, Pinal, and Yavapai Counties are large silver-mining counties.

8. Nevada and Colorado secured silver from complex as well as from the dry and siliceous ores while two thirds of Washington silver came from copper ores and three fourths of Oregon silver from dry and siliceous ores.

TABLE III.—*Mining of silver in the several States in 1929* [1]

State	Total	Dry and siliceous ores [2]		Lead ores [3]		Copper ores	
		Ounces	Percent of total	Ounces	Percent of total	Ounces	Percent of total
	Ounces						
Total	60,851,908	11,153,036	18.3	31,750,158	52.2	17,948,714	29.5
Alabama	1	1					
Alaska	472,800	121,200	25.6			351,600	74.4
Arizona	7,543,283	403,550	5.3	540,747	7.2	6,598,986	87.5
California	1,176,895	568,213	48.3	61,499	5.2	547,183	46.5
Colorado	4,397,374	2,098,774	47.7	1,513,668	34.4	784,932	17.9
Georgia	16	16					
Idaho	9,414,403	31,869	.3	9,314,124	99.0	68,410	.7
Illinois	3,700			3,700	100.0		
Michigan	20,795					20,795	100.0
Missouri	181,638			181,638	100.0		
Montana	12,716,977	1,198,602	9.4	4,229,368	33.3	7,289,007	57.3
Nevada	4,923,526	2,829,562	57.5	1,838,710	37.3	255,254	5.2
New Mexico	1,113,546	54,031	4.8	789,130	70.9	270,385	24.3
North Carolina	21,106	8	(4)			21,098	99.9
Oregon	30,009	23,119	77.0			6,890	23.0
Pennsylvania	5,972					5,972	100.0
South Dakota	85,182	85,182	100.0				
Tennessee	81,281					81,281	100.0
Texas	1,020,516	1,017,746	99.7	99	(4)	2,671	.3
Utah	17,592,396	2,714,126	15.4	13,269,700	75.4	1,608,570	9.2
Vermont	3,284					3,284	100.0
Washington	47,182	7,030	14.9	7,775	16.5	32,377	68.6
Wyoming	26	7	26.9			19	73.1

[1] Compiled from U.S. Treasury Department, Annual Report of the Director of the Mint for the fiscal year ended June 30, 1930.
[2] Includes small quantity of silver from placer mines.
[3] Includes silver in lead, silver-lead, lead-zinc, copper-lead, copper-lead-zinc, and zinc ores.
[4] Less than 0.1 percent.

WORLD PRODUCTION OF GOLD AND SILVER

9. *Gold.*—Over 57 percent of the world's gold production in 1928 came from South Africa as is shown on table IV. The United States accounted for but 10.86 percent of the 1928 world production of gold. What is of equal importance is the fact that gold production in this country has steadily declined relatively for the last 7 decades and since

1915 the actual amount of gold produced has shown a steady decline except for a very slight upward swing during 1923 and 1924.

10. *Silver.*—The greatest silver-producing country in the world is Mexico which accounted for 42 percent of the total world production of 257,925,154 fine ounces in 1928. The United States ranks second with 22.65 percent. As South America produced over 11 percent and Canada 8.5 percent, the Western Hemisphere is the source of approximately 85 percent of the silver production of the world.

TABLE IV.—*World production of silver and gold in 1928* [1]

Country	Silver		Gold	
	Fine ounces	Percent	Fine ounces	Percent
Total	257,925,154	100.00	19,755,622	100.00
North America	188,899,718	73.23	4,734,414	23.96
United States	58,426,004	22.65	2,144,720	10.86
Canada	21,936,407	8.50	1,890,592	9.57
Mexico	108,537,307	42.08	699,102	3.53
South America	28,883,310	11.20	416,734	2.11
Asia	15,080,065	5.85	1,222,476	6.19
Europe	10,933,682	4.24	1,361,010	6.89
Oceania	10,304,420	4.00	687,528	3.48
Central America	2,558,548	.99	60,469	.31
Africa	1,265,411	.49	11,272,991	57.06

[1] Compiled from U.S. Treasury, Annual Report of Director of Mint for fiscal year ended June 30, 1930.

EXTRACTION AND REFINING OF GOLD AND SILVER

11. *Extraction.*—Although the production of gold and silver is intertwined, processes of great importance in the extraction of one metal are of lesser significance in the production of the other metal only because gold predominates in dry and siliceous ores and silver in complex ores. Amalgamation, cyanidation, and placer dredging are the principal processes used to produce gold bullion, while copper, lead, and complex ore concentration and refining results in the procurement of the largest amount of silver.

12. The pulverizing of siliceous ore, bringing it in contact with mercury or dissolving it in sodium cyanide, separating the amalgam or filtering and decanting the cyanide solution are methods requiring only limited amounts of electricity. While electrolysis has been tried as a method of precipitation, it is not in active use. Nor is the electric furnace applied to any extent in refining the dry cyanide precipitate or the retort bullion. It is not, therefore, until gold and silver bullion from dry and siliceous ores reaches the refining stage that the electric cell becomes a factor of importance.

13. The methods by which copper and zinc refineries separate gold and silver from the ore treated are described in the reports on "power in copper and copper alloy production", and "power in zinc and lead production." As these reports carry precious-metal treatment through the dore furnaces in which these metals are separated from major impurities, this description of gold and silver refining will begin with the "parting" of the precious metals. Although this is still done by sulphuric acid in small plants, larger refineries and the mints employ electrolysis.

14. *Electrolytic refining of silver.*—The dore from copper, lead, or zinc refineries is received at the parting plant in the form of anodes. These are placed in pine boxes having perforated false bottoms covered with muslin. The crystals are washed with water and some ammonia until the absence of copper is assured. They are dried and placed in baskets covered on inner and outer sides with cotton duck.

15. The electrolytic cells are in series and newer cells operate at 40 amperes per square foot of anode surface. The voltage is variable but averages about 3 volts. Five anodes are placed in a cell. The electrolyte is made up of silver and copper nitrate. Graphite or steel plates serve as the cathodes. When the current passes through the anode, the silver is deposited as crystals on the cathode from which it is periodically scraped. These crystals are washed, melted in a retort, and cast into bars of 1,100 troy ounces. The energy consumption per pound of silver deposited varies from 0.357 kilowatt-hours in Thum cells to 0.158 kilowatt-hours in Moebius cells. Or, 1 fine ounce requires from 13.2 to 28 watt-hours.

16. *Gold slime.*—The gold and impurities remain undissolved in the muslin lining of the basket. This lining is removed periodically and the electrolyte drained out. The gold slime is boiled with sulphuric acid to remove any silver. It is washed, melted, and cast into anodes for refinement.

17. *Electrolytic refinement of gold.*—Gold anodes from silver refineries or from gold-mining operations are placed in a cell containing an electrolyte of gold chloride and hydrochloric acid. The gold is deposited on cathodes of pure gold. Silver sinks as an insoluble chloride and any platinum present remains in solution and is recovered. The yield is approximately 180 pounds gold of 999.8 fine in 24 kilowatt-hours or 1 pound gold requires in final refinement 0.133 kilowatt-hours; 1 fine ounce gold 11 watt-hours.

Production and Refinement of Gold and Silver

QUANTITY PRODUCED AND REFINED

18. While the United States Bureau of Mines gives figures on gold and silver content of ores mined, the United States Bureau of the Mint quotes as domestic production the total unrefined domestic gold reaching the United States mints, assay offices, and private refineries within a given year. According to the Bureau of the Mint, the domestic production of gold during 1929 was 2,208,386 fine ounces. Silver production reached 61,327,868 ounces as compared with 58,462,507, ounces in 1928. Of this amount, 1,229,774 fine ounces of gold and 61,016,943 ounces of silver were new domestic product of private refineries, and 978,612 fine ounces of gold and 310,925 fine ounces of silver were deposited at mint or assay offices.

19. Private silver and gold refineries in turn deposit much of their gold at mints and a small amount of their silver. The mints, therefore, become the largest refineries of gold. Because not all bullion received is refined immediately, because much old gold and silver is refined over again each year, because foreign bullion is also refined, the actual amount of gold and silver that is treated electrolytically each year may not be identical with that received by the Government and private refineries. For example, during the fiscal year end-

ing June 1930, the United States mints at San Francisco, Denver, and New York produced 2,755,400 fine ounces of gold for the market and 1,332,603 fine ounces of gold were re-refined for use in the electrolytic refining process. Or, in these three units alone, more marketed gold was electrolytically refined than had been received from the mines.

20. The mint refinement of gold for the market required, therefore, only 30,309 kilowatt-hours of electricity while a total of 45,000 kilowatt-hours electricity was consumed at mints in order to make possible such market production.

21. While mints become the big refineries of gold, private refineries continue to handle the mass of silver. For the year ending June 1930, private refineries refined 61,016,943 fine ounces of silver while mints report an output of 3,156,096 fine ounces, making a total of 64,173,039 fine ounces refined silver. Or, marketed silver required approximately 1,283,500 kilowatt-hours of energy.

22. *Companies refining silver and gold.*—As has been stated, new gold refining takes place to a large extent at the mints in San Francisco, Denver, and New York. Large amounts of silver and some gold are refined by the American Smelting and Refining Co. in its plants at Selby, Calif.; Baltimore, Md.; and Maurer, N.J.; The Anaconda Copper Co. at Raritan, N.J.; the Balbach Smelting and Refining Co. at Newark, N.J.; the United States Metals Refining Co. at Carteret, N.J.; and the United States Smelting Lead Refinery Incorporated, at East Chicago, Ind.

23. In addition there are numbers of small firms refining old gold and silver. The United States Census lists 57 firms engaged in "reducing and refining not from the ore." These are located chiefly in New Jersey, Rhode Island, and New York.

World Consumption

CONSUMPTION OF GOLD

24. A little over 71 percent of all the gold consumed in 1928 was used in coinage, though this proportion does not hold throughout the several countries as is shown by table VI. In fact, the most conspicuous feature of the table is the complete reversals of proportions of gold used in coinage and industrially by countries reporting gold consumption. However, the largest consumers of gold use it in coinage principally. The United States which accounted for over 57 percent of the world's consumption in 1928 (though it furnished less than 11 percent of the world's production in the same year) converted over three fourths of all the gold it used into money. The British Empire—which is the next largest user—consumed almost 90 percent in coinage.

25. *Competitive conditions.*—Because gold is the monetary standard of the most important nations of the world, because the world's supply of gold is conspicuously limited, because the production of gold in the United States has been steadily declining since 1915, and because in this country the price of gold is fixed at $20.67 a fine ounce, the precious metal does not have to face the competition which confronts the output of every other industry not excluding the output of silver mines. The nations of the world compete for gold. Its market is always assured.

TABLE V.—*World consumption of gold in 1928* [1]

[Value in United States dollars]

Country	Grand total		Use in coinage		Used industrially	
	Value	Per-cent	Value	Per-cent	Value	Per-cent
Total	[2] $413,732,129	100.00	$294,500,867	71.18	$119,231,262	28.82
United States	236,440,659	57.12	177,360,000	75.01	59,080,659	24.99
British Empire	109,059,889	26.36	97,179,986	89.11	11,879,903	10.89
France	21,268,539	5.13	249	[3]	21,268,290	100.00
Mexico	13,509,350	3.26	13,409,650	99.26	99,700	.74
Egypt	9,104,122	2.20	9,886	.11	9,094,236	99.89
Switzerland	[4]		[4]	[4]	6,978,300	[4]
Rumania	3,547,239	.85	3,474,000	97.94	73,239	2.06
China	[4]		[4]	[4]	3,099,708	[4]
Austria	2,947,309	.75	1,513,767	51.36	1,433,542	48.64
Germany	[4]		[4]	[4]	1,715,040	[4]
Portugal	[4]		[4]	[4]	1,562,456	[4]
Netherlands	[4]		1,310,248	[4]	[4]	[4]
All other countries [5]	3,183,270	.78	243,081	7.64	2,940,189	92.36

[1] Compiled from Report of Director of the Mint for year ended June 30, 1930.
[2] Including amounts used only in coinage or industrially by 5 countries as noted.
[3] Less than 0.1 per cent.
[4] No report.
[5] No other country consumed as much as $1,000,000.

26. *Consumption of silver.*—Almost four fifths of the world's total consumption of silver in 1928 was used in coinage, though in some countries industry and the arts absorbed more silver than did coinage. China, which consumed more than half of all the silver produced in that year, put over 99 percent of it into coinage. On the other hand, the United States, which is the next largest consumer (though it absorbed less than 15 percent of the world total consumption for 1928) converted over four fifths of what it did use to industrial and art purposes. The sterling-silverware industry is the largest consumer, while chemical and photographic-film industries together absorb about 10,500,000 ounces. France and Switzerland also used more silver in the industries and art than in coinage. Table VI following shows the world consumption for 1928 by principal absorbing countries.

27. *Competitive conditions.*—Because silver is a commodity (and important as a commodity) as well as a monetary metal, it is affected by price fluctuations based on variations in supply. This, in turn, is greatly affected when an important country changes its monetary standard from silver to gold and melts down silver coins into bullion for the general silver market. The British Empire made this change for India in 1925. The debasement of India silver and its influx into the market as a competitor with the regular silver-mine production has been one of the principal causes for the decline in the price of silver to a record low level. The last Congress authorized a commission charged with the duty of bringing about some agreement with the British Government and other countries concerned looking to the rehabilitation of the world's silver market. No prediction, of course, can be made as to the outcome.

TABLE VI.—*World consumption of silver in 1928* [1]

Country	Grand total		Used in coinage		Used industrially	
	Fine ounces	Percent	Fine ounces	Percent	Fine ounces	Percent
Total	[2] 276,850,322	100.00	216,093,260	78.05	60,757,062	21.95
China	143,032,373	51.66	142,343,174	99.52	689,199	.48
United States	41,975,986	14.80	6,428,323	15.31	35,547,663	84.69
British Empire	21,311,436	7.70	12,747,731	59.82	8,563,705	40.18
France	17,492,290	6.32	6,985,220	39.94	10,507,070	60.06
Germany	[3]	[3]	12,315,955	[3]	[3]	[3]
Nicaragua	[3]	[3]	11,395,322	[3]	[3]	[3]
Austria	6,192,695	2.20	5,535,002	89.38	657,693	10.62
Italy	[3]	[3]	5,439,434	[3]	[3]	[3]
Japan	[3]	[3]	4,422,072	[3]	[3]	[3]
Netherlands [4]	[3]	[3]	3,186,906	[3]	[3]	[3]
Irish Free State	[3]	[3]	1,656,818	[3]	[3]	[3]
Switzerland	1,641,659	.59	469,792	28.62	1,171,867	71.38
Egypt	[3]	[3]	[3]	[3]	1,363,761	[3]
All other countries [5]	5,423,615	1.94	3,167,511	58.41	2,256,104	41.59

[1] Compiled from "Report of Director of the Mint for year ended June 30, 1930."
[2] Including amounts used only in coinage and industrially by countries as noted.
[3] No report.
[4] Includes Netherland East Indies.
[5] No other country consumed as much as 1,000,000 fine ounces.

RARE OR MINOR METALS

28. There are a number of metals which may be reduced electrolytically or electrothermally but which are produced only in small quantity or which have not been manufactured, as yet, commercially. A short accounting of such metals as are being produced in this country is given, not because their manufacture is of any present significance in the development of the Nation's water power, but because normal growth may make such industries valuable adjuncts to other larger producing units.

TUNGSTEN

29. Although the largest amount of tungsten is employed as ferrotungsten in the manufacture of tungsten steel described on pages 392–393 of "The Electric Furnace in the Iron and Steel Industry", a small but increasing tonnage is made into electric-lamp filaments and into contact points in electric ignition equipment.

30. The nearly pure tungsten metal is either refined from the ore by an electrothermal process or is obtained from tungstic acid by the alumino-thermic process described in "Power in Aluminum Production."

31. When metallic tungsten is manufactured in an electric furnace the ore is first pulverized and fused with sodium carbonate to produce sodium tungstate and oxides of associated manganese and iron. These oxides are dissolved from the mixture and the sodium tungstate is treated with hydrochloric acid to precipitate tungstic acid. This acid is purified by several conversions to a salt and back to an acid, after which it is heated to an oxide of tungsten.

32. The oxide of tungsten is reduced to metallic tungsten in the hydrogen atmosphere of an electric furnace. Hydrogen conbines with the oxygen and volatilizes, leaving metallic tungsten in powdered form. This powder is pressed into bars, each of which is sintered to

incandescence by passing a heavy current through it in a hydrogen atmosphere. A 99.95 percent pure tungsten results.

33. This bar is worked into rods after being heated in a third electric furnace. Rods are cut into disks with abrasive wheels. These disks are welded to screws and rivets by means of brazing copper in a fourth hydrogen-atmosphere electric furnace.

MOLYBDENUM

34. Molybdenum is also a metal that is consumed principally as ferromolybdenum but when pure is valued as filaments and as grid wires of radio tubes. A molybednite concentrate is roasted in a current of air, the sulphur in the concentrate being burnt off as sulphur dioxide. The oxide of molybednum remaining is condensed. It is refined and reduced to metallic molybdenum by a stream of hydrogen in the electric furnace. This powdered metal is pressed into bars and sintered before being formed into rods or sheets. Final operations convert it into fine wires and into plates and cathodes for vacuum tubes.

35. The two largest producers of the pure metal tungsten and of the pure metal molybdenum are the Fansteel Products Co. of North Chicago, Ill., and the Tungsten Electric Corporation with plants in Union City, N.J.

COBALT-TUNGSTEN ALLOYS

36. Tools made of tungsten carbide cemented with cobalt are attracting wide attention because their life is many times greater than that of high-speed tungsten machine tools. Alloys of cobalt, chromium, and tungsten in varying proportions are being employed in acid- and heat-resistant equipment. The metal cobalt may be obtained from its oxide (which has been obtained through a series of operations from cobalt ores) by electric-furnace reduction. Coke is added to reduce the oxide. Chromium metal is manufactured commercially by the chemical extraction of chromium oxide from chromite and by the reduction of the oxide by the thermit process.

37. The three metals, tungsten, cobalt, and chromium are melted together in an electric furnace at over 1,500° C. These alloys are produced by the Haynes Stellite Co., now a subsidiary of the Union Carbide and Carbon Corporation.

38. *Sources of cobalt.*—The world's cobalt was produced chiefly by the Union Miniere du Haut Katanga in the Belgian Congo, and Deloro Smelting and Refining Co., Ltd., of Canada. The United States producers received their ore from the Cobalt District of Canada. The lead ores of Missouri are associated, however, with cobalt as well as with nickel and copper.

TANTALUM

39. Tantalum has not as assured a position in industry as the foregoing metals, but it is applied to a limited extent in several industries. The Fansteel Products Co. of Chicago is manufacturing it.

40. Tantalum is used as elements in amplifying tubes, to maintain high vacuums in radio tubes, as spinnerets in rayon thread formation, and for equipment in chemical laboratories. The metal is derived from the ore "tantalite" found in Western Australia although it may

be secured from the ore columbite of South Dakota. Ore is pulverized and fused with potassium hydroxide to make soluble tantalates and columbates. After these have been dissolved and filtered, the solution is treated with hydrofluoric acid which gives a double fluoride of tantalum and potassium and potassium fluorycolumbate. After precipitation of the tantalum-potassium fluoride, it is reduced to a pure metal tantalum in an electric furnace. The potassium fluorycolumbate may also be electrolyzed to metallic columbium.

It is possible also to reduce tantalum by the thermit process.

BARIUM

41. Domestic production of metallic barium began in 1929 for use in high-nickel alloys. It is also being used as a "getter" in radio vacuum tubes in competition with tantalum. While American methods of manufacture are not known, the metallic barium produced in Germany is made electrolytically. Barium chloride is electrolyzed and the amalgam formed is distilled to pure barium.

42. As barite has been mined extensively for use in the lithopone industry, the mining branch of the barium industry is well established in the United States. California, Missouri, Georgia, North Carolina, Tennessee, and Virginia are the principal mineral producing States.

CERIUM

43. The metal cerium is usually made from the accumulated residues of the gas-mantle industry which employs thorium nitrate in the making of incandescent mantles. The residue, an oxide of cerium, is dissolved in hydrochloric acid. Phosphorus and sodium compounds are removed with barium chloride, while iron, manganese, and chromium are removed with ceric oxide. After evaporation and fusion in cast-iron pots, the mixture is electrolyzed at 850° C.

44. When alloyed with iron, ferro-cerium is the ignition element in miner's safety lamps and the sparking element in cigar lighters. It was made by the New Process Metals Co. of Newark, N.J., which is now a part of the Tungsten Electric Corporation.

LITHIUM

45. A small percentage of lithium added to lead produces a good bearing metal. It is also alloyed with aluminum, and research is underway concerning its use in copper-wire bars. It is a deoxidizing agent in the refining of copper. Large deposits containing small amounts of lithium occur in California, Arizona, New Mexico, and South Dakota.

46. Lithium is extracted as a carbonate from its minerals by a chemical process. From the carbonate, bromide, chloride, hydride, and other salts are prepared. In the presence of potassium chloride, the fused lithium salts are electrolyzed to the metal lithium. The General Electric Co. has produced some lithium.

BERYLLIUM

47. Beryllium is used as a window in X-ray tubes. But experiments are underway by the Beryllium Corporation of America in the utilization of the metal as a constituent of light alloys. Beryl, the metal, is found in Colorado, Maine, and South Dakota.

48. The reduction involves the electrolysis of a mixture of beryllium oxyfluoride and barium-fluoride requiring 45 kilowatt-hours per pound, or of fused beryllium chloride requiring much less current.

BISMUTH

49. The bismuth produced in this country is recovered electrolytically from the slags of lead refineries. It is consumed in low-melting alloys and by the pharmaceutical industry. As the supply available if all were recovered from lead refining exceeds the demand, the United States Bureau of Standards is working on potential uses of the metal.

50. In the electrolytic refining, sheet lead covers the cell bottom and acts as the cathode. The anodes are in a basket lined with duck. Bismuth chloride and free hydrochloric acid solution form the electrolyte. The bismuth is deposited as nodules on the cathode and the deposits are broken down every 8 hours.

METALS REFINED ELECTROLYTICALLY IN COUNTRIES OTHER THAN THE UNITED STATES

51. *Nickel.*—Although nickel is fairly widespread in its occurrence, over 90 percent of the world's production comes from the Sudbury Field in the Province of Ontario, Canada. All production is by one company, The International Nickel Co. of Canada, Ltd. Refining of nickel is accomplished electrolytically at Port Colborne, where plants have a capacity of 43,200 short tons per annum. Platinum is recovered from such refining. This is shipped to a precious-metals refinery at Acton, England.

52. *Tin.*—Tin was refined electrolytically in the United States during and after the War at Perth Amboy, N.J. But in 1923 the industry was abandoned, as it was not commercially feasible to operate a tin smelter in this country. All virgin tin had to be imported, the Federated Malay States, Bolivia, and Netherlands East Indies, being the principal tin mining countries. And the mining and smelting industry was well controlled by British, Dutch, and German interests.

APPENDIX II

STUDY OF COST OF POWER TRANSMISSION FROM COLUMBIA RIVER PLANTS TO MARKET CENTERS (100 TO 250 MILES)

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Introduction.—The investigation herein discussed was undertaken for the purpose of determining as closely as possible the probable cost of transmitting electrical energy from the several proposed generating sites on the Columbia River to adjacent markets. These markets include the Puget Sound region lying between Bellingham and Portland and the Inland region tributary to Spokane. Inspection of the map showing the locations of the proposed power plants covering the Columbia Basin project, indicates that to transmit power to these markets from the various proposed power sites on the