IC bureau of mines information circular 8206

MARKETING ORES AND CONCENTRATES OF GOLD, SILVER, COPPER, LEAD, AND ZINC IN THE UNITED STATES

By Melford H. Salsbury, William H. Kerns, Frank B. Fulkerson, and George C. Branner

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

1964

MARKETING ORES AND CONCENTRATES OF GOLD, SILVER, COPPER, LEAD, AND ZINC IN THE UNITED STATES

By Melford H. Salsbury, William H. Kerns, Frank B. Fulkerson, and George C. Branner

* * * * * * * * * * * information circular 8206

UNITED STATES DEPARTMENT OF THE INTERIOR
Stewart L. Udall, Secretary

BUREAU OF MINES
Marling J. Ankeny, Director

This publication has been cataloged as follows:

Salsbury, Melford H

Marketing ores and concentrates of gold, silver, copper, lead, and zinc in the United States, by Melford H. Salsbury [and others. Washington] U. S. Dept. of the Interior, Bureau of Mines [1964]

150 p. illus., tables. (U. S. Bureau of Mines. Information circular 8206)

Includes bibliography.

1. Ores–Marketing. 2. Gold ore–Marketing. 3. Silver ore–Marketing. 4. Copper ore–Marketing. 5. Lead ore–Marketing. 6. Zinc ore–Marketing. I. Title. (Series)

TN23.U71 no. 8206 622.06173

U. S. Dept. of the Int. Library

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C., 20402 - Price $1.25

CONTENTS

CONTENTS--Continued

ILLUSTRATIONS

TABLES

MARKETING ORES AND CONCENTRATES OF GOLD, SILVER, COPPER, LEAD, AND ZINC IN THE UNITED STATES

by

Melford H. Salsbury,[1] William H. Kerns,[2] Frank B. Fulkerson,[3] and George C. Branner[4]

ABSTRACT

The maximum net return from the sale of ores and concentrates of gold, silver, copper, lead, and zinc accrues to the producer when these mine products are marketed to the best advantage. Data are presented that the producer, especially the small mine operator, can use to survey available markets and make a preliminary estimate of the net return to be expected from an ore, on the basis of typical mill, smelter, and freight schedules. A review of the industry is presented by States in which recent production statistics are given, marketing facilities are discussed, and locations of principal mining districts, custom mills, and smelters are shown. Explanations of treatment processes, ore types, treatment charges, payments for metals, and deductions are given. Published rail and truck freight rates for mine products, based on marketing patterns developed over many years, are listed and explained.

INTRODUCTION

A major function of the Bureau of Mines is to investigate the Nation's mineral resources--their conservation, development, and utilization. Statistics on production and consumption of mineral commodities are collected and disseminated, and studies are made to give a better understanding of a region's minerals in relation to the Nation's needs and to impart information that may contribute to more efficient mine operations.

[1] Mining engineer, Bureau of Mines, Area V, Tucson, Ariz.
[2] Physical science administrator, Bureau of Mines, Area V, Denver, Colo.
[3] Commodity-industry analyst, Bureau of Mines, Area VII, Albany, Oreg.
[4] Formerly Bureau of Mines commodity-industry analyst, San Francisco, Calif., now 150 Scenic Drive, Piedmont, Calif.

Work on manuscript completed February 1963.

The primary purpose of this report is to present data that will be useful to the producer of gold, silver, copper, lead and zinc ores and concentrates in determining if a choice of ore markets is available and, if so, in choosing which marketing combination is likely to give a maximum return on ore shipments. In line with this objective, an effort is made to answer typical requests for marketing information, often received by the Bureau of Mines in the form of specific questions:

1. What mills and smelters in my vicinity are equipped to handle my products.

2. What are the freight rates to these plants?

3. What are the treatment charges, what metals are paid for, and how much is paid at typical plants?

4. What are the penalties for certain mineral constituents?

5. Why do ore purchasers pay for only certain constituents and penalize for certain others?

6. Should a certain ore be milled or shipped directly to a smelter?

7. What are the metallurgical principles on which milling and smelting processes depend?

Another purpose of this report is to revise the data published in Information Circulars (12, 13, and 14)[5] in 1935 and 1936, now out of print. Use of this data, much of it in tabular form in the appendix, should enable a prospective shipper to compute an estimated net return from ore shipments.

A final choice of market and shipping route for a particular ore or concentrate cannot be made solely from the information in this circular because applicable mill and smelter ore-purchasing schedules and freight rates are subject to change for several reasons, among them the following:

1. Treatment and transportation costs are increasing.

2. The rate of payment for metals changes from time to time, according to the metal market.

3. Transportation patterns and facilities change.

4. Custom treatment plants suspend or resume operations as economic conditions dictate, and no list of available plants remains valid indefinitely.

---

[5]Underlined numbers in parentheses refer to items in the bibliography at the end of this report.

In some cases, small operators of lead-zinc mines who are not prepared to mill their own ore have already suffered a loss of market because very few custom milling facilities remained in operation after lead and zinc prices declined. Many shippers have only one practical smelter market because other smelting plants are not located so as to be competitive with respect to a particular mine.

Some smelting companies publish standard or open treatment schedules applicable to the different types of ore purchased. Such schedules seldom apply in their entirety to a specific ore, but serve as a starting point from which to set up a schedule for each ore product offered. Some open schedules do not contain a full list of charges, but state that such charges are a matter for individual negotiation. Assurance that a producer will furnish a steady supply of ore on contract or a certain quality of ore desired by a particular plant may induce that plant to offer concessions not called for in any open schedule. Obviously, then, problems in marketing ores cannot be solved without current information.

The current data necessary for making a final choice of plants must be obtained by negotiation with the purchasing departments of custom milling and smelting companies. Purchasing departments of custom plants in the United States are listed in appendix R. A mine operator first should submit to ore buyers information as to the probable quantity, mineral content, and grade of ore to be offered. If the buyer is not familiar with the ore, a sample and possibly a trial shipment may be required. If the ore is acceptable, the prospective buyer will offer a schedule of treatment charges, penalties, and payments based on inspection and laboratory tests of the sample. Only then can a producer make realistic comparisons of treatment and transportation options and choose the combination most favorable to his operation.

For the operator who does not have a choice of markets, the chief value of this circular may lie in the explanations and comparison of treatment schedules, ore-buying practices, and transportation routes. Such data should bring a better understanding of marketing factors that will help a mine operator to evaluate the probable worth of his ore and the advisability of upgrading by selective mining or beneficiation. The conditions under which an ore is likely to be marketed have a bearing on minable grade, as well as the type and capacity of milling facilities. Thus the operator of a property in the exploration or early development stage might benefit from such information, even though ore production is still anticipated. Marketing information only supplements other data necessary in making decisions bearing on development of a mine. New or improved milling methods or smelter practices are being introduced, and grades and types of ores that previously were not marketable may become amenable to treatment. Such information is continually available in technical and trade journals and in reports issued by the Bureau of Mines, universities, and professional societies. A number of such publications are listed in the bibliography. It should be evident to the reader that professional advice, not only on mineral marketing but also on mine and mill operation and design, is essential at some point in developing a mining property to the production stage.

ACKNOWLEDGMENTS

The assistance of many companies that furnished data on base treatment charges, payments, and deductions, including copies of settlement sheets for shipments of custom material, is gratefully acknowledged. Trucking and railroad companies, State public utility commissions, and the Interstate Commerce Commission cooperated fully in furnishing truck and rail freight rates. The General Services Administration, Transportation and Public Utilities Service, Denver, Colo., and San Francisco, Calif., provided the bulk of the point-to-point railroad freight rates presented in this report.

The following company officials were particularly helpful in furnishing data:

Max W. Bowen, general manager, Golden Cycle Corporation, Colorado Springs, Colo.

Glenn A. Burt, assistant to the manager, Ore Purchasing and Metallurgical Department, International Smelting & Refining Co., Salt Lake City, Utah.

Harold Foard, former superintendent of smelter, Miami plant, International Smelting & Refining Co., Miami, Ariz.

Darrell Gardner, general manager, Magma Copper Co., Superior, Ariz.

J. Paul Harrison, manager, Colorado Department, American Smelting & Refining Co., Denver, Colo.

R. L. Jourdan, vice president, American Smelting & Refining Co., Ore Department, New York 5, N.Y.

K. H. Marchesi, metallurgical analyst, The Bunker Hill Co., Kellogg, Idaho.

Robert M. McGeorge, assistant manager, Southwestern Department, American Smelting & Refining Co., El Paso, Tex.

J. T. Roy, manager, Selby plant, American Smelting & Refining Co., San Francisco, Calif.

R. F. Welch, manager, Southwestern Ore Purchasing Department, American Smelting & Refining Co., Tucson, Ariz.

Others in the Bureau of Mines who were directly concerned with furnishing data or who assisted in the preparation of this report are F. F. Netzeband, mining engineer, Mineral Resource Office, Area IV, Bartlesville, Okla.; Robert D. Thomson, Chief, Mineral Resource Office, Area I, Pittsburgh, Pa.; Avery H. Reed, Jr., Chief, Mineral Resource Office, Area II, Knoxville, Tenn.; Samuel A. Gustavson, Supervisory commodity-industry analyst, Mineral Resource Office, Area III, Minneapolis, Minn.; and D. H. Mullen, mining engineer, Mineral Resource Office, Area V, Denver, Colo.

REVIEW OF BASE AND PRECIOUS METAL MINING

Recent Base-Metal Economic History

The mining, milling, and smelting of ores and concentrates of gold and silver, and the base metals, copper, lead, and zinc, are economically important industries in many parts of the United States. In Arizona, Idaho, Nevada, Utah, and South Dakota, base and precious metals accounted for over half of the value of all mineral production in 1960. The five leading states in the value of mine output of gold, silver, copper, lead, and zinc in 1960 were Arizona ($366 million), Utah ($176 million), Montana ($68 million), Nevada ($53 million), and Idaho ($35 million) (table 1).

A severe drop in domestic base-metal production occurred in 1958 (table 2). Production of lead continued to decline in 1959 and 1960, but at a slower rate, whereas zinc recovered slightly by the end of 1960. In spite of losses through strikes at a number of western operations, copper production at the end of 1960 had recovered nearly to the levels of 1956 and 1957, but production of lead and zinc was still considerably below that of 1956. World copper demand kept pace with high production in 1961 and copper prices remained stable. Consumption of lead and zinc did not keep up with a greatly increased world production in recent years, resulting in a drop in prices. Although lead and zinc mines in Idaho were closed in 1960 for many months by strikes, and imports were somewhat restricted by quotas, the domestic supply has exceeded consumption for several years. An announcement was made at the end of 1960 that limited operation of several tristate properties in Kansas, Missouri, and Oklahoma would be resumed; but at the end of 1961 substantial reactivation of the district had not materialized. Virtually all small lead and zinc mines in the United States were idle at the end of 1961, leaving the larger, lower cost operations as the only active mines.

Government assistance to lead and zinc mining in recent years was a continuation of the import quota system, and a subsidy program for small lead-zinc mines. Congress has authorized assistance in the form of a limited subsidy payable to small lead and zinc producers, but the number of mining operations eligible for such assistance is small. Import quotas on lead and zinc have remained in effect, but no tariff was imposed.

In November 1961, sale of U.S. Treasury silver stocks to commercial users was suspended, a measure long advocated by silver producers in a market situation where industrial silver consumption has greatly exceeded domestic mine production. The immediate result was an increase of the commercial price of silver to more than $1.00 per ounce. A further significant advance in the silver price may easily occur. The U.S. Treasury has proposed to replenish depleted stocks of Government-owned silver needed for small coinage by using monetary silver. This supply would be made available by replacing silver-backed silver certificates in circulation with Federal Reserve notes. Such a policy would limit domestic demand to industrial requirements.

TABLE 1. - Recoverable gold, silver, copper, lead, and zinc in 1960, by States

State	Gold		Silver		Copper		Lead		Zinc		Total value	
	Ounces	Value (thousands)	Thousand ounces	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Short tons	Value (thousands)	Gold, silver, copper, lead, zinc (thousands)	All minerals[1] (thousands)
Alaska........	168,197	$5,887	26	$ 23	41	$ 26	23	$ 5	-	-	$ 5,941	$ 21,862
Arizona.......	143,054	5,007	4,775	4,322	538,605	345,784	8,495	1,988	35,811	$ 9,239	366,340	415,776
Arkansas......	-	-	-	-	-	-	-	-	50	13	13	153,813
California....	123,713	4,330	180	163	1,087	698	440	103	465	120	5,414	1,402,214
Colorado......	61,269	2,144	1,659	1,502	3,247	2,085	18,080	4,231	31,278	8,070	18,032	341,142
Idaho.........	6,135	215	13,647	12,351	4,208	2,702	42,907	10,040	36,801	9,495	34,803	57,441
Illinois......	-	-	-	-	-	-	3,000	702	29,550	7,624	8,326	391,313
Kansas........	-	-	-	-	-	-	781	183	2,117	546	729	487,121
Kentucky......	-	-	-	-	-	-	558	131	869	224	335	413,516
Michigan......	-	-	-	-	56,385	36,199	-	-	-	-	36,199	429,032
Missouri......	-	-	16	14	1,087	698	111,948	26,196	2,821	728	27,636	156,014
Montana.......	45,922	1,607	3,607	3,265	91,972	59,046	4,879	1,142	12,551	3,238	68,298	179,062
Nevada........	58,187	2,037	707	640	77,485	49,745	987	231	420	108	52,761	80,285
New Mexico....	5,423	190	304	275	67,288	43,199	1,996	467	13,770	3,553	47,684	648,215
New York......	-	-	49	45	-	-	775	181	66,364	17,122	17,348	254,061
North Carolina.	1,826	64	212	192	([2])	([2])	424	99	-	-	355	44,968
Oklahoma......	-	-	-	-	-	-	936	219	2,332	602	821	777,925
Oregon........	835	29	([3])	([3])	6	4	-	-	-	-	33	54,419
Pennsylvania...	([4])	([4])	([4])	([4])	[2]7,907	[2]5,076	-	-	13,746	3,559	8,635	818,264
South Dakota...	554,771	19,417	108	98	1	1	-	-	-	-	19,516	46,780
Tennessee.....	123	4	65	58	12,723	8,168	-	-	91,394	23,579	31,809	143,332
Utah..........	368,255	12,889	4,783	4,329	218,049	139,987	39,398	9,219	35,476	9,153	175,577	429,938
Virginia......	-	-	-	-	-	-	2,152	504	19,885	5,142	5,646	203,794
Washington....	[4]129,012	[4]4,515	[4]628	[4]569	78	50	7,725	1,808	21,317	5,500	12,442	70,005
Wisconsin.....	-	-	-	-	-	-	1,165	273	18,410	4,750	5,023	77,171
Wyoming.......	40	1	([3])	([3])	-	-	-	-	-	-	1	436,335
Total....	1,667,772	58,336	30,766	27,846	1,080,169	693,468	246,669	57,722	435,427	112,365	949,737	8,733,798

[1]Total values of all minerals subject to change because certain preliminary data used for fuels.
[2]Production of North Carolina and Pennsylvania combined.
[3]Quantity less than 1,000 ounces and value less than $1,000.
[4]Production of Pennsylvania and Washington combined.

TABLE 2. - Mine production of recoverable gold, silver, copper, lead, and zinc, 1956-60
(Quantity and value in thousands)

Metal	1956		1957		1958		1959		1960		Total
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	quantity
Gold...............ounces	1,827	$63,950	1,794	$62,776	1,739	$60,874	1,604	$56,133	1,667	$58,336	8,631
Silver...............do..	38,722	35,044	38,165	34,541	34,111	30,872	31,194	28,233	30,766	27,846	172,958
Copper..........short tons	1,104	938,532	1,087	654,289	979	515,127	825	506,455	1,080	693,468	5,075
Lead.................do..	353	110,787	338	96,730	267	62,566	256	58,786	247	57,722	1,461
Zinc.................do..	542	148,503	532	123,235	412	84,113	425	97,787	435	112,365	2,346
Total value..........	-	1,296,816	-	971,571	-	753,552	-	747,394	-	949,737	-

At the end of 1961, the ultimate combined effect on the mining industry of the changed market conditions for silver and the lead and zinc subsidy was not clear. Lead and zinc prices had declined at the end of 1961 to around 10 cents and 12 cents per pound respectively, a level that does not encourage operation of small, and generally high-cost mines, even with higher silver prices. Silver mined in the United States is largely a byproduct of copper and lead mining. The silver content of most copper ores is so small that the effect of a change in silver prices is negligible. The silver content of lead and lead-zinc ores may be significant in value, but market changes within the probable silver price range will have much less effect on total value of most ores and on production than the price of lead and zinc. Inasmuch as an oversupply of these metals is likely to continue, notwithstanding the low-price level, a logical method of supporting the market is promoting increased consumption. This is the approach taken by the lead and zinc industry through trade associations. Improvement admittedly is difficult in the face of competition with aluminum, plastics, and other materials for markets that traditionally have used lead and zinc. As one phase of promotion, the industry has sponsored research in metallurgy and industrial applications that has improved utilization of lead and zinc in manufacturing and stimulated some new uses. The industry undoubtedly will continue to pursue this policy.

Classification of Ores and Concentrates

The following classification of mineral products is commonly used in the mining industry, and the definitions given will apply throughout this circular.

Ore is a mineral or mineral aggregate that can be mined and marketed at a profit. At least one mineral (a naturally occurring chemical element or assemblage of elements) is valuable; the valueless minerals make up the gangue or waste.

A base-metal ore that contains valuable amounts of two or more metals (i.e., copper, lead, and zinc) is termed a complex ore. Ores are further classed by the type of contained valuable minerals. The five most important such types of minerals occurring in base-metal ores are native (metal in free or metallic state), sulfide (metal combined with sulfur), oxide (metal combined with oxygen), carbonate (metal combined with carbon and oxygen), and silicate (metal combined with silicon and oxygen). Ores containing a combination of oxide, carbonate, and silicate minerals are commonly grouped as oxidized ores. The term mixed is used to describe ores containing both sulfide- and oxide-group minerals. Ores can be classified further as milling or direct-smelting ores. A milling ore can be treated and separated into one or more concentrates containing the bulk of the valuable minerals and some gangue and a tailing consisting chiefly of gangue minerals and any unrecovered residue of valuable minerals. Normally this residue cannot be recovered economically.

As a means of categorizing statistics for production of gold, silver, copper, lead, and zinc by class of ore and material treated, a classification of ores and concentrates of gold, silver, copper, lead, and zinc, based on smelter terminology, smelter settlement contracts, and metal recovery, was devised and adopted by the Bureau of Mines in 1905. This classification, with modifications to cover lowering of economic ore grades and improvements in metallurgy, has been used continuously in the statistical tables published by the Bureau of Mines in the Minerals Yearbook and other reports. Concentrates are classified under the same rules as ores. The term "ores" is often used in a collective sense that includes both ore as mined and ore products (concentrates). It covers all mined products that are sold to smelters or equivalent plants for the valuable metals contained. The current basis of ore classification (6) is as follows:

> Copper ores include smelting ores that contain 2.5 percent or more recoverable copper and ores and tailings concentrated or leached chiefly for their copper content, irrespective of the precious metal content. Ores leached in place or ores for which the tonnage cannot be calculated are excluded; slags smelted for their copper content are included.
>
> Lead ores are those that contain 5 percent or more recoverable lead, irrespective of the precious metal content; and ores, tailings, or slags that are treated chiefly for their lead content.
>
> Zinc concentrating ores include those from which a marketable zinc concentrate is made, irrespective of precious metal content. Virtually no zinc ore is now smelted directly except slags, which, when fumed, are classified as smelting ore and may contain as little as 5 percent recoverable zinc.
>
> The complex ores are combinations of those enumerated above; they will be designated by the names of their constituent base metals in alphabetical order, irrespective of the predominance of value.
>
> Gold, gold-silver, and silver ores with the base-metal content too small to be classified in accordance with the above are 'dry' ores, regardless of method or treatment. Dry ores, chiefly, siliceous, are valuable for their silver and gold contents and, in some instances, for their fluxing properties. Dry gold ores are defined as those in which the gold value equals or exceeds three-fourths of the combined gold and silver values; dry silver ores are those in which the silver value equals or exceeds three-fourths of the combined gold and silver values. In dry gold-silver ores both the gold and silver values equal or exceed one-fourth of the combined gold and silver values.
>
> Tailings and slags follow the same scheme of classification as ores.
>
> The classifications are not modified by considerations of payments of metals by smelters or custom mills, or by method of treatment by the smelters.

On this basis, the 10 classes of ores and concentrates are as follows: Copper, copper-lead, copper-zinc, copper-lead-zinz, lead, lead-zinc, zinc, dry gold, dry silver, and dry gold-silver, further differentiated as sulfide, oxide, or mixed ore. All data presented in this publication showing the classes of ores and concentrates are based on this classification.

In 1957, 43 percent of the gold output in the United States was recovered from dry ores of gold, gold-silver, and silver; 32 percent from copper ore; 19 percent from gold-bearing placer gravel; and the remainder from ores of copper, lead, and zinc. Thirty-two percent of the silver came from dry ores; 29 percent from copper ore; and the remainder from gold-bearing placer gravel and various ores of copper, lead, and zinc. Most copper came from copper ores, and most lead and zinc came from lead, zinc, or lead-zinc ores.

In dry ores of gold, gold-silver, and silver, the gold occurs principally as the native metal or as alloys of gold and silver. Gold enters into only one series of natural compounds, the telluride minerals, calaverite, sylvanite, and petzite. Silver in dry gold-silver and dry silver ores occurs mainly as a native element and the silver minerals, argentite, cerargyrite, and in lesser amount as proustite, pyrargyrite, and stephanite. Silver is also a minor constituent of gold telluride minerals.

Gold may occur in base-metal ores as the recognizable native element, but more commonly is found in auriferous pyrite, chalcopyrite, sphalerite, other sulfide minerals, and their alteration products.

Silver in base-metal ores is present as the silver minerals argentite, cerargyrite, proustite, pyrargyrite, and stephanite, but more commonly occurs in argentiferous tetrahedrite, tennantite, and galena, and their alteration products. Gold and silver are not recognizable except by analysis, unless they occur as distinct, visible minerals.

Copper occurs in copper, copper-lead, copper-lead-zinc, and copper-zinc ores as one or more of five types of copper ore minerals; sulfides (mainly chalcopyrite, chalcocite, bornite, covellite, and enargite), oxides (cuprite), carbonates (mainly malachite and azurite), silicates (chrysolla), and native copper. Most of the copper produced in the United States as well as throughout the world comes from ores containing sulfide copper minerals; however, the quantity recovered from oxide, carbonate, and silicate minerals of copper has been increasing.

In lead and lead-zinc-ores, the lead occurs chiefly as the lead sulfide mineral, galena; the sulfate, anglesite, and the carbonate, cerussite, are less abundant but important oxide minerals. In the lead-zinc and zinc ores, the principal zinc mineral is the zinc sulfide, sphalerite. In the oxidized zones, the commercially important zinc minerals are the zinc carbonate, smithsonite; the zinc oxides, franklinite and zincite; and the zinc silicates, calamine and willemite.

Ore Marketing Patterns in 1960

The following description of the flow of ores and concentrates of gold, silver, copper, lead, and zinc is based on marketing patterns in effect during 1957-60. The discussion is confined to the States in which base and precious metals have been produced or processed. Tables 3, 4, and 5 list the mining districts from which ores and concentrates came and the treatment plants to which shipments were made. Figures 1, 2, and 3 show the locations of mining districts, mills, smelters, and other treatment plants in the United States. Operations at some of the mining camps listed have been recessed, and a number of mills and smelters are no longer in operation. However, because some districts and treatment plants probably would be reactivated in an improved market, they are noted in this circular. Current production statistics can be obtained from the Minerals Yearbooks published annually by the Bureau of Mines.

TABLE 3. - Principal mining districts or areas from which ores and concentrates of gold, silver, copper, lead, and zinc were produced in 1957

State	County	Mining district	Figure 1, symbol
Arizona........	Cochise......	Cochise (Dragoon).................	1
		Turquoise.........................	2
		Warren (Bisbee)...................	3
	Gila.........	Banner (Christmas)................	4
		Globe-Miami.......................	5
	Graham.......	Aravaipa..........................	6
	Greenlee.....	Copper Mountain (Morenci).........	7
	Mohave.......	Owens-Cedar Valley................	8
		Wallapai..........................	9
	Pima.........	Ajo...............................	10
		Amole.............................	11
		Baboquivari.......................	12
		Empire............................	13
		Helvetia (Rosemont)...............	14
		Pima..............................	15
		Silver Bell.......................	16
	Pinal........	Bunker Hill.......................	17
		Mineral Creek (Ray)...............	18
		Old Hat...........................	19
		Pioneer (Superior)................	20
	Santa Cruz...	Harshaw...........................	21
		Oro Blanco........................	22
		Patagonia (Duquesne)..............	23
	Yavapai......	Agua Fria.........................	24
		Big Bug, Black Canyon, Hassayampa, and Walker.........................	25
		Copper Basin......................	26
		Eureka............................	27
		Verde (Jerome)....................	28
	Yuma.........	Castle Dome.......................	29
		Cienega...........................	30

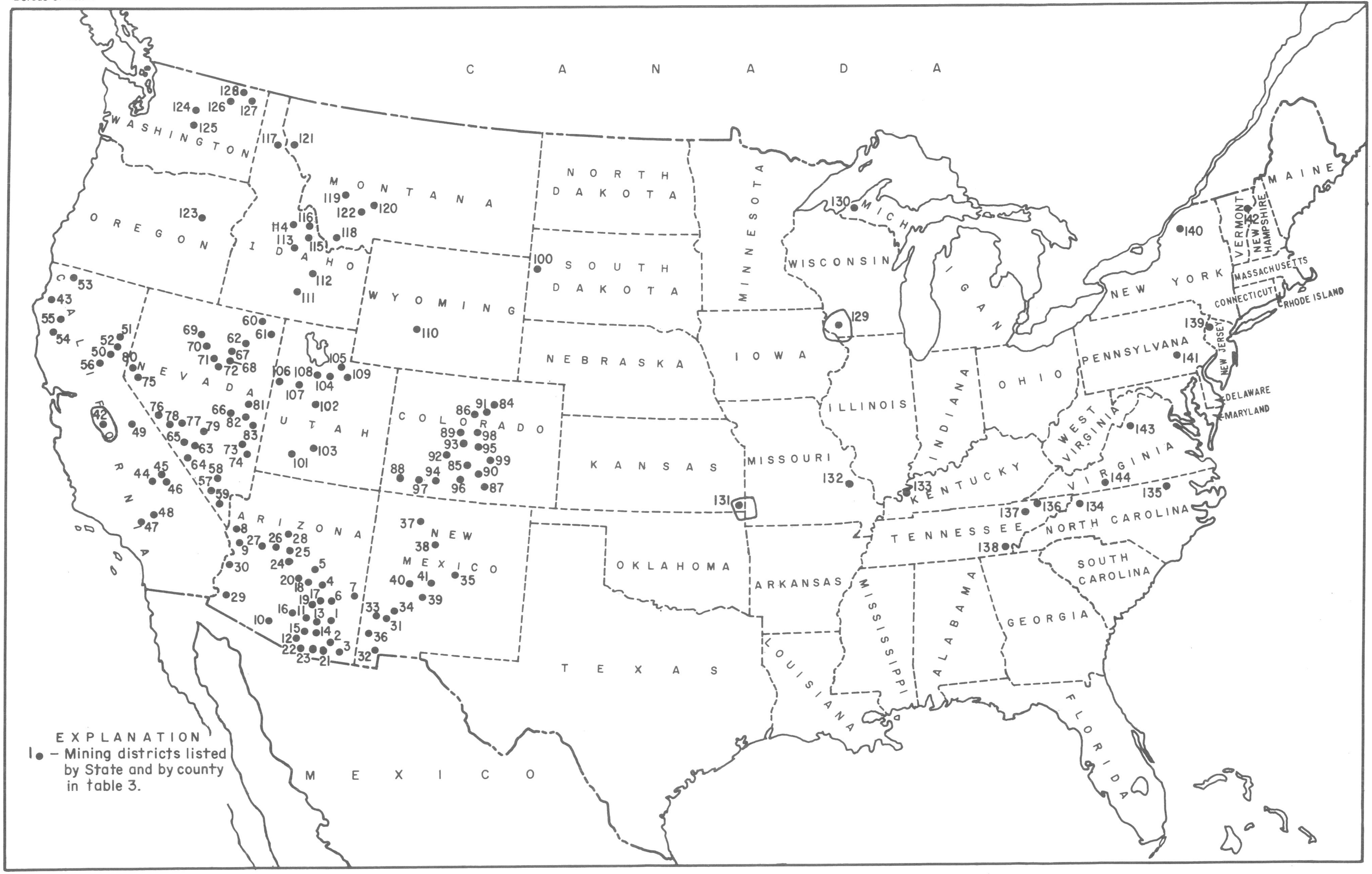


FIGURE 1. - Principal Mining Districts From Which Ores and Concentrates of Gold, Silver, Copper, Lead, and Zinc Were Produced in 1957.

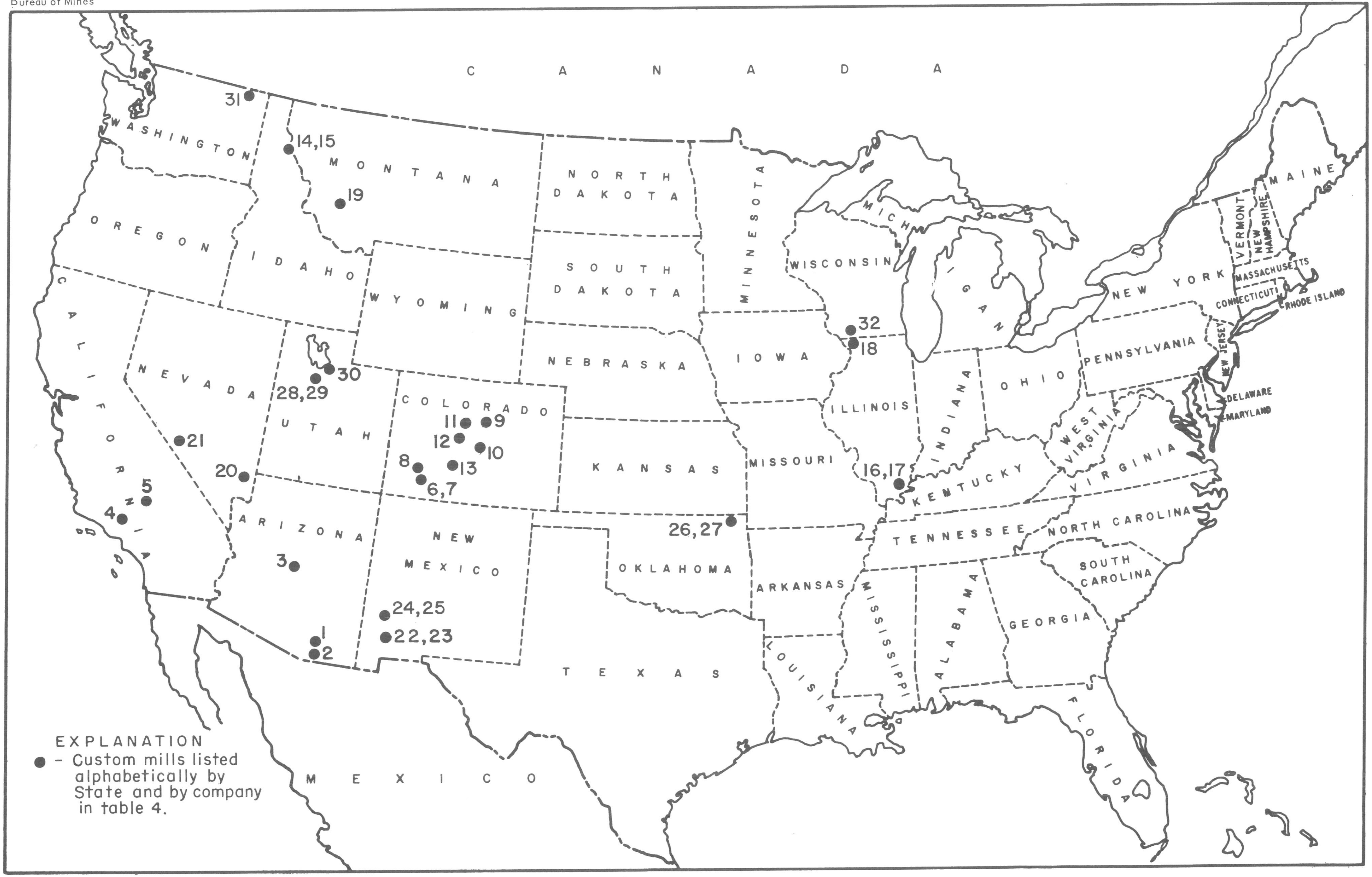


FIGURE 2. - Location of Custom Mills for Ores of Gold, Silver, Copper, Lead, and Zinc.

730-683 O-64 (Face p. 10) No. 2

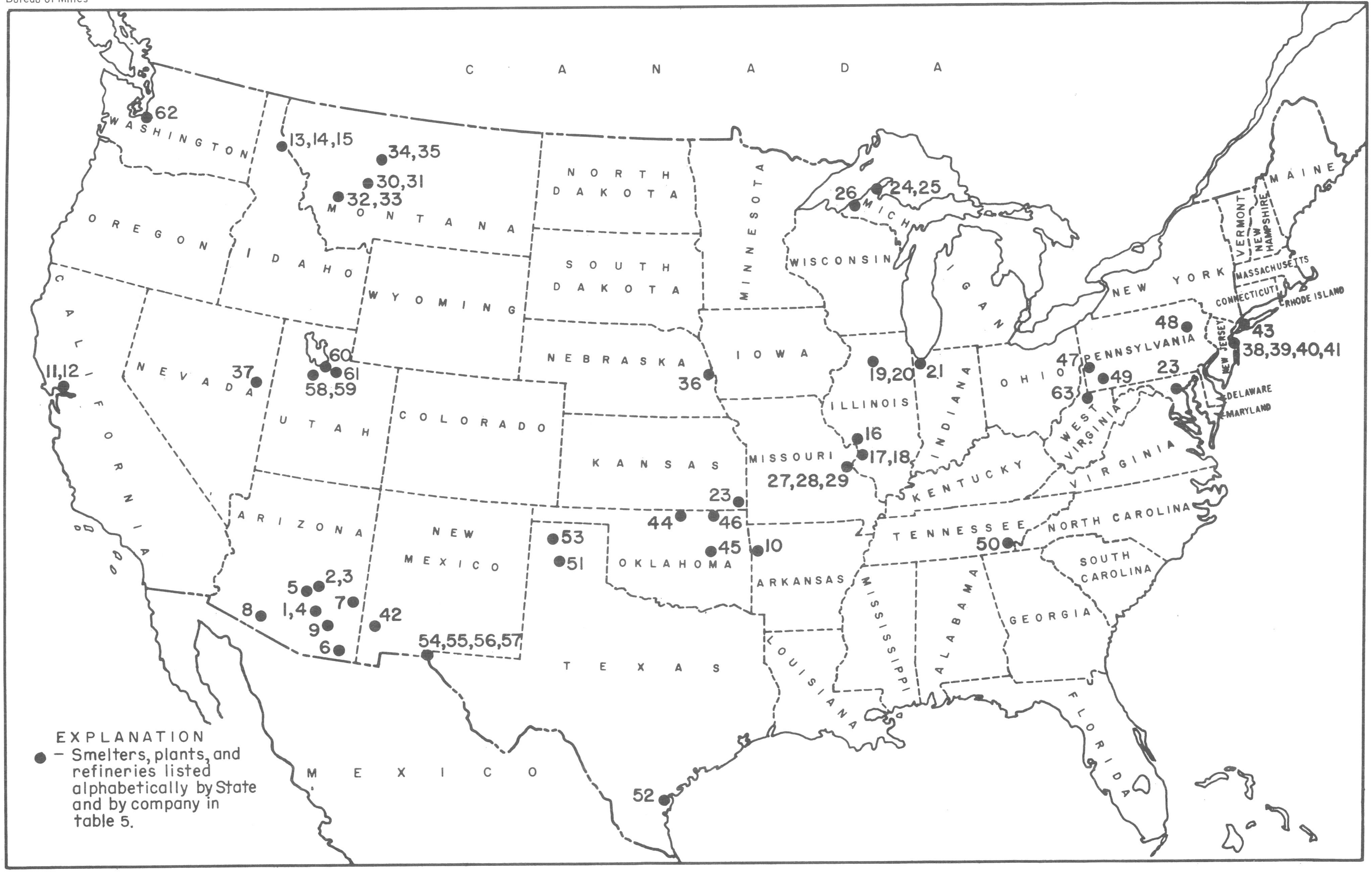


FIGURE 3. - Location of Smelters, Plants, and Refineries Treating Ores, Concentrates, and Metals of Gold, Silver, Copper, Lead, and Zinc.

730-683 O-64 (Face p. 10) No. 3

TABLE 3. - Principal mining districts or areas from which ores and concentrates of gold, silver, copper, lead, and zinc were produced in 1957--Continued

State	County	Mining district	Figure 1, symbol
New Mexico.....	Grant........	Central..........................	31
		Eureka...........................	32
		Pinos Altos......................	33
		Swartz...........................	34
	Guadalupe....	Pintado..........................	35
	Hidalgo......	Lordsburg........................	36
	Sandoval.....	Cuba.............................	37
	Santa Fe.....	Cerrillos, Cooper, San Pedro, and New Placers................	38
	Socorro......	Hansonberg.......................	39
		Magdalena........................	40
	Torrance.....	Carocito.........................	41
California.....	Amador, Calaveras, El Dorado, Madera, Mariposa, Tuolumne.	East Belt, Mother Lode, West Belt	42
	Humboldt.....	Trinity River South (Hoopa)......	43
		Darwin...........................	44
	Inyo.........	Lee..............................	45
		Modoc............................	46
	Kern.........	Mojave...........................	47
		Randsburg........................	48
	Mono.........	Homer............................	49
	Nevada.......	Grass Valley-Nevada City.........	50
	Plumas.......	Sawpit Flat......................	51
	Sierra.......	Alleghany-Downieville............	52
	Siskiyou.....	Klamath River....................	53
	Trinity......	Hayfork..........................	54
		Trinity River....................	55
	Yuba.........	Browns Valley....................	56
Nevada.........	Clark........	Goodsprings (Yellow Pine)........	57
		Las Vegas........................	58
		Searchlight......................	59
	Elko.........	Contact..........................	60
		Delano...........................	61
		Merrimac.........................	62
	Esmeralda....	Klondyke.........................	63
		Montezuma........................	64
		Silver Peak......................	65
	Eureka.......	Eureka...........................	66
		Maggie Creek.....................	67
		Railroad.........................	68
	Humboldt.....	Awakening........................	69
		Golconda.........................	70
	Lander.......	Battle Mountain..................	71
		Bullion..........................	72

TABLE 3. - Principal mining districts or areas from which ores and concentrates of gold, silver, copper, lead, and zinc were produced in 1957--Continued

State	County	Mining district	Figure 1, symbol
Nevada--Continued.	Lincoln......	Jack Rabbit (Bristol)............	73
		Pioche (Ely).....................	74
	Lyon.........	Yerington........................	75
	Mineral......	Aurora...........................	76
		Candelaria.......................	77
		Cedar Mountain...................	78
	Nye..........	Tonopah..........................	79
	Storey.......	Comstock Lode....................	80
	White Pine...	Cherry Creek.....................	81
		Robinson.........................	82
		Tungstonia.......................	83
Colorado......	Boulder......	Central, Gold Hill, Grand Island.	84
	Chaffee......	Monarch..........................	85
	Clear Creek..	Alice, Argentine, Empire, Griffith, Idaho Springs, Montana, and Trail Creek.	86
	Custer.......	Hardscrabble.....................	87
	Dolores......	Pioneer..........................	88
	Eagle........	Red Cliff (Battle Mountain)......	89
	Fremont......	Cotopaxi.........................	90
	Gilpin.......	Northern, Southern...............	91
	Gunnison.....	Domingo, Elk Mountain............	92
	Lake.........	California.......................	93
	Mineral......	Creede...........................	94
	Park.........	Buckskin Gulch, Horseshoe........	95
	Saguache.....	Bonanza............	96
	San Juan, San Miguel, and Ouray.	San Juan.........................	97
	Summit.......	Breckenridge, Montezuma..........	98
	Teller.......	Cripple Creek....................	99
South Dakota..	Lawrence.....	Whitewood (Ida Gray), Portland, and Bald Mountain.	100
Utah..........	Beaver.......	Rocky, San Francisco, Star and North Star.	101
	Juab and Utah	Tintic...........................	102
	Piute........	Gold Mountain, Mount Baldy, Ohio	103
	Salt Lake....	West Mountain (Bingham)..........	104
	Summit.......	Uintah...........................	105
	Tooele.......	Clifton..........................	106
		Dugway...........................	107
		Ophir, Rush Valley...............	108
	Wasatch......	Blue Ledge, Snake Creek..........	109
Wyoming.......	Fremont......	Atlantic City and South Pass.....	110
Idaho.........	Blaine.......	Mineral Hill-Camas and Warm Springs.	111

TABLE 3. - Principal mining districts or areas from which ores and concentrates of gold, silver, copper, lead, and zinc were produced in 1957--Continued

State	County	Mining district	Figure 1, symbol
Idaho--Continued.	Custer.......	Alder Creek......................	112
		Bayhorse.........................	113
	Lemhi........	Blackbird........................	114
		Blue Wing........................	115
		McDevitt.........................	116
	Shoshone.....	Coeur d'Alene (Beaver, Hunter, Evolution, Placer Center, Yreka).	117
Montana........	Beaverhead...	Argenta..........................	118
	Granite......	Flint Creek......................	119
	Jefferson....	Colorado.........................	120
	Sanders......	Eagle............................	121
	Silver Bow...	Butte (Summit Valley)............	122
Oregon.........	Grant........	Granite..........................	123
Washington.....	Chelan.......	Railroad Creek (Chelan)..........	124
		Wenatchee........................	125
	Ferry........	Republic.........................	126
	Pend Oreille.	Metaline.........................	127
	Stevens......	Northport........................	128
Illinois, Iowa, Wisconsin.	Jo Daviess...	Upper Mississippi Valley..........	129
	Dubuque......		
	Grant........		
	Iowa.........		
	Lafayette....		
Michigan.......	Houghton.....	Lake Superior....................	130
	Keweenaw.....		
	Ontonagon....		
Kansas, Missouri, Oklahoma.	Cherokee.....	Tri-State........................	131
	Jasper.......		
	Newton.......		
	Ottawa.......		
Missouri.......	Madison......	Southeastern Missouri............	132
	St. Francois.		
	Washington...		
Illinois.......	Hardin.......	Kentucky Fluorspar...............	133
	Pope.........		
Kentucky.......	Caldwell.....		
	Crittenden...		
	Livingston...		
North Carolina.	Ashe.........	Ore Knob.........................	134
	Halifax......	Enfield..........................	135
Tennessee......	Hancock......	Treadway.........................	136
	Jefferson....	Mascot...........................	137
	Polk.........	Ducktown.........................	138
New Jersey.....	Sussex.......	Franklin Ogdenburg...............	139
New York.......	St. Lawrence.	St. Lawrence.....................	140
Pennsylvania...	Lebanon......	Cornwall.........................	141
Vermont........	Orange.......	Stafford.........................	142
Virginia.......	Rockingham...	Timberville......................	143
	Wythe........	Austinville......................	144

TABLE 4. - Custom mills for treating ores of gold, silver, copper, lead, and zinc (Includes operating plants and idle plants available on demand as of 1961)

Figure 2, symbol	Location of plant	Name of plant	Name of operator	Type of mill	Capacity (short) tons per day)	Products[1] (concentrates unless otherwise stated)	Purchase or toll[2]	Treatment or base charge[3] (dollars per ton)	Remarks
	ARIZONA								
1.......	Sahuarita.....	San Xavier......	McFarland & Hullinger.	Selective flotation.	100	Pb (Cu-Au-Ag) and Zn.	Toll....	4.50	Mill purchased from The Eagle-Picher Co. in March 1957. Treatment charge includes delivery of toll concentrates into railroad cars.
2.......	Patagonia.....	Trench..........	Nash & McFarland.	....do.......	200	.....do.......	Purchase	4.50-5.00	Mill acquired from American Smelting and Refining Co. (Asarco) in 1957. Has purchased ore only from Duquesne mines.
3.......	Humboldt......	Iron King.......	Shattuck-Denn Mining Co.	Selective flotation	1,000	.....do.......	Toll....	-	No custom ore treated since 1954.
				Cyanidation.	300	Au-Ag bullion			
	CALIFORNIA								
4.......	Rosamond......	Burton Brothers.	Burton Brothers	Cyanidation.	150	.....do.......	..do....	5.50	Last operated in 1955.
5.......	Randsburg.....	Butt Lode.......	Butt Lode Mining Co.	Amalgamation and tables.	30	Au-Ag retort sponge.	..do....	5.00-12.00	
	COLORADO								
6.......	Silverton.....	Pride...........	Argyle Mining and Milling Co.	Selective flotation.	80-100	Pb(Cu-Au-Ag) and Zn.	..do....	7.00	Inactive in 1961.
7.......	...do.........	Shenandoah......	Standard Uranium Corp.	Selective flotation and tables.	750	.....do.......	..do....	([4])	Do.
8.......	Ouray.........	Bay City........	Bay City Mining & Milling Co., Inc.	Selective flotation and jigs.	100	.....do.......	..do....	7.00	Do.
9.......	Idaho Springs, Central City, Georgetown, Silver Plume, Black Hawk.	Front Range, Dixie, Black Eagle, Silver Spruce, Silver King, Commonwealth, Burleigh, Mendota, Boodle, Glory Hole, and others.	Various.........	Selective flotation, bulk flotation, jigs, and tables.	50-200	.....do.......	Purchase and/or toll.	([4])	Inactive in 1961. Most of these mills are intact and available for lease or sale.
10.......	Cripple Creek..	Carlton.........	Golden Cycle Corp.	Flotation and cyanidation.	1,000	Au-Ag-bullion.	Purchase	([5])	Closed in January 1962.
11.......	Montezuma......	Plymouth........	John & Vera Jeffrey.	Selective flotation.	50	Pb (Cu-Au-Ag) and Zn.	Toll....	4.50	Inactive in 1962.
12.......	Leadville......	Resurrection....	Resurrection Mining Co.	Selective flotation.	500	.....do.......	Purchase	([6])	Operations suspended in 1957. Equipment intact.
13.......	Bonanza........	Superior........ (National Minerals).	Superior Mines. Corp.	....do.......	150	.....do.......	..do....	([4])	Inactive in 1961.
	IDAHO								
14.......	Wallace.......	Golconda........	Golconda Lead Mines.	....do.......	200	.....do.......	Toll....	([4])	
15.......	...do.........	Rex.............	Zanetti Bros.	....do.......	200	.....do.......	..do....	([4])	

	ILLINOIS								
16.......	Rosiclare.....	Rosiclare.......	Aluminum Co. of America	Heavy media and selective flotation.	600	Fluorspar-Zn-Pb.	Purchase	(6)	
17.......	...do.........	Ozark-Mahoning..	Ozark-Mahoning Co.	....do........	385	.....do.......	..do....	(5)	
18.......	Galena........	Graham..........	The Eagle-Picher Co.	Selective flotation and jigs.	1,500	Pb (Ag), Zn...	..do....	(6)	
	MONTANA								
19.......	Anaconda......	Anaconda........	The Anaconda Co.	Selective flotation.		Zn............	..do....	(4)	No ore purchased in 1961.
	NEVADA								
20.......	Pioche........	Caselton........	Combined Metals Reduction Co.	....do........	1,800	Cu, Pb (Au-Ag), Zn.	..do....	(4)	Inactive since 1957.
21.......	Silver Peak...	Silver Peak.....	United States Mining and Milling Co.	Cyanidation...	250-300	Au-Ag bullion.	..do....	(4)	Inactive in 1961.
	NEW MEXICO								
22.......	Deming........	Asarco..........	Asarco.........	Selective flotation.	650-750	Cu, Pb, and Zn.	..do....	(4)	Inactive since 1957.
23.......	...do.........	Peru............	Peru Mining Co.	....do........	300	.....do.......	..do....	(4)	Reopened in 1961.
24.......	Hanover.......	Hanover.........	Empire Zinc Division, The New Jersey Zinc Co.	....do........	-	.....do.......	..do....	(4)	
25.......	Bayard........	Bullfrog........	United States Smelting Refining and Mining Co.	....do........	600	.....do.......	..do....	(4)	
	OKLAHOMA								
26.......	Cardin........	Central.........	The Eagle-Picher Co.	Heavy media, selective flotation, and jigs.	12,000	Cu, Pb, and Zn.	Purchase and toll.	(4)	Reopened in 1961.
27.......	Commerce......	Barbara J.......	American Zinc, Lead and Smelting Co.	....do........	1,000	.....do.......	..do....	(4)	Do.
	UTAH								
28.......	Bauer.........	Bauer...........	Combined Metals Reduction Co.	Selective flotation.	500	Cu, Pb (Au-Ag), Zn.	Purchase	(4)	Inactive since 1958.
29.......	Tooele........	Tooele..........	International Smelting and Refining Co.	....do........	1,500	.....do.......	..do....	(6)	Inactive since 1958. Custom milling ores diverted to Midvale, Utah, after this date.
30.......	Midvale.......	Midvale.........	United States Smelting Refining and Mining Co.	....do........	1,700	.....do.......	Purchase and toll.	(5)	
	WASHINGTON								
31.......	Northport.....	Admiral.........	Admiral Consolidated Mining Co.	....do........	75	Pb (Au-Ag), Zn.	Toll....	(4)	Inactive since 1958.
	WISCONSIN								
32.......	White Oak,	Vinegar Hill....	Vinegar Hill Division, American Zinc, Lead and Smelting Co.	....do........	600	Pb (Ag), Zn...	Purchase	(4)	

[1] Symbols in parentheses denote minor metals in mill heads and concentrates.
[2] "Purchase" denotes ores purchased outright; "toll" denotes ores treated under contract when shipper retains title.
[3] Additional data shown in appendix.
[4] No scheduled treatment charge; payment negotiated.
[5] See treatment schedule in appendix.
[6] Purchase schedule not available.

TABLE 5. - Smelters, plants, and refineries for treating gold, silver, copper, lead, and zinc ores, concentrates, and metals

Figure 3, symbol	Location of plant	Company	Type of smelter, plant, or refinery	Class of material treated (ores and concentrates unless otherwise stated)	Annual capacity[1] (short tons) Charge[2]	Annual capacity[1] (short tons) Refined metal	Purchase ore or concentrate outright	Treat ore or concentrate on toll basis and return product to shipper	Treat company ore or concentrate only	Remarks on principal source of ore and concentrate for plant and other pertinent data.
	ARIZONA									
1.......	Hayden.......	American Smelting and Refining Co.	Copper smelter.	Copper, gold-silver.	300,000	-	X	X	X	Major Arizona producers and [3].
2.......	Inspiration..	Inspiration Consolidated Copper Co.	Electrolytic copper refinery.	Leach solution and anode copper.	-	[4]45,000	-	-	X	Company Inspiration mine.
3.......	Miami........	.....do........ (formerly International Smelting and Refining Co.)	Copper smelter.	Copper, gold-silver.	360,000	-	X	X	-	Inspiration Consolidated Copper Co., Miami Copper Co. mines, and [3].
4.......	Hayden.......	Kennecott Copper Corp., Ray Mines Div.	....do.......	.....do.......	400,000	-	-	-	X	Company Ray mines. Smelter operation began in July 1958.
5.......	Superior.....	Magma Copper Co.	....do.......	.....do.......	150,000	-	X	-	-	Company Superior mines and [3].
6.......	Douglas......	Phelps Dodge Corp., Douglas Reduction works.	....do.......	.....do.......	1,250,000	-	X	-	-	Company Copper Queen and Lavender mines and [3].
7.......	Morenci......	Phelps Dodge Corp., Morenci Branch.	....do.......	.....do.......	900,000	-	-	-	[5]X	Company Morenci mine and custom flux.
8.......	Ajo..........	Phelps Dodge Corp., New Cornelia Branch.	....do.......	.....do.......	300,000	-	-	-	[5]X	Company Ajo mine and custom flux.
9.......	San Manuel...	San Manuel Copper Corp.	....do.......	.....do.......	360,000	-	-	-	X	Company San Manuel mine.
	ARKANSAS									
10.......	Fort Smith...	Athletic Mining & Smelting Co.	Zinc smelting plant.[6]	Zinc ores, concentrates, and fumes.	-	[7]80	X	-	-	Company Arizona mines, [3], and [8].
	CALIFORNIA									
11.......	Selby........	American Smelting and Refining Co.	Silver-lead smelter and refinery.	Lead, gold-silver.	192,000	[9]72,000	X	-	-	(3, 8)
12.......	...do........	.....do........	Zinc slag-fuming plant.	Zinc slag and fume.	-	(10)	-	-	-	Zinc slag from lead smelter and smelter dump.
	IDAHO									
13.......	Bradley (Kellogg).	Bunker Hill & Sullivan Mining & Concentrating Co.	Silver-lead smelter and refinery.	Lead, gold-silver.	300,000	[9]100,000	X	-	-	Company Bunker Hill and Star mines, [3], and [8].

14.......	Silver King (Kellogg).	The Bunker Hill Electrolytic Zinc Plant.	Electrolytic zinc plant.	Zinc concentrate.	-	[11]73,800	X	-	-	Company Bunker Hill and Star mines, [3], and [8].
15.......	Kellogg......	The Bunker Hill Co.	Zinc slag-fuming plant.	Zinc slag and fume.	-	(10)	-	-	-	Zinc slag from lead smelter and smelter dump zinc slag.
	ILLINOIS									
16.......	Alton (Federal)	American Smelting and Refining Co.	Silver-lead smelter and refinery.	Lead, gold-silver.	-	[9]128,000	X	X	-	[3]Closed.
17.......	East St. Louis.	American Zinc Co. of Illinois.	Zinc smelting plant.[6]	Zinc (and residues).	-	[7]35	X	X	-	Company mines in Missouri and Tennessee, [3] and [8].
18.......	Monsanto.....	.....do........	Electrolytic zinc plant.	Zinc fume, calcine, and residue.	-	[11]60,000	X	X	-	Plants in Idaho, Oklahoma, Pennsylvania, Texas, Utah, Canada, and Mexico.
19.......	La Salle.....	Matthiessen & Hegeler Zinc Co.	Zinc smelting plant.[6]	Zinc.........	-	[7]90	X	X	-	Northern Illinois, Wisconsin, Tri-State district, and [8].
20.......	Depue........	The New Jersey Zinc Co.	Zinc smelting plant.[12]	Zinc and residues.	-	(10)	X	X	-	Company Colorado mines, [3], and [8]. Treats primarily roasted and sintered zinc concentrates and oxide ore.
	INDIANA									
21.......	East Chicago.	U.S.S. Lead Refinery, Inc.	Electrolytic silver-lead refinery.	(13)	-	[9]40,000	-	-	-	(10)
	KANSAS									
22.......	Galena.......	The Eagle-Picher Co.	Silver-lead smelter and refinery.	Lead.........	(10)	(10)	X	-	-	Company Oklahoma and Illinois mills and [3] in tri-state district. Primarily a pigment plant.
	MARYLAND									
23.......	Baltimore....	American Smelting and Refining Co.	Electrolytic copper refinery.	(13)	-	[4]198,000	-	-	-	(10)
	MICHIGAN									
24.......	Hubbell	Calumet & Hecla, Inc.	Copper smelter and refinery.	Copper concentrates and copper scrap.	100,000	[14]60,000	-	-	X	Company mines and reclamation plants.

See footnotes at end of table.

TABLE 5. - Smelters, plants, and refineries for treating gold, silver, copper, lead, and zinc ores, concentrates, and metals--Continued

Figure 3, symbol	Location of plant	Company	Type of smelter, plant, or refinery	Class of material treated (ores and concentrates unless otherwise stated)	Annual capacity[1] (short tons) Charge[2]	Annual capacity[1] (short tons) Refined metal	Purchase ore or concentrate outright	Treat ore or concentrate on toll basis and return product to shipper	Treat company ore or concentrate only	Remarks on principal source of ore and concentrate for plant and other pertinent data.
	MICHIGAN--Continued									
25.......	Hancock......	Quincy Mining Co.	Copper smelter and refinery.	Copper concentrates and copper scrap.	-	[14]12,000	X	-	-	Company reclamation plant and Copper Range's Champion mine concentrates. Smelter idle in 1958 and first 6 months of 1959.
26.......	White Pine...	White Pine Copper Co.	....do.......	.....do.......	-	[14]55,000	-	-	X	Copper Range ores.
	MISSOURI									
27.......	Herculaneum	St. Joseph Lead Co.	Silver-lead smelter and refinery.	Lead..........	-	[9]120,000	-	-	X	Company southeastern Missouri mines, Belmont mine in New York, [3], and [8].
28.......	St. Louis....	Lewin-Mathes Co. Division of Cerro Corp.	Copper refinery.	Copper concentrates and scrap.		42,500	-	-	X	
29.......	Herculaneum	St. Joseph Lead Co.	Zinc slag-fuming plant.			(10)	-	-	X	Hot slag and fume from lead smelter and smelter dump slag.
	MONTANA									
30.......	East Helena..	American Smelting and Refining Co.	Silver-lead..	Lead, gold....	360,000	-	X	-	-	Butte mines, [3], and [8].
31.......	...do........	The Anaconda Co.	Zinc slag-fuming.	Zinc slag and fume.	-	(10)	X	-	-	Zinc slag from lead smelter and smelter dump slag.
32.......	Anaconda.....	.....do........	Copper smelter.	Copper, gold-silver.	1,000,000	-	X	-	-	Butte mines, [3], and [6].
33.......	...do........	.....do........	Electrolytic zinc plant.	Zinc concentrate.	-	[11]86,500	X	X	-	Butte mines, [3], plant closed in 1960.
34.......	Great Falls..	.....do........	....do.......	.....do.......	-	[11]162,000	X	X	-	Butte mines, [3], and [8].
35.......	...do........	.....do........	Electrolytic copper.	(13)	-	[4]150,000				(10)
	NEBRASKA									
36.......	Omaha........	American Smelting and Refining Co.	Silver-lead refinery.	(13)	-	[9]180,000	-	-	-	(10)
	NEVADA									
37.......	McGill.......	Kennecott Copper Corp. Nevada Mines Div.	Copper smelter.	Copper, gold-silver.	440,000	-	-	-	X	Company mines and custom fluxing ore.

38.......	NEW JERSEY Carteret.....	American Metal Climax, Inc.	Copper smelter and electrolytic and fire refinery.	Copper ores and concentrates and residues.	245,000	[4]150,000 [14]121,000	X	-	-	Concentrates from Vermont and North Carolina.
39.......	Barber.......	American Smelting and Refining Co.	Silver-lead refinery.	(13)	-	[9]96,000	-	-	-	
40.......	...do........	.....do........	Electrolytic copper refinery.	(13)	-	[4]168,000	-	-	-	(10)
41.......	Raritan (Perth Amboy).	International Smelting and Refining Co.	....do.......	(13)	-	[4]240,000	-	-	-	(10)
42.......	NEW MEXICO Hurley.......	Kennecott Copper Corp.	Copper smelter and fire refinery.	Copper concentrates.	400,000	[14]84,000	-	-	X	Company Chino mine. Fire refinery operated intermittently.
43.......	NEW YORK Laurel Hill..	Phelps Dodge Refining Corp.	Copper smelter and electrolytic refinery.	.....do.......	200,000	[4]175,000	X	-	-	Appalachian Sulfides, Inc., mines in Vermont and North Carolina and Bethlehem Cuba Iron mine in Pennsylvania.
44.......	OKLAHOMA Blackwell....	American Metal Climax, Inc.	Zinc smelting plant.[6]	Zinc ore and concentrates and flue dust.	-	[7]266	X	-	-	Primarily.[8]
45.......	Henryetta....	The Eagle Picher Co.	....do.......	Zinc...........	-	[7]150	X	-	-	Company Oklahoma and Illinois mines and [3] from Tri-State district, Illinois, and Wisconsin.
46.......	Bartlesville.	National Zinc Co.	....do.......	Zinc concentrates, calcines, oxides, and residue.	-	[7]114	X	-	-	[3] from Colorado Arizona, Tri-State district, and [8].
47.......	PENNSYLVANIA Josephtown...	St. Joseph Lead Co.	Zinc smelting plant.[12]	Zinc...........	(10)	-	X	-	-	Company New York and Missouri mines, 3, and [8].
48.......	Palmerton....	The New Jersey Zinc Co.	....do.......	Zinc ore and concentrates and residues.	113,000	-	X	-	-	Company New Jersey, Colorado, Tennessee, Pennsylvania and Virginia mines, [3], and [8].
49.......	Donora.......	United States Steel Corp.	Zinc smelting plant.[6]	Zinc...........	70,000	-	X	-	-	Material from Tennessee and New York; closed November 23, 1957.
50.......	TENNESSEE Copperhill...	Tennessee Copper Co.	Copper smelter.	Copper.........	70,000	-	-	-	-	Company mines in Tennessee.

See footnotes at end of table.

TABLE 5. - Smelters, plants, and refineries for treating gold, silver, copper, lead, and zinc ores, concentrates, and metals--Continued

Figure 3, symbol	Location of plant	Company	Type of smelter, plant, or refinery	Class of material treated (ores and concentrates unless otherwise stated)	Annual capacity[1] (short tons)		Purchase ore or concentrate outright	Treat ore or concentrate on toll basis and return product to shipper	Treat company ore or concentrate only	Remarks on principal source of ore and concentrate for plant and other pertinent data.
					Charge[2]	Refined metal				
	TEXAS									
51.......	Amarillo.....	American Smelting and Refining Co.	Zinc smelting plant.[6]	Zinc..........	-	[7]160	X	X	-	Company mines in Colorado and New Mexico (inactive), [3], and [8].
52.......	Corpus Christi	.....do........	Electrolytic zinc plant.	Zinc concentrates and fume.	-	[11]105,000	X	X	-	Do.
53.......	Dumas........	.....do.......	Zinc smelting plant.[6]	.....do.......	-	[7]137	X	-	-	(3, 8)
54.......	El Paso......	.....do.......	Copper smelter.	Copper, gold-silver.	400,000	-	X	X	-	Company mines in Arizona and Missouri, [3], and [8].
55.......	...do........	.....do.......	Silver-lead smelter.	Lead-zinc, gold-silver.	360,000	-	X	X	-	Company mines in Colorado and New Mexico (inactive), [3] and [8].
56.......	...do........	.....do.......	Zinc-slag-fuming plant.	Zinc slag.....						Hot slag and fume from lead smelter and smelter dump slag.
57.......	...do........	Phelps Dodge Refining Corp.	Electrolytic copper refinery and copper fire refinery.	(13)	-	{[4]290,000 / [14]25,000	-	-	} X	Company mines.
	UTAH									
58.......	Tooele.......	International Smelting and Refining Co.	Silver-lead smelter.	Lead-zinc, gold-silver.	300,000	-	X	X	-	(3, 8)
59.......	...do........	.....do.......	Zinc slag-fuming plant.	Zinc oxide and carbonate ores and zinc slag.	(10)	-	X	X	-	Hot slag and fume from lead smelter and smelter dump slag.
60.......	Garfield.....	Kennecott Copper Corp.	Copper smelter and electrolytic copper refinery.	Copper concentrates.	1,225,000	[4]204,000	-	-	[5]X	American Smelting and Refining Co. accepted custom ore and concentrate at the copper smelter until January 1, 1959, when the new owner Kennecott Corp., assumed operation.

	UTAH--(Continued)									
61.......	Midvale......	United States Smelting, Refining and Mining Co.	Silver-lead smelter and refinery.	Lead, gold-silver.	250,000	[9]72,000	X	-	-	Midvale smelter was closed in June 1958 and subsequently dismantled. Company continued to buy custom material which was treated at International Smelting and Refining Co. Tooele smelter on a toll basis.
	WASHINGTON									
62.......	Tacoma.......	American Smelting and Refining Co.	Copper smelter and electrolytic refinery.	Copper, gold-silver, and siliceous gold ores.	600,000	[4]114,000	X	X	-	(3, 8)
	WEST VIRGINIA									
63	Meadowbrook..	Meadowbrook Corp., subsidiary of Matthiessen & Hegeler.	Zinc smelting plant.[12]	Zinc..........	-	[11]42,000	X	-	-	[3] principally from Arkansas, Wisconsin, Missouri, and [8] principally from Canada.

[1] Based on American Bureau of Metal Statistics Yearbook, Thirty-Seventh Annual Issue for the year 1960.
[2] Includes flux but not fuel.
[3] Small lots of domestic custom ore or concentrate.
[4] Refined copper.
[5] Purchased custom silica fluxing ore or material only.
[6] Horizontal retorts.
[7] Daily capacity for spelter.
[8] Foreign ore and concentrate.
[9] Refined pig lead.
[10] Data confidential or not available.
[11] Slab zinc.
[12] Vertical retorts.
[13] Not applicable.
[14] Fire refined copper (with varying amounts of silver).

Alaska

Production of newly mined base- and precious-metal ores in Alaska in 1960 was limited to gold, silver, and a few tons of high-grade lead ore. Over 99 percent of the gold came from placer operation and the balance from six small lode mines scattered throughout the State.

Base-metal mining in Alaska has been at a standstill for a number of years, although exploration for copper deposits was in progress in 1960 and 1961. The only recorded production of base metals in 1960 consisted of two shipments of a few tons each of high-grade lead-silver-gold ore from the Hyder district in southern Alaska.

Marketing gold and silver presents no problem. Both metals are recovered as bullion by gravity concentration, amalgamation, and cyanidation in plants at the mines. Bullion shipments to the U.S. Mint at San Francisco, Calif., or Denver, Colo., can be made conveniently by air. Gold and silver in bullion form can also be sold to licensed buyers; for example, certain local banks. Occasionally, heavy mineral concentrates containing gold are obtained as a byproduct of placering operations. This class of material can be sold to lead or copper smelters, but more often is discarded or stockpiled in hope of a profitable market in the future.

Base-metal ores as mined, or as concentrated in mills located at the mines, have been shipped to the copper smelter of the American Smelting & Refining Co. at Tacoma, Wash., and to the Selby, Calif., lead smelter of the same company. Both plants are at tidewater. One of the two small Alaska shipments of lead-silver-gold ore made in 1960 went to the East Helena, Mont., lead smelter of the American Smelter & Refining Co., and the other to the Selby, Calif., plant. The nearest plant to which Alaskan zinc ores or concentrates could be shipped is the Bunker Hill Co. electrolytic plant at Kellogg, Idaho.

The marketing of ores from southeastern Alaska is discussed in detail in a 1958 Bureau of Mines publication (18).

Arizona

In 1960, mineral production in Arizona increased 27 percent in value over that of 1959, largely because of increased copper output. At least three new copper deposits now under development are expected to come into production in the next few years.

Most of the major producers of copper have integrated mining, milling, and smelting operations (table 6). All have their own concentrators or leaching plants, and eight firms operate smelters.

Another method of treating oxidized copper ores, the segretation process, has been introduced recently at the Lake Shore property of Transarizona Resources, Inc., south of Casa Grande. This process, which produces a metallic copper concentrate, may have increasing importance in copper metallurgy (9, 11, 26).

TABLE 6. - Leading copper-producing operations in Arizona in 1960[1] [2]

Operation	Company	District	County	Type of mining	Type of treatment	Concentrator (company owned)	Smelter
Morenci[3]....	Phelps Dodge Corp.	Copper Mountain	Greenlee	Open pit...	Flotation, leaching.	Morenci........	Morenci.[4]
San Manuel[3].	San Manuel Copper. Corp.	Old Hat........	Pinal...	Underground	...do.....	San Manuel.....	San Manuel[4]
New Cornelia	Phelps Dodge Corp.	Ajo...........	Pima....	Open pit...	Flotation.	Ajo...........	Ajo.[4]
Lavender pit	.......do.........	Warren.........	Cochise.	....do.....	Flotation, leaching.	Bisbee.........	Douglas.[4]
Copper Queen	.......do.........	......do.......	...do...	Underground	..do......	...do..........	Do.
Ray pit.....	Kennecott Copper Corp.	Mineral Creek..	Pinal...	Open pit...	..do......	Ray............	Hayden.[4]
Inspiration.	Inspiration Consolidated Copper Co.	Globe-Miami....	Gila....	....do.....	..do......	Inspiration....	Inspiration.[5]
Esperanza[3]..	Duval Sulphur & Potash Co.	Pima...........	Pima....	....do.....	Flotation.	Esperanza......	Custom.
Silver Bell Unit.[3]	American Smelting and Refining Co.	Silver Bell....	...do...	....do.....	Flotation, leaching.	Silver Bell....	Hayden[4] or El Paso.
Magma.......	Magma Copper Co.[6]	Pioneer........	Pinal...	Underground	Flotation.	Superior.......	Superior.[4]
Copper Cities	Tennessee Corp....	Globe-Miami....	Gila....	Open pit...	..do......	Copper Cities..	Custom.
Miami.......	.......do.........	......do.......	...do...	Underground	Leaching..	...do..........	Do.
Castle Dome dump.	.......do.........	......do.......	...do...	Open pit...	..do......	....	Do.
Pima........	Pima Mining Co....	Pima...........	Pima....	....do.....	Flotation.	Pima...........	Do.
Bagdad[3].....	Bagdad Copper Corp.	Eureka.........	Yavapai.	....do.....	Flotation, leaching.	Bagdad.........	Do.
Old Dick[7]...	Cyprus Mines Corp.	......do.......	...do...	Underground	Flotation.	Old Dick.......	Do.
Daisy, Palo Verde.	Banner Mining Co.	Pima...........	Pima....	Underground open pit.[8]	..do......	Daisy..........	Do.

[1]Adapted from Bureau of Mines Minerals Yearbook 1960.
[2]Gold and silver were obtained as byproducts of copper mining.
[3]Molybdenum was obtained as a byproduct of copper mining.
[4]Company owned smelter.
[5]Smelter purchased from International Smelting and Refining Co. in 1960.
[6]Successor to Miami Copper Co.
[7]Copper-zinc ore mined.
[8]Daisy open pit operated by Pima Mining Co.

The five properties that mined complex ores in 1960 are shown in table 7. These mines accounted for most of Arizona's lead and zinc production in 1960, in contrast with 181 producing mines in 1949. Gold, silver, and copper were also recovered. The principal product from the Old Dick mine is copper, but the zinc content in the ore makes this mine the second largest producer of zinc in the state.

TABLE 7. - Arizona mines producing complex ores in 1960

Company	Mine	Location	County	Principal products
McFarland & Hullinger.....	Johnson Camp, Moore shaft.	Johnson Camp	Cochise....	Zinc.
Nash & McFarland..........	Flux.........	Patagonia...	Santa Cruz.	Zinc-lead.
Cyprus Mines Corp.........	Old Dick.....	Near Bagdad.	Yavapai....	Copper-zinc.
B. S. & K. Mining Co......	Atlas........	Near Silver Bell.	Pima.......	Zinc.
Shattuck-Denn Mining Corp.	Iron King....	Humboldt....	Yavapai....	Zinc-lead.

The five mills shown in table 8 are operated primarily to serve the owners' company or lessee operations. Ores from other properties are accepted on a custom basis. However, no ores from lead-zinc mines without milling facilities were shipped to any of the plants shown in table 8 in 1960.

TABLE 8. - Custom mills available to Arizona ores in 1960

Location of plant	Company operating plant
Johnson Camp, Ariz.................	McFarland & Hullinger.
Patagonia, Ariz. (Trench)..........	Nash & McFarland.
Humboldt, Ariz. (Iron King)........	Shattuck-Denn Mining Corp.[1]
Deming, N. Mex.:	
(Asarco)........................	American Smelting & Refining Co.[2]
(Peru)..........................	Peru Mining Co.[3]

[1] No custom ores were being treated by the Shattuck-Denn Mining Corp. in 1960.
[2] Not operating in 1960.
[3] Reactivated in 1960 primarily for ores from Grant County, N. Mex., mines.

Base-metal ores and concentrates from operations that do not maintain their own smelter can be marketed at copper, lead, and zinc smelting plants in Arizona, Oklahoma, and Texas, as listed in table 5.

Arkansas

A small production of lead and zinc concentrates from an operation in Marion County was reported in 1960.

The zinc smelting plant of the Athletic Mining & Smelting Co. at Fort Smith, Ark., operated at a very low rate in 1960 under contract with the

American Zinc, Lead & Smelting Co. This plant was supplied chiefly from retreated tailings from the Tri-State District of Kansas, Missouri, and Oklahoma.

California

Marketing of gold and silver in California presents a few problems. The output from placer and lode mining at points scattered throughout the State is recovered in gravity, amalgamation, and cyanide plants as gold and silver bullion and sold to the U.S. Mint at San Francisco, Calif. Small amounts of gold and silver are recovered and marketed with base-metal concentrates.

Copper is mined at properties in five counties, but an operation in Inyo County and another in Humboldt County accounted for most of California's production in 1960.

Inyo County copper, along with gold and silver, is a byproduct of tungsten production. Most of California's yearly lead and zinc production of a few hundred tons each, also comes from Inyo County.

In 1959, the Butte Lode Mining Co. mill at Randsburg accepted custom gold and silver ores amenable to recovery by amalgamation and gravity concentration. No other custom mill was in operation in California, although operators of private treatment plants occasionally accepted outside ore as an accommodation to small producers. Gold and silver ores from Eastern California have been treated at the custom cyanide mill of the United States Mining & Milling Co. at Silver Peak, Nev. Operations at this mill were suspended in 1961.

The closest custom milling facilities for lead and zinc ores from California are available at the Midvale, Utah, plant of the United States Smelting Refining & Mining Co. Milling plants of Combined Metals Reduction Co. at Caselton (Pioche), Nev., and Bauer, Utah, and the plant of the International Smelting and Refining Company at Tooele, Utah, which formerly accepted custom lead-zinc ore, have been closed. Presumably one of the Combined Metals Reduction Co. plants will be available again under more favorable market conditions.

No custom milling facilities for copper ores are available to California producers. A limited market for copper-, gold-, and silver-bearing silica fluxing ore is available at the copper smelter of Kennecott Copper Corp. at McGill, Nev., where they are accepted by prearrangement on an as needed basis. Copper ores and concentrates can be sold to copper smelters of the American Smelting & Refining Co. at Tacoma, Wash., and Hayden, Ariz., and to The Anaconda Co. plant at Anaconda, Mont. Shipment to the Magma Copper Co. smelter at Superior, Ariz., or the American Smelting & Refining Co. smelter at El Paso, Tex., might be advantageous in certain cases.

Logical markets for lead concentrates are the lead smelters of the American Smelting & Refining Co., Selby, Calif., and East Helena, Mont., and of The Bunker Hill Co., Kellogg, Idaho. However, the International Smelting & Refining Co. accepts high-grade zinc oxide and carbonate ores for its zinc-fuming plant at Tooele, Utah, and zinc concentrates without deleterious impurities are accepted at the electrolytic zinc plant of the Anaconda Co. at Great Falls, Mont.

Colorado

Custom mills in Colorado operated between 1950 and 1960 are listed in table 4. All of these were closed in 1962, although the Carlton custom cyanide mill of The Golden Cycle Corp. in the Cripple Creek district, Teller County, was operated until January 1, 1962. This plant served an integrated gold-mining operation that produced slightly more than half of the State's gold output in 1960. Treating gold telluride ore largely from three mines and several mine dumps, the Carlton mill operated in 1960 and 1961 at much less than its rated capacity of 1,000 tons daily. The mill is not designed to treat gold ores containing appreciable amounts of base metals. However, dry gold ores from other districts would have been treated, if offered.

In 1960, most of the copper, lead, and zinc ores, which also contained some gold and silver, were mined and milled by the State's major producers as follows:

Company	Operation	Concentrator	Product
Idarado Mining Co	Treasury-Tunnel-Black Bear-Smuggler Union.	Pandora mill at Telluride, Colo.	Copper, lead, and zinc concentrates and gold bullion.
The New Jersey Zinc Co.	Eagle...........	Eagle mill at Gilman, Colo.	Lead and zinc concentrates and copper ore.
Camp Bird Colorado, Inc.	Camp Bird........	Camp Bird mill near Ouray, Colo.	Lead and zinc concentrates.
Emperius Mining Co.	Emperius.........	Emperius mill at Creede, Colo.	Gold-silver ore, lead and zinc concentrates.
Rico Argentine Mining Co.	Rico Argentine...	Rico mill at Rico, Colo.	Lead and zinc concentrates.

In 1960, Colorado producers of lead, zinc, and copper ores and concentrates had a choice of the following custom mills and smelters and plants:

Class of ore or concentrate	Location of plant	Company operating plant
	Custom smelters	
Lead..............	El Paso, Tex........	American Smelting & Refining Co.
	Tooele, Utah........	International Smelting & Refining Co.
Zinc..............	Amarillo, Tex.......	American Smelting & Refining Co.
	Bartlesville, Okla..	National Zinc Co.
	Anaconda, Mont......	The Anaconda Co.
	Corpus Christi, Tex.	American Smelting & Refining Co.
Copper............	El Paso, Tex........	American Smelting & Refining Co.
	Custom mills	
Copper, lead, zinc.	Midvale, Utah.......	United States Smelting Refining & Mining Co.

Starting in 1957, low lead and zinc prices forced the closing of many Colorado mines and mills, including all Leadville, Colo., operations and the Keystone Unit of the American Smelting & Refining Co. near Crested Butte, Colo. Smaller operations scattered through the Colorado mineral belt were also inactive in 1960 and 1961. None of the 15 or more Colorado lead-zinc-copper custom mills listed in table 4 was operating in 1961. Many of them, including the Resurrection mill at Leadville, the largest custom mill in Colorado, could be reactivated. The last remaining custom smelter in Colorado, the Arkansas Valley lead smelter of the American Smelting & Refining Co. at Leadville, was closed permanently in February 1961.

Operators who had ore contracts with the Leadville smelter have been able to market ores at the El Paso, Tex., plant of the same company, using the Leadville treatment schedule and paying freight charges equal to the former cost of shipping to Leadville. Less-than-carload lots can be shipped to the American Smelting & Refining Co. Globe refinery at Denver, Colo., where shipments are sampled and accumulated for forwarding to Texas plants. Partial payment is made to shippers after receipt of the ore at the Globe plant.

Idaho

In 1960, Idaho continued as the Nation's premier silver-producing State and ranked second in the production of lead and third in the output of zinc. Most of the metals came from five mines in the Coeur d'Alene mining region of Shoshone County in the northern part of the State. These mines are listed as follows:

Mine	Ore	Operator	Owner
Bunker Hill.....	lead-zinc....	The Bunker Hill Co...	The Bunker Hill Co.
Star............	...do........	Hecla Mining Co......	Do.
Sunshine........	silver.......	Sunshine Mining Co...	Sunshine Mining Co.
Page............	lead-zinc....	American Smelting and Refining Co.	American Smelting and Refining Co.
Galena..........	silver.......	.....do..............	Callahan Mining Corp. (mine leased to Asarco and The Day Mines, Inc.)
Lucky Friday....	lead.........	Hecla Mining Co......	Lucky Friday Silver Lead Mines Co.

The Bunker Hill Co. has an integrated mining, milling, smelting, and refining operation in the Coeur d'Alene mining region. In addition to mining and milling, the operation includes a silver-lead smelter and refinery and an electrolytic zinc plant. Custom concentrate from foreign and domestic sources furnishes much of the material treated. Small lots of crude lead ore are purchased.

There is very little custom milling in Idaho. Two small custom mills, Golconda and Rex, were operated in the Coeur d'Alene mining region in the 1950's, but both were shut down by the end of the decade. Ore from the Lucky Friday, which had been treated at the Golconda mill, was diverted to a new mill at the Lucky Friday mine in 1960. Before declining lead and zinc prices forced closure of many mines, a number of lessees had ore milled in plants owned and operated by the lessor companies.

The principal mine outside the Coeur d'Alene mining region active at the end of 1960 was the Clayton mine (lead-zinc) of the Clayton Silver Mines in Custer County. The company operated a mill and shipped concentrates to a custom lead smelter and an electrolytic zinc plant.

A total of 44 base-metal mines and 16 silver mines were active in 1960. Many were small mines that sent crude ore to lead and copper smelters. Because mines in central and southern Idaho had to ship ore from 300 to 600 miles to reach smelter destinations, only high-grade crude ore could be shipped at a profit. Shipments of crude and concentrate were made from this area to smelters in Idaho, Utah, Washington, and Montana.

Silver is an important byproduct from base-metal mining in the State; similarly, copper and lead are recovered from the silver ore produced.

Illinois

Lead and zinc production in Illinois comes from two districts, northern Illinois (Jo Daviess County) and southern Illinois (Hardin and Pope Counties).

In 1960, in the northern Illinois district, a part of the Upper Mississippi Valley district of Illinois, Iowa, and Wisconsin, Tri-State Zinc, Inc., mined lead-zinc ore, and The Eagle-Picher Co. mined zinc ore and treated it in the company-owned Gray and Graham mills respectively. In addition to ore from the company-owned Graham, Snyder, Spillane, and Feehan properties in this district and other mines in Wisconsin, The Eagle-Picher Co. accepted custom ore from other operations at the Graham mill. Other producers in this district included the Little Ginte Mining Co. (lead-zinc ore) and Hickory Hill Mining Co. (lead ore). Some lead-zinc custom ore has been shipped from this district to the American Zinc, Lead & Smelting Co., Vinegar Hill mill in Lafayette County, Wis.

In the Illinois-Kentucky fluorspar district, lead and zinc concentrates were recovered as byproducts or coproducts of fluorspar mining. Principal producers were Aluminum Company of America, Minerva Oil Co., and Ozark-Mahoning Co. Aluminum Company of America operated the Fairview-Blue Diggings mine and Rosiclare mill and accepted custom ore from nearby mines in Illinois and Kentucky. Minerva Oil Co. operated the Crystal and Minerva No. 1 mines and mills. Ozark-Mahoning Co. operated mines near Cave in Rock and a mill at Rosiclare. Custom ores were also purchased from other companies.

Custom smelters and plants located in Illinois and neighboring States are listed in table 5.

Kansas

The entire State production of lead and zinc originates in Cherokee County, a part of the Tri-State District in Kansas, Missouri, in Oklahoma.

The mines in the district were inactive in 1960 except for cleanup operations in several mines and retreatment of mill tailings. The large companies that have operated in Cherokee County and in adjoining Ottawa County, Okla., either directly or through lessees, include the St. Louis Smelting and Refining Division, (National Lead Co.) and The Eagle-Picher Co. The National Lead Co. sold its Ottawa County interests to Eagle-Picher Co. and dismantled its Ballard No. 8 mill in 1959. The Eagle-Picher Co. operates a lead smelter at Galena, Kans. Eagle-Picher Co. Central custom mill at Cardin, Okla., remains available for Tri-State ores. Details on customary marketing of ore and concentrate produced in the Tri-State District are given in the section on custom smelting.

Kentucky

Lead and zinc are recovered as byproducts or coproducts of fluorspar mining in the parts of the Kentucky-Illinois fluorspar district in Livingston County, Ky. The district is discussed in the Illinois section. No custom mills or smelters are located in the State; all ores are shipped to Illinois mills.

Michigan

The entire 1960 production of copper in Michigan came from underground mines and tailing-reclamation plants in the Lake Superior district. Calumet & Hecla, Inc., operated eight mines and one reclamation plant in Houghton and Keweenaw Counties and a copper smelter and refinery at Hubbell. In Houghton County, Quincy Mining Co. operated a tailing-reclamation plant and copper smelter and refinery, and Copper Range Co. operated the Champion mine and Freda concentrator. White Pine Copper Co., subsidiary of Copper Range Co., operated the White Pine copper mine, mill, smelter, and refinery in Ontonagon County and smelted concentrates from the Copper Range Co. Freda mill.

All Michigan copper mines treat ore locally either in company-owned facilities or under contract in nearby plants. No custom treatment facilities as such exist. Michigan copper is sold mainly as fire-refined copper, although some electrolytic copper is produced. The small silver content of Michigan ores remains in the fire-refined product, also known as Lake copper, used in industry without electrolytic refining.

Missouri

In 1960, production of lead and zinc, with byproduct copper, silver, cobalt, and nickel, was centered in the southeastern Missouri district (Madison, St. Francois, and Washington Counties). The St. Joseph Lead Co. operates mines and mills in Washington and St. Francois Counties, and the National Lead Co. operates the Madison mine and mill in Madison County. All mines in southeastern Missouri are captive operations, and no custom-milling facilities exist.

Drilling exploration in recent years near the junction of Iron, Washington, and Crawford Counties in the southeastern Missouri district has disclosed new, large reserves of lead ore about 40 miles west of the older lead-mining

730-683 O-64—3

area. The ore has a small content of copper and zinc. Development in this area by the St. Joseph Lead Co. reached production in 1961. A complex of three new shafts, mill facilities, and a company-built town at Viburnum represents a reported investment of nearly $20 million. Operation of the new facility has increased Missouri production appreciably.

The part of the Tri-State district in southwestern Missouri was inactive in 1960.

The St. Joseph Lead Co. operates a lead smelter and refinery at Herculaneum, Mo., primarily for treatment of company ores from southeastern Missouri. While custom ores were accepted in the past, a policy change in early 1961 abolished such ore purchases, resulting in a loss of market for most independently produced Tri-State and midwestern lead concentrates. These concentrates are now subject to high shipping costs to El Paso or other distant custom plants as listed in table 5.

Montana

Montana was the Nation's third largest copper-producing State in 1960. The Butte district of Silver Bow County produced from complex ore 99 percent of the State's output of copper, 80 percent of the silver, 47.5 percent of the gold, and 38 percent of the lead and the zinc. Production was recorded from 129 State lode mines. Significant production outside of Butte came from the Jack Waite mine (lead-zinc) in Sanders County and the Algonquin mine (zinc) in Granite County. Production from other Montana base-metal mines in 1960 ranged from less than a hundred tons to a few thousand tons of ore each. The Mayflower and West Mayflower mines in Madison County produced a sizable quantity of gold.

The mining operations of the Anaconda Co. at Butte, the milling and smelting plants at Anaconda, the electrolytic zinc plants at Anaconda and Great Falls, and associated fabricating and marketing subsidiaries in Montana and elsewhere form an industrial complex that performs every step in converting raw ore into finished metal products.

The Anaconda Co. operates a copper mill and smelter at Anaconda. The mill was scheduled for removal to Butte in 1962. Suitable copper and gold ores and concentrates are purchased for treatment at the copper smelter. In 1959, a change was made in specifications for acceptable gold-silver smelting ores relating to minimum silica content. Other changes may occur from time to time.

Also at Anaconda, the company operates a zinc mill and electrolytic zinc plant; however, the plant was shut down in 1960 because the amount of zinc ore mined at Butte was greatly reduced. Custom zinc ore occasionally has been treated at the zinc mill. An electrolytic zinc plant at Great Falls treats concentrate produced by The Anaconda Co. and processes purchases and toll material from many parts of the world.

Lead ores and concentrates from Montana mines, including the Butte mines, can be marketed at the lead smelter of the American Smelting and Refining Co. at East Helena, which treats shipments from foreign and domestic mines.

Mine shipments sometimes are made to smelting plants outside of Montana, particularly to northern Idaho; however, shipments to the more distant plants are seldom economical.

Nevada

In 1960, lode mines in 16 Nevada counties produced base and precious metals, recording a 30-percent increase in value over that of 1959. The increase was attributable largely to greater copper and silver output in White Pine County. Zinc showed an increase, but gold and lead output decreased.

The Anaconda Co. operation in Lyon County, the Kennecott Copper Corp. operation in White Pine County, and the Bristol Silver Mines Co. operation in Lincoln County supplied most of the copper. Lead was produced from ores mined primarily for the lead content, from copper, gold, and silver ores, and as a byproduct of manganese mining in Clark County. Zinc was recovered from ores mined primarily for a content of lead, silver, or gold. Production of both lead and zinc in Nevada has shown an overall decline between 1955 and 1960. The number of operating mines had decreased, and a formerly large producer of both metals in the Pioche district of Lincoln County, Combined Metals Reduction Co., has been inactive since 1957.

A substantial part of the gold and silver was a byproduct of White Pine County copper mining. Mines in Lander, Esmeralda, Nye, and Mineral Counties accounted for most of the balance of gold and silver, together with a small byproduct production from Eureka, Elko, and Lincoln County lead mines.

In the Robinson district of White Pine County, the open-pit and underground operations of the Nevada Mines Division, Kennecott Copper Corp., and the Consolidated Copper Mines Corp. furnish sulfide copper ore to the Kennecott copper concentrator and smelter at McGill, Nev. The blister copper produced is refined out of the State. The McGill smelter also accepts custom ores of copper, gold, and silver from Nevada, Utah, and California by prearrangement on an as needed basis depending on silica requirements for fluxing. Deep-drilling exploration below present mine workings in the Robinson district has disclosed substantial additional copper reserves.

Operations of The Anaconda Co. in Lyon County on oxide copper ores mined in the Yerrington pit at Weed Heights and treated in a leaching plant continued in 1960. A new flotation mill to treat the sulfide copper ores that have been found at depth is under construction.

No custom mills for the treatment of copper, lead, or zinc ores were in operation in Nevada in 1960. The closed Combined Metals Reduction Co. custom lead-zinc flotation plant at Caselton in the Pioche district is intact and presumably will be reopened under improved market conditions. The Silver Peak cyanide plant of the United States Mining & Milling Co. and the new cyanide plant of the Argentum Mining Co., both serving Esmeralda, Nye, and Mineral County silver mines, were in operation in 1960 and 1961. Operations were suspended in the second half of 1961, but the plants remain intact.

Smelting plants in California, Idaho, Montana, and Utah to which Nevada ores may be shipped are listed in table 5.

New Jersey

The only base- or precious-metal ore found in commercial quantities in New Jersey is the oxide zinc ore of the Franklin-Ogdensburg district, Sussex County. The Sterling Hill mine, closed in 1957, was subsequently reactivated by the New Jersey Zinc Co. to compensate for a temporary loss of some production at the company's Tennessee operations. Custom-milling or smelting facilities are not available in New Jersey.

New Mexico

Most of the base- and precious-metal ores mined in New Mexico come from the Central district of Grant County and from Hidalgo and Socorro Counties. Very minor production comes from nine other counties. Most of the copper and a substantial part of the gold and silver comes from the integrated open pit mining, milling, and smelting operation of the Chino Mines Division, Kennecott Copper Corp., at Santa Rita, Grant County. Except for a strike in 1959, the Chino pit has operated continuously in recent years. Three other groups of mines, closed in 1957 or 1958, were reopened in 1959 and produced copper, lead, zinc, gold, and silver in 1960. These included lessee operations at the Continental Copper mine of the United States Smelting Refining & Mining Co., the Hanover lead-zinc mine of The New Jersey Zinc Co., and the Kearney zinc mine of the Peru Mining Co. Custom concentrating mills run in connection with the three operations are the Bayard and Hanover mills in the mining area and Peru Mining Co. concentrator at Deming, N. Mex. The Groundhog Unit of the American Smelting & Refining Co. in the Central district remained closed in 1960. This operation included a custom concentrating mill at Deming, N. Mex.

In the Lordsburg district of Hidalgo County, three mining operations produce copper, silver, minor quantities of lead and zinc and nearly all the gold mined in New Mexico outside of Grant County. The ore from one of these, the Bonney-Miser's Chest group, operated by the Banner Mining Co., is concentrated in the company mill. No custom milling facilities are available.

In 1960, five mines in Socorro County produced lead, zinc, and silver with minor amounts of gold and copper. The leading producer was the Linchberg mine of The New Jersey Zinc Co., operated by a lessee. The ore is shipped to The New Jersey Zinc Co. Hanover concentrator. No custom milling facilities are available in Socorro County.

Custom mills and smelters available to New Mexico producers are listed in table 5.

New York

The entire production of zinc, lead, and silver in New York comes from captive mine operations of the St. Joseph Lead Co. in St. Lawrence County. The lead and silver content of the sulfide ores is comparatively minor.

Zinc concentrates from company plants at the Edwards zinc mine and at the Balmat lead-zinc mine are shipped to the company zinc smelting plant at Josephtown, Pa. Lead-silver concentrates from the Balmat mill and lead residues from the Josephtown zinc smelter are shipped to the company lead-silver smelter at Herculaneum, Mo. No custom facilities for zinc or lead ore or concentrates are available in New York State. The Phelps Dodge Refining Corp. operates a copper smelter and electrolytic refinery at Laurel Hill, N. Y. This is primarily a refining plant for the company's Arizona production, but a small tonnage of copper concentrates from operations in eastern States is treated on a custom basis.

North Carolina

In 1960, the entire base- and precious-metal production of North Carolina came from the Ore Knob mine of Appalachian Sulfides, Inc. Sulfide ores containing copper and byproduct gold and silver were mined and milled in company-owned facilities at the rate of 800 tons per day. Copper concentrates were shipped to the Laurel Hill, N. Y., smelter of the Phelps Dodge Refining Corp., the Carteret, N. J., smelter of American Metal Climax, Inc., and even the El Paso, Tex., plant of the American Smelting & Refining Co.

In Vance County, the Tungsten Mining Corporation recovers lead with byproduct gold and silver by flotation of accumulated tungsten tailings at the Hamme mine.

Lead and zinc mines in Halifax County were idle in 1960, although shipments of lead concentrates were recorded.

Oklahoma

The Oklahoma section of the Tri-State lead district lies within Ottawa County. Except for minor production from several Ottawa County mines and from retreatment of mill tailings at the Eagle-Picher Bird Dog mill west of Picher, Okla., the district was idle in 1959 and 1960. However, production of concentrates from these limited operations increased somewhat in 1960.

Early in 1961, The Eagle-Picher Co. reopened the Central mill, north of Commerce, Okla., and the American Zinc, Lead & Smelting Co. resumed milling operations at the Barbara J. mill near Cardin, Okla. Although current market prices for lead and zinc remained low, the operating companies deemed it advisable to encourage mining operations on a small scale in order to maintain or rehabilitate mine workings in anticipation of an improved market. Inevitable depletion of ore reserves has occurred during the long span of Tri-State operations, and maintenance of a high production level from remaining reserves, many of them marginal, is not to be expected.

A description of marketing practices that were in effect when the Tri-State District was last in full operation is included in the section on custom milling and smelting.

The occurrence of lead-zinc sulfide mineralization in the Tri-State District in flat sedimentary beds of great areal extent at depths up to a few hundred feet led to mine development through many shallow shafts. Only moderate production is obtained from any one shaft, and hundreds of shafts have been in operation during peak-production periods. A system of mining peculiar to the Tri-State District is used. A unique feature is the hoisting system, in which hoists are mounted directly over the shafts. Ore is lifted with amazing speed in buckets (cans) through untimbered vertical shafts.

The normally small production from a single shaft led eventually to the establishment of a few central milling plants serving a considerable area. Noticeable in Tri-State landscapes are the piles of chat, a coarse mill tailing discarded in the jigging operation widely used in older Tri-State mills. Chat piles and slimes from earlier operations have been and are being retreated by more efficient milling processes. Chat is also sold for road metal and other crushed-rock requirements.

Although a number of the smelting companies previously active in the Tri-State District also operated mines on company account, the largest tonnage came from operations of independent miners on fee or leased land. Ore was normally sold f.o.b. the mine or, in earlier years when nearly every mine had a mill, f.o.b. the mill. The producer was responsible only for loading ore, either in trucks or railroad cars. The purchaser arranged for delivery to custom mill or smelter.

In the 1930's concentrates were shipped to as many as 20 different smelters or zinc oxide plants. In 1959, three smelters treated nearly all the Tri-State ore produced. Smelters and pigment manufacturers customarily maintain ore buyers in the Tri-State District. The Central custom mill of The Eagle-Picher Co. at Cardin, Okla., and the Barbara J. mill of the American Zinc, Lead & Smelting Co. at Commerce, Okla., provide a combined daily capacity of 13,000 tons, ample to serve the needs of the district and provide a market for the small and the large producers.

Smelters in Illinois, Kansas, and Oklahoma listed in table 5 have been logical markets for Tri-State concentrates. Three are zinc smelters in Blackwell, Henryetta, and Bartlesville, Okla., that treat concentrates shipped from other States and foreign countries. However, the lead smelter at Herculaneum, Mo., which formerly accepted custom lead concentrates, no longer does so, and most independent operators must seek a lead market as far away as El Paso, Tex.

Oregon

Production of base and precious metals in Oregon is not currently significant. Output of gold and silver is at an alltime low. Placer mining in Josephine County accounted for 63 percent of the 835 ounces of gold produced in the State in 1960. The balance came from other small placer operations and from the Buffalo gold mine and the Standard copper mine in Grant County. Copper was produced in small quantities from the Standard mine in Grant County and the Copper Eagle in Josephine County. Only minor quantities of lead and zinc have been mined in Oregon and none in 1959 and 1960.

No custom milling facilities are available in Oregon. Copper and gold-silver concentrates are normally shipped to the American Smelting & Refining Co. smelter at Tacoma, Wash.

Pennsylvania

The State's entire output of copper, gold, and silver in 1960 was recovered as byproducts of iron ore mined at the Cornwall mine of the Bethlehem Cornwall Corp. and concentrated in the company's Lebanon plant. Copper-gold-silver concentrates were shipped to the Phelps Dodge Refining Corp. copper smelter at Laurel Hill, N.Y.

Significant quantities of zinc ore were mined and milled at the Friedensville zinc mine of The New Jersey Zinc Co. in Lehigh County. Concentrates were shipped to the company's Palmerton, Pa., smelter, which also treats concentrates and other products from company operations in several other States.

The Josephtown zinc smelter of the St. Joseph Lead Co. treats concentrates shipped from company mines in New York and Missouri. Both plants accept custom ores, if offered.

Custom milling plants have never been built in Pennsylvania.

South Dakota

In 1960, gold and silver were the only members of the base- and precious-metal group mined in South Dakota, all from the Homestake Mining Co. operation in Lawrence County. One-third of the Nation's gold output came from this one operation. Gold and silver bullion was obtained by amalgamation and cyanidation in a company-owned mill at Lead and shipped to the U.S. Mint at Denver, Colo.

Small quantities of copper, lead, and zinc have been mined in South Dakota. A cleanup shipment of copper from the dump of the Maloney Blue Lead mine in Pennington County was made in 1960.

Tennessee

Copper, zinc, gold, and silver are mined in Tennessee exclusively by large companies. In the Ducktown district of Polk County, the Tennessee Copper Co. mines and mills sulfide ore, obtaining sulfur, iron, copper, zinc, gold, and silver. Sulfur, manufactured into sulfuric acid and sulfur dioxide, is the most valuable constituent of the ore. Copper concentrates are smelted in the company's smelter at Copperhill, Tenn.; zinc concentrates are shipped to The New Jersey Zinc Co. zinc-smelting plant at Palmerton, Pa.

In 1960, three companies mined sulfide zinc ores in Hancock, Jefferson, and Knox Counties. The New Jersey Zinc Co. operated the Jefferson City mine in Jefferson County and the Flat Gap mine in Hancock County. The Flat Gap operation has opened up a new zinc deposit 45 miles northeast of the Mascot-Jefferson City district. American Zinc Co. of Tennessee operates zinc mines in Jefferson and Knox Counties, and the Tennessee Coal & Iron Division of United States Steel Corp. operates the Zinc Mine Works in Jefferson County. The American Zinc Co. ships zinc concentrates to the smelter of an associated company at East St. Louis, Ill.; The New Jersey Zinc Co. concentrates go to the company's Palmerton, Pa., smelter. Tennessee Coal & Iron Division has a market for concentrates at the St. Joseph Lead Co. zinc smelter at Josephtown, Pa., or at any of the other smelters, all of which accept custom ores.

Texas

Significant quantities of base and precious metals are not mined in Texas. However, in 1960, a few tons of lead ore from the Bonanza Mining Co., shipped from Sierra Blanca, Tex., was received at the American Smelting & Refining Co. lead smelter in El Paso, Tex., and about 20 tons of low-grade copper ore shipped by M. Hunt from Munday, Tex., and by H. McEackern from Plainview, Tex., was received at the copper smelter in El Paso, Tex. Copper, lead, and zinc plants process ore, concentrates, and blister copper from other States and foreign countries (table 5).

Utah

Utah has a substantial production of all the base and precious metals. Output of all base metals increased in 1960 over that of 1959, the largest being a 50-percent increase in copper that made Utah the second largest producer in the Nation.

The overall production increases came largely from the mines in the Bingham Canyon district, Salt Lake County, which returned to full production after labor trouble in 1959. In 1960, Salt Lake County produced over 99 percent of the State's copper, 98 percent of the gold, 79 percent of the silver, 73 percent of the lead, and 67 percent of the zinc, all from large, integrated operations. Other Utah production was centered in the Park City district in Wasatch, Summit, Utah, and Salt Lake Counties. Nine other Utah counties, headed by Juab County, produced small tonnages of base- and precious-metal ores. Uranium ores from San Juan County, treated in the Texas-Zinc Minerals Corp. plant at Mexican Hat, Utah, contributed small quantities of gold, silver, copper, lead, and zinc concentrates.

The Utah Copper Division of the Kennecott Copper Corp., the largest operator in the State in 1961, produced from porphyry copper ore most of the copper, and the byproduct gold and silver. The operation includes the Bingham open pit, the Arthur and Magma concentrators, the Garfield copper smelter, purchased in 1959 from the American Smelting & Refining Co., and an electrolytic copper refinery. The United States Smelting Refining & Mining Co. Lark and U.S. mines near the Bingham pit are the State's largest producers of complex ores containing lead and zinc with some copper, gold, and silver, followed by the New Park and United Park City group of mines in Wasatch and Summit Counties.

A flotation mill operated by the United States Smelting Refining & Mining Co. at Midvale, treats complex ore from the company's Lark and U.S. mines and also purchases custom-milling ores from the Park City mines and elsewhere. The Midvale plant was the only operating custom mill in Utah in 1961. A custom mill at Tooele was dismantled, and the Bauer custom mill of Combined Metals Reduction Co. was closed in 1958.

Straight copper ores and concentrates from small producers have had no local market since 1958, after the Kennecott Copper Corp. acquired the Garfield copper smelter, formerly operated as a custom plant by the American Smelting & Refining Co. However, the Garfield smelter occasionally purchases under contract certain special fluxing ores. High-silica ores containing copper, gold, or silver are also purchased by negotiation at the McGill, Nev. copper smelter of the Kennecott Copper Corp. on an as needed basis. Copper ores and concentrates other than Kennecott ore must be marketed at smelters outside the State. Arizona and Texas plants are possible markets (table 5).

Since the dismantling of the United States Smelting Refining & Mining Co. Midvale lead smelter in 1958, Utah has had one lead smelter at Tooele, operated by International Smelting & Refining Co. as a custom plant. Lead ores can be marketed here or at the Selby, Calif., lead smelter of the American Smelting & Refining Co. High-grade oxide zinc ores can be marketed at a slag-fuming plant operated in connection with the Tooele smelter. Zinc concentrates were shipped to The Anaconda Co. electrolytic zinc plant at Anaconda, Mont. This plant was not operating in 1961, leaving the Great Falls plant of The Anaconda Co. as the only Montana market. Other possible markets for Utah concentrates are plants in Idaho, Oklahoma, and Texas (table 5).

Exploration and development in progress in Utah in 1961 give promise of expanded copper, lead, and zinc production. Substantial increase of lead-zinc reserves in the Park City district as the result of recent work by three companies had led to planning for a new mill in the district. Exploration in the East Tintic district, a former major Utah producer, in Iron County, in Beaver County, and elsewhere, indicates the occurrence of significant new deposits of copper, lead, and zinc. It is unlikely that these developments, carried on chiefly by large mining companies, will lead to the establishment of new custom milling facilities for small operators.

Vermont

No base or precious metals were mined in Vermont in 1959 or 1960. A former producer, Appalachian Sulfides, Inc., last mined and milled copper ore containing a small amount of silver at the Elizabeth mine near South Stratford in 1958. Copper concentrates were shipped to the copper smelter of the Phelps Dodge Refining Corp. at Laurel Hill, N.Y. If mining in Vermont is resumed, the same marketing pattern presumably could be established.

Virginia

In 1960, sulfide zinc ore was mined and milled at the Tri-State Zinc, Inc., Bowers-Campbell mine near Timberville, Rockingham County, and lead-zinc ore at The New Jersey Zinc Co. Ivanhoe mine at Austinville, Wythe County. Zinc concentrates from the Bowers-Campbell mill were shipped to the zinc smelter of the St. Joseph Lead Co. at Josephtown, Pa. Zinc concentrates from the Ivanhoe mine went to The New Jersey Zinc Co. smelter at Palmerton, Pa. Lead concentrates were shipped to the American Smelting & Refining Co. lead smelter at Alton, Ill., until it was closed in July 1959. An alternate market for lead concentrates, the Herculaneum, Mo., lead smelter of the St. Joseph Lead Co., is no longer available for custom ore.

Washington

In 1960, Washington produced dry gold-silver ores and complex sulfide ores of gold, silver, copper, lead, and zinc from 17 lode mines in eight counties. However, nearly all the production was supplied by the Knob Hill mine (gold-silver, Ferry County), the Gold King mine (gold-silver, Chelan County), and the Pend Oreille and Grandview mines (lead-zinc, Pend Oreille County). Only small mines were operated for copper after the Holden mine, Chelan County, the main producer, was closed in 1957. Byproduct copper was recovered during concentration of lead-zinc ore.

No custom milling facilities are available in Washington since the closing of the Admiral flotation mill at Northport, Stevens County, in 1958. All milling in 1960 was done in private plants at the properties. Copper and gold-silver concentrates and ores were marketed at the American Smelting & Refining Co. copper smelter at Tacoma. Lead ores and concentrates were shipped to The Bunker Hill Co. lead smelter at Kellogg, Idaho, and to the American Smelting & Refining Co. smelter at East Helena, Mont. Available markets for zinc concentrates were the electrolytic zinc plants at Kellogg, Idaho, and Great Falls, Mont.

Wisconsin

In 1960, mines in the Wisconsin section of the Upper Mississippi district of Wisconsin, Illinois, and Iowa produced significant tonnages of lead-zinc sulfide ores.

The American Zinc Lead & Smelting Co. operated the Vinegar Hill mine and mill in Lafayette County. The Eagle-Picher Co. operated the Shullsburg mine and mill and Birkett-Bastian-Andrews mine in Lafayette County. Ore from the latter mine is concentrated at the company's Graham custom mill at Galena, Ill. The Eagle-Picher Co. also operated the Linden mine and mill in Iowa County. Custom ore has been accepted at the Linden mill. The Piquette Mining Co. operated a mine and mill in Grant County. Custom smelters in Illinois listed in table 5 are the principal markets for Wisconsin ore.

Wyoming

A few tons of ore containing copper, gold, and silver, and a few ounces of placer gold, mined in the Atlantic City area near Lander, constituted the entire Wyoming production of base and precious metals in 1960.

Treatment Methods For Various Classes of Ores

The following section summarizes the usual treatment methods for various types of copper, lead, zinc, and precious metal ores and some possible process improvements. Advantages and disadvantages of the treatment methods as they relate to realization from sales of various types of ores also are discussed. The terms used are defined earlier in this text (Classification of Ores and Concentrates).

Dry Ores of Gold, Gold-Silver, and Silver

Dry ores of gold and/or silver have, by definition, little or no base-metal content. They can be marketed at a smelter if the precious metal content is enough to offset the penalty normally assessed for base-metal deficiency. Such ores generally have a high content of silica, a constituent often in demand at copper smelters as a flux, and extremely low-grade, dry, fluxing ores may be marketable because of a premium paid for silica. Many gold and silver ores too low in grade for direct smelting can be milled to make a marketable product (7). If the precious metals are essentially inseparable from base-metal minerals by milling, the ores can be upgraded by base-metal gravity or flotation methods, producing a marketable concentrate for smelting. Ores containing chiefly native gold and silver are referred to as free milling ores: that is, the gold and silver can be recovered by gravity, amalgamation, and/or cyanidation, with production of a precious metal sponge or bullion that is shipped directly to the U.S. Mint.

Because precious metals may be in the free state or may be present in an ore in forms that cannot be physically separated from base metals, combinations of gravity concentration, amalgamation, flotation, and cyanidation may be necessary to recover them.

Copper Ores

Copper ores can be shipped directly to a copper smelter if the content of copper plus any gold, silver, and silica is high enough to return a profit. A minimum content of about 5 percent copper is necessary for ores that return no payment for other metals. Any mineral content or deficiency that calls for a penalty at a copper smelter raises grade requirements.

Many copper ores that do not qualify as direct-smelting ores can be processed by other methods. Flotation, the usual process for concentrating sulfide copper ores, predominates at copper operations in the Western United States.

Oxidized copper ores are not very amenable to gravity or flotation concentration, but many oxide and some mixed ores too low in grade for direct smelting are leached with sulfuric acid-ferric sulfate solutions, producing a metallic copper product either by chemical precipitation with iron or by electrolysis. Carbonate minerals such as azurite and malachite; oxides, tenorite and cuprite; the silicate, chrysocolla; the sulfate, brochantite; the basic chloride, atacamite; and other oxide minerals are readily soluble in water, sulfuric acid, or acid-ferric sulfate solutions. The sulfide minerals, chalcocite and bornite, are also soluble in acid solution, but most other copper sulfide minerals and native copper are not. Even though insoluble sulfides can be rendered soluble by roasting, and native copper is soluble in ammoniacal solutions, flotation generally is a better method of recovering these minerals. If the oxide content is enough to justify the expense of leaching the flotation tailings, a combination of flotation followed by acid leaching is feasible for mixed copper ores.

Ammoniacal leaching with ammonium carbonate salts has been used on native copper ores and on copper carbonate ores that contain too much acid-consuming calcite or dolomite for acid leaching, but the process has no current application.

A recently developed process, copper segregation, is being used on a low-grade, Arizona chrysocolla ore containing too much iron, calcite, and clay for leaching (9, 11, and 26). The process appears to be applicable to other oxide or mixed ores.

Lead Ores

Lead ores of all classes are shipped directly to a lead smelter if the lead content is sufficiently high (usually over 20 percent). A lower grade is commonly smelted directly if associated gold and silver will compensate for a lower lead content and return more profit than milling before smelting. Sulfide (galena) ores can be readily concentrated by standard gravity and/or flotation methods. The same general methods can be applied to oxidized or mixed ores, but metal recovery is lower, and the cost of milling is higher (8). Oxide or mixed ores of smelting grade sometimes may be marketed to advantage without milling even though concentration is possible, because the net return from direct shipment may exceed that from marketing concentrates when cost and metallurgical losses incurred in milling are taken into account.

Zinc Ores

Zinc ores available in the United States are virtually all too low-grade for direct treatment either in thermal or electrolytic plants. Zinc treatment schedules places a premium on high-grade ore and penalize the producer severely for failure to meet grade specifications. Only high-grade material will return a profit to the shipper under such conditions.

Ores containing chiefly the zinc sulfide sphalerite, are readily concentrated by gravity and flotation methods to make a high-grade marketable product. Ores which also have a high content of iron sulfide (pyrite) may require selective flotation techniques to separate pyrite from sphalerite and thus produce a higher-grade concentrate. Sulfide ores that contain appreciable quantities of marmatite, a zinc-iron sulfide of variable composition, may not produce a marketable, high-grade concentrate because chemically combined iron and zinc cannot be separated by ore-dressing methods.

Oxidized zinc ores that meet grade specifications can be marketed without prior treatment, but low-grade ores have no market as smelter or electrolytic plant feed. Ore containing the oxides, zincite and franklinite, and the silicate, willemite, formerly mined in Sussex County, N.J., was an exception. This ore was concentrated by a combination of magnetic and gravity processes. Straight oxide or mixed sulfide-oxide ores cannot be concentrated to yield good recoveries with the usual milling processes.

Large reserves of zinc sulfide ore amenable to current milling techniques are available on a world-wide basis, and the zinc price level that results from this plentiful supply situation has not encouraged research leading to utilization of low-grade oxide or mixed ores. However, some promising experimental work on flotation of oxidized zinc ores has been done (10), and flotation is used abroad (2, 10).

Low-grade oxide zinc ores, as well as lead-smelter slag, can be treated in fuming furnaces to produce an impure zinc oxide that can be purified and marketed as the oxide or used as a feed for zinc smelters (7, 35). However, no market exists in the United States for low-grade custom fuming ores. The value of such ores within the normal zinc price range is not enough to pay the cost of mining and shipping. Custom plants may treat their own slag and other residues or use limited amounts of low-grade ore available in captive mining operations, but purchase of such ore from others is not economical.

Complex Ores

Copper-lead, copper-lead-zinc, copper-zinc, and lead-zinc complex ores sometimes present a frustrating marketing problem to the small operator. Sale of any of these ores without beneficiation results in the maximum payment for some metals and reduced or no payment for others.

No payment is normally made at a copper smelter for lead and zinc, and, at some plants, a penalty is assessed for a zinc content above a certain maximum. At a lead smelter, partial payment is made for the contained copper at 6 to 10 cents a pound less than the quoted market price. Some lead smelters pay nothing for contained zinc while others assess a penalty for a zinc content over 5 to 10 percent. One lead smelter that operates in connection with an electrolytic zinc plant pays for part of the zinc at 30 percent of the market quotation.

Rarely, a complex ore, as mined, contains enough zinc for direct shipment to a zinc smelter, where only a partial payment may be made for copper or lead at a price well below market. Payment for the content of gold and silver in mine products shipped to zinc smelters is also much reduced. Lead and copper smelters pay for a substantial part of the gold and silver content of ores.

Summary

The price paid for metals at any plant is based largely on the recoveries of the different metals that can be made with the metallurgical processes in use. Valuable metals which a plant is not primarily designed to recover become impurities or residues that require further processing, possibly at other locations. The price paid the shipper for a byproduct metal reflects the cost of such additional treatment. Where byproduct metals such as arsenic, antimony, bismuth, selenium, and tellurium are present in ores and must be removed in refining or recovered from smelter fume at a cost approaching or exceeding their market value, no payment for them is made to the producer, and a penalty may be charged.

The answer to the marketing of complex ores is beneficiation, producing a concentrate of each metal that can be shipped to appropriate plants to obtain the highest payments and the minimum deductions. Different combinations of gravity concentration, flotation, and leaching are used to effect separation of the valuable minerals into marketable products. For ores having a significant content of free gold or silver, amalgamation and cyanidation are often applied.

A decision to concentrate a given ore in preference to direct shipment hinges on the amenability of the ore to treatment and the balance between overall returns and costs. Factors that must be considered include milling costs, freight costs, smelter costs, capital costs for mill construction, and returns from smelters or other ore purchasers for the ore or concentrates. The availability of an appropriate custom milling plant may enter into the decision with references to mill construction. If a mining operation does not have enough reserves to justify mill construction, and no custom milling facilities are available, a prevalent condition in the United States, an operator necessarily has a more limited marketing choice.

Ore Preparation and Sampling Before Shipment

It has been said that ore beneficiation begins in the mine: That is to say, mining techniques are as much a part of the concentrating process as treatment in a milling plant. Selective mining, whereby ore and waste are separated in the actual mining process, alone may provide enough upgrading to make an economic mine product out of ore that is too low in grade to stand dilution with waste. Ore often is separated into sized fractions by screening when mineral content is related to the fineness of the material. Hand sorting to separate larger fragments of ore and waste results in an upgraded product. Some mines, particularly gold mines, have elaborate ore houses equipped with grizzlies, screens, ore washers, and picking belts to remove and discard waste material.

To mine and process ore efficiently, the mine operator must have the best possible data on the mineral content of mine products. In the mine, mineral content and grade sometimes can be estimated by visual inspection. However, some ores cannot be differentiated visually from waste or occur in deposits having no visible physical boundaries. Ore margins in such deposits are defined only by assay limits, determined by finding the point where the mineral content becomes too low to justify mining. In any case, analyses of ore samples must be relied on to control mining and milling operations.

Sampling may be defined as the process of selecting a small quantity of any material representative of a larger amount of the same material. Under ideal conditions, a sample would contain all of the constituents in the same proportion as the greater mass of material. The success of a sampling procedure depends on how nearly this ideal is approached. In the sampling of ores and ore products, ideal conditions do not exist because the mineral content of ore in place or broken ore is erratically distributed. The more erratic the distribution, the larger or more numerous the samples must be to approach representative proportions.

Proper sampling is very important to the mine operator in every production step from the ore face in the mine to the delivery of the ore to the ultimate purchaser. Rock in place in mining faces, broken material in stopes, in transit underground, and as delivered on surface must be sampled to differentiate between ore and waste and to route the material to the proper destination--the ore bin or waste dump.

Ore or ore products, as introduced into a milling plant, as formed at different stages in the milling process, and as finally discharged as concentrates or tailings, must all be sampled in order to control treatment processes efficiently.

Proper sampling techniques, then, are very important in all phases of mining and milling. When samples are not truly representative, disappointment and misunderstanding can result not only within a mining organization but also between producer and ultimate purchaser. Mistrust of public assayers and custom plants is a common outgrowth of improper sampling methods.

Sampling the rock in place and the broken material before delivery to the bins of a treatment plant is, with few exceptions, done by hand. A rather high probability of error exists unless samplers are carefully trained. There is a human tendency to take biased samples because mineral content of a mine product commonly is distributed unevenly between soft and hard portions of rock in place or coarse and fine fractions of broken ore. In most cases, the more easily sampled portions of an ore contain a high proportion of the valuable minerals. It is therefore almost axiomatic that, if a hand sample is in error, it will be richer than the ore represented.

Most custom mill and smelter operators prefer that a prospective shipper sample his material before shipment, have the sample analyzed by a commercial laboratory, and report the results of this test. If a shipper is new to the prospective buyer, or if the material is from a deposit unknown to the custom mill or smelter operator, the buyer will usually request a sample and make an analysis free of charge. Buyers sometimes accept a truckload or other small lot of ore as a trial shipment. When facilities are not available at or near a mine, analytical work is usually held to a minimum consistent with the need of information for guidance.

Selected references in which are discussed standard and accepted methods of ore sampling are listed in the bibliography (16, 24, 30).

CUSTOM MILLING AND SMELTING

History of Base- and Precious-Metal Recovery Plants

The history of the domestic base-metal mining industry, covering over 100 years, is a part of the story of industrial expansion in the United States (3, 5, 7, 15, 35). In the eastern half of the country, discoveries of copper, lead, and zinc and an expanding demand for metals and metal products led to establishing smelters to turn raw ores into materials needed in a growing industrial economy. Because gold and silver were not found in the Eastern States in sufficient quantity to be an important economic factor, early mining was concerned chiefly with the base metals.

In contrast, the early development of the mineral industry in the West was based almost entirely on gold and silver. Before the mid-sixties, there was little interest in base-metal deposits because there was no way to market the ores; only the precious metals, which could be recovered on the spot in a salable form, gave promise of a quick return to the miners. Nevertheless, following the discovery of gold in California in 1849, the search for gold and silver led to the discovery of base-metal deposits at many points in the territories that eventually became the 11 Western States and South Dakota. Early Indian and Spanish workings in the southwest were rediscovered along with new deposits.

At first gold was won from deposits of gravel along streams (placers) and from the shallow oxidized portions of veins from which the placers were derived by simple but inefficient gravity and amalgamation methods. Some of the gold, much of the silver, and all of the base metals contained in the ores were lost. As the easily worked placers and shallow vein deposits neared exhaustion, mining was extended into deeper unoxidized portions of the veins which contained complex sulfide ores of copper, lead, and zinc, as well as gold and silver. Because the gold and silver in these refractory ores could not be recovered efficiently by milling alone, smelting was introduced in the West to treat these ores and recover gold, silver, lead, and copper. In the early days, zinc in complex ores was not recovered, and an ore with a high zinc content could not be marketed.

Copper smelting was introduced in Michigan as early as 1850, and by the 1880's, many lead and copper smelters had been established throughout the West. The rate of growth of the smelting industry in the West depended on availability of transportation as well as ore supplies, and growth was slow before the advent of railroads. One exception was a lead smelter in Nevada built in 1866. However, this plant was constructed to recover the silver in the available ores--the lead was discarded.

Zinc smelting was never established permanently in the Rocky Mountains or Far West because suitable ores that could be smelted without concentration were not available. Later, when efficient concentrating processes had been developed, the availability of good rail transportation to established zinc smelters in Texas, Oklahoma, and the Midwest discouraged construction of local plants. Small plants designed to treat the low-grade zinc oxide and sulfide ores of the Leadville, Colo., mines survived to the late 1920's but never were a significant factor in U.S. production.

The early Western smelters were all custom plants, supplied by many independent mine operations. A successful smelting enterprise requires a complex installation of costly facilities and equipment and an assured ore supply for a period long enough to liquidate the capital cost of construction. No one mine or small group of mines in the early days could furnish an adequate ore supply, and a single smelter served many mines. In a few large districts, such as Leadville, Colo., several smelters were built. Inevitably a competitive situation developed where several smelters bid for a limited mine output, particularily as ore production declined. Unlike Leadville, many mining camps were too small to support a local smelter, and most smelters were built at locations serving several districts, usually at centrally located valley points where fuel, other supplies, and transportation facilities were available. In only a few cases did a plant built for a single district survive declining local ore supplies by importing ore.

Operators of the early smelters in the West usually did not engage in mining by choice, but many of them entered the mining business after the supply of ore from independent operations dwindled. Today, one company may carry on all phases of mining, milling, smelting, and refining as well as fabricating and marketing of finished mineral and metal products. The newer smelters have been erected specifically as units of integrated mining operations. As a result, many smelter operators no longer treat custom ores, although some companies with a background of custom operation continue to process ore supplied by independent operators along with ore from their own mines.

Many of the early smelters did not survive because they were not based on sound economics or reliable ore supplies. A noteworthy exception is the Selby, Calif. lead smelter of the American Smelting and Refining Co. at Tidewater or San Francisco Bay, which has operated continuously since 1866 on foreign and domestic ores. Five lead smelters remain active in the West, of which two are supplied largely from foreign sources. The copper industry continues to support 14 Western smelters, 8 of them in Arizona (Table 5).

Zinc leaching as a substitute for zinc smelting (retorting) was introduced in 1914. It was particularily applicable to Idaho and Montana ores, because these complex lead-zinc sulfide ores containing gold and silver could be treated successfully, and the necessary cheap electric power was available. Recovery of the zinc from these ores by smelting was not economically feasible at the time leaching was introduced because a suitable high grade zinc concentrate for furnace feed could not be produced by available gravity milling processes. Moreover, the necessary fuels for smelting were not available locally, and shipment of ores to distant established plants was too costly. Even though development of selective flotation later made possible production of high grade zinc concentrates suitable for retorting, leaching remains the

730-683 O-64—4

preferred process in Idaho and Montana where two zinc leaching plants are in operation, one in each state.

Early Western mine operators were compelled to turn to lower-grade ores as the richer ores approached exhaustion. In order to use them, upgrading processes were necessary because the unit cost of smelting ore was too high to allow a profit on low-grade material. Gravity concentration methods developed from the simple equipment used in placering or patterned after techniques used in the eastern and midwestern mineral industry were used at first. Gradual improvement of these processes was achieved in the 50-year period ending in 1910, but little change in milling occurred until the introduction of the flotation process in 1911. This was followed a few years later by the introduction of selective, or differential, flotation whereby two or more ore constituents could be efficiently concentrated into separate products. Flotation techniques are the basis of nearly all present day milling processes although they may be used in conjunction with gravity, leaching or other techniques. Some form of flotation is suitable for simple sulfide ores of copper, lead, and zinc with or without accompanying gold and silver, and for complex ores of these metals as well.

Flotation is the basic process responsible for expansion and dominance of the low-grade copper-mining industry in world copper production. Selective flotation has made possible the production of lead and zinc from complex lead-zinc sulfide ores that formerly yielded little or no profit. Oxidized and mixed base-metal ores still cannot be treated efficiently by flotation, but progress in research indicates that these problems can eventually be solved (2, 8, 10, 17).

Other milling processes have been or are being developed for the treatment of ores. Among them are the cyanidation process for gold and silver ores, leaching for oxidized copper ores, both established methods, and the recent copper segregation process (9, 11, 26), still under development, for treatment of certain copper ores, Of other techniques developed for ore beneficiation, two have important applications in the base-metal industry: The sink-float process has found application in the Tri-State district, the Coeur d' Alene district of Idaho, and at the Old Dick copper-zinc mine of the Cyprus Mines Corp. in Yavapai County, Arizona; magnetic concentration of zinc ores has been used by the New Jersey Zinc Co. in Colorado and New Jersey. Other processes that have had little or no applications in base-metal milling may be important in the future.

Sampling and Settlement of Ore Shipments

A purchaser of ore first determines the mineral content as a basis for calculating value and amenability to treatment. General characteristics of an ore is usually obtained in advance of shipment to the purchasing plant, but each shipment must be sampled individually on arrival. A sample is required that contains as nearly as possible all the ore constituents in the proportion they are present in the whole shipment. For completely homogeneous material, any method of sampling is theoretically satisfactory, because any part of such material is representative of the whole. Examples of commodities proximating this ideal are such agricultural products as wheat, corn, or rice. The further a material departs from homogeneity, the more care must be used in sampling; this is generally the case with ores and ore products, which are inherently nonhomogeneous. Ore concentrates generally are finely divided materials that approach the ideal more nearly than other mine products but are still not homogeneous.

In an ore-sampling procedure, the objective is to obtain a small representative sample as nearly homogeneous as careful preparation will provide so that analyses of several portions of the final sample will give comparable results. This objective is more nearly attainable by mechanical sampling than by any other method.

Several designs of mechanical ore samplers are in general use. The different systems have the one objective to produce an uncontaminated, representative ore sample at a reasonable cost, and this is achieved in a properly designed and operated plant. A mechanical sampling plant is usually part of a primary crushing plant where ore shipments are processed enroute to bins or stockpiles. A flowsheet for a sampling plant is shown in figure 4. An automatic sample cutter diverts about one-fifth of the ore stream into the sampling plant where, in a series of operations, the sample is processed to a progressively smaller weight, ending with a bulk sample of several hundred pounds. Up to this point, the procedure is carried on in automatic equipment.

The bulk sample from the sampling plant is again crushed in laboratory grinders, thoroughly mixed, and passed over riffling devices that divide a sample into two equal parts at each pass. This series of steps can be done by hand or in semiautomatic equipment to produce a finely ground sample of a few pounds weight called a pulp.

An older method of processing the bulk sample is coning and quartering, in which the sample is mixed thoroughly by hand-shoveling and formed into a coned pile that is flattened out and divided into four quarters. Two opposite quarters are removed, and the procedure is repeated on the remaining portions until the desired sample weight is reached. Coning and quartering is inferior to riffling because some segregation and uneven division of the sample are likely.

The rejected part of the bulk sample is retained in storage for reference in the event of disagreement between shipper and buyer. The pulp, after careful screening and mixing, is divided into four or more portions of equal size,

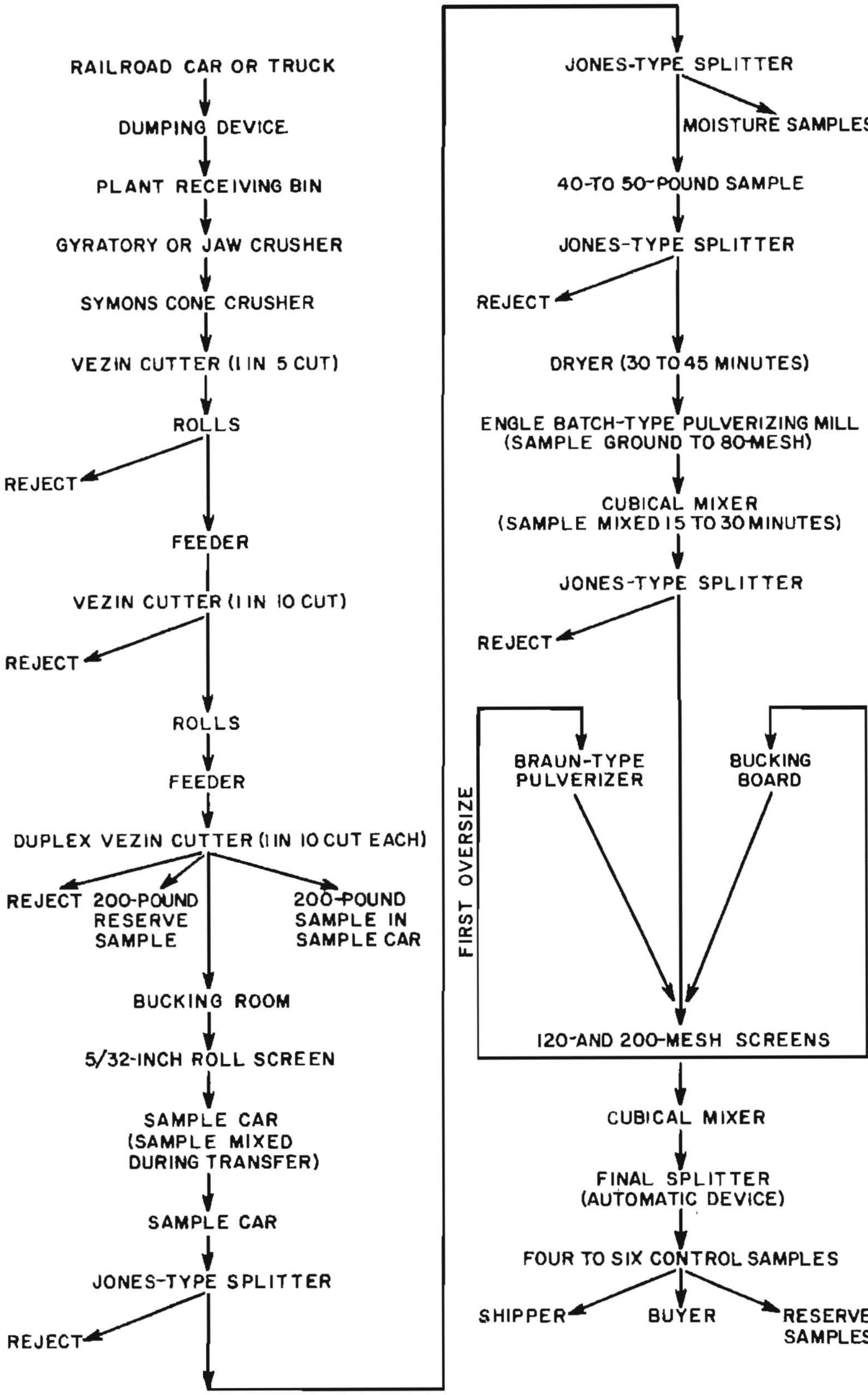


FIGURE 4. - Flowsheet for a Sampling Plant.

preferably in an enclosed automatic device to reduce the chances of sample contamination. Two of these final samples, called controls, are analyzed separately by or for the buyer and the shipper for each important metal or mineral constituent. Analyses are run in duplicate or even quadruplicate. If the results of the control assays are close enough for agreement as defined in smelter schedules, settlement of the ore is made on the basis of the average of the control results. If not, a reserve sample is analyzed by an independent laboratory as an umpire. Usually the middle assay of two controls and the umpire becomes the settlement value. This procedure varies at some plants, where the average of the three assays is the settlement value. If there are wide discrepancies between control and umpire assays for any constituent, analyses for this constituent are repeated; if the discrepancies persist, new controls are prepared from the bulk sample held in storage, and the entire procedure of analyzing and comparing assays is repeated. If the shipper does not submit control analyses, the buyers' controls govern settlement.

The greatest differences in control analyses, that is the splitting limits, which ore buyers will permit in making settlements based on average control values are not the same at all plants. Typical splitting limits range between 0.25 and 0.4 percent for base metals, 0.3 and 0.5 ounces per ton for silver, and 0.02 and 0.03 ounces per ton for gold.

The rate of payment for valuable minerals in an ore product, the freight and treatment rates, and the royalty rates a lessee-shipper may have to pay a mine owner are usually dependent on the grade of the ore. The assay values at which these factors operate to increase treatment, royalty, or other charges are known as breaking points. It may be of advantage to the shipper not to exceed a certain ore value in making a settlement on an ore with a value near a breaking point because an increase in charges may exceed any increase in value. This condition sometimes leads to jockeying, a practice whereby a shipper, after evaluating all factors, endeavors to effect an ore settlement at an advantageous level not necessarily in agreement with control assays.

Formerly, commercial sampling plants were available at various points throughout the West to sample ore in transit as an independent service to shippers. Thus, a shipment might have been sampled twice, once in transit and again on arrival at destination. Analysis of two independent samples of the same ore normally should show little variation--not over 2 or 3 percent deviation in the total content of each metal, expressed either in percent or ounces per ton.

Mechanical sampling is particularly necessary for mine-run ores and precious-metal ores because hand methods do not produce representative samples from such material. Mine-run ores generally contain material with a wide range in particle size, and valuable minerals in these ores tend to segregate in either fine or coarse fractions. Precious-metal ores contain sparse, erratically distributed gold and silver, which have substantial value even though present in overall insignificant quantity compared to the total weight of the ore. A comparatively small error in precious-metal assay is costly either to the shipper or buyer.

Concentrates are finely divided and sticky when wet. If sampled in this condition, they pack and hang up in sampling mechanisms and cannot be sampled fairly in automatic equipment. Samples of concentrates or other finely divided material often are taken by thrusting pipes or augers into ore piles at a number of points to obtain a reasonably representative sample. This is feasible because finely divided materials tend to be somewhat homogeneous. The resulting sample is reduced in bulk and prepared by standard laboratory methods.

For extremely wet, clayey, or frozen ore that also tends to hang up in the sampling mechanisms, older sampling methods, now largely discarded, can be used if pipe or auger sampling is impractical. Grab samples taken from a shipment before unloading, or fractional shoveling samples taken by hand during unloading, occasionally are used; however, because these methods are subject to the sampler's error and bias, they should be avoided if there is a reasonable possibility of preparing a shipment for mechanical sampling. Simple drying may suffice, and an effort should be made to protect all mine products from exposure to unnecessary moisture, both in the mine and in transit. In severe winter weather, frozen material may be loaded at the mine or shipments may freeze in transit. Receiving plants usually have facilities for thawing frozen ore, but extra cost to the shipper and delay in sampling may result from extremely wet ores.

Selected references on standard, accepted methods of ore sampling are found in texts in the bibliography (24, 29).

Precautions in Sampling

Cleanliness

A number of precautions should be observed in the sampling procedure. All parts of the sampling mechanism that come into contact with the ore stream must be carefully cleaned between sample runs to prevent contamination from remnants of a previous shipment. As a sample is reduced in size, the possibility of accidental or deliberate contamination (salting) increases, so the final stages of sample preparation are carried on in restricted quarters and with equipment in which a high degree of cleanliness can be maintained. Obviously, all equipment in a sampling plant should be designed for ease of cleaning and replacement of worn parts.

Because excessive dust loss can affect the proportions of valuable minerals and waste in a sample, dust should be minimized, particularly in precious-metal ores. A small amount of water sprayed on the ore stream during unloading and processing is helpful in reducing dust loss from unusually dry ores without appreciably increasing moisture content of a sample.

Metallics

A pulp is passed through a 100- to 200-mesh screen just before the final sample division to insure a uniform, finely ground product. Any coarse particles not readily pulverized are screened out in the process. Such material, usually consisting of flattened malleable flakes called metallics, may be only bits of iron worn from machinery, or fragments of copper blasting caps or wire in the ore, but it may also contain native gold, silver, or copper. Irrespective, coarse metallics are screened out of the final pulp because they probably would have an unrepresentative distribution in the final samples. Removing metallics from the pulp is sufficient if the ores do not contain native metals. If native gold or silver is likely to be present, an assay of the metallics is made and the result applied as a proportional correction to the control analyses.

Western ores rarely contain significant amounts of native silver or copper, but native gold is more common. Michigan ores may contain native copper in quantity. The importance of removing metallics from gold ores can be emphasized by considering the effect of allowing metallics to remain in the final pulp. A gold content of as little as 0.1 ounce per ton (3.4 parts per million), or even less, is of consequence. If a portion of this gold should be present in the final pulp as a few, comparatively large, malleable flakes, disportionate amounts of metallics may appear in the approximately 15- or 30-gram portions of pulp used for each assay. Control assay returns on such samples would not represent the gold content of the ore fairly and would probably not be in close enough agreement for settlement.

Moisture Content of Ore Products

Payments for ore products are based on dry weight of a shipment as received; therefore, determination of moisture content is made as soon as possible after a shipment is weighed in. As many as four moisture samples, each weighing several pounds, are cut from the bulk sample, carefully weighed, dried at low heat, and again weighed. The difference in weights before and after drying, averaged for the several samples, is taken as the moisture content of the ore. Care is taken not to subject moisture samples to enough heat to drive off any other volatile elements in the ore, including water of crystallization.

A moisture determination is made promptly because ore products tend to dry out, and a sample analyzed some time after an ore shipment is weighed in would not represent the true moisture content of the ore as received. Because prompt analysis is necessary, the moisture content of ores is based solely on the buyer's determinations. Several moisture samples from the same ore may show a considerable range in moisture content, and an average value for two or four samples may differ considerably from high and low values. On high-grade ores, where a small difference in the weight of shipment can make a considerable difference in the total value, as many as 10 or more moisture samples may be taken. Because crushing and handling in the sampling process itself cause some drying of the sample, some plants arbitrarily add a small percentage to the moisture content as determined by the laboratory in order to compensate for this drying effect. A minimum moisture deduction of 1 percent is made at some treatment plants.

The Milling Process

Background

The cost of shipping and smelting ores is related primarily to the amount of material that must be handled, although grade of material is also a factor. The freight and treatment rates applying to higher grade material are usually higher. On the other hand, rate of payment by the smelter for metal content may be slightly higher for higher grade material. A shipper normally can expect more gain by shipping a small lot of high-grade concentrates than he would have by shipping the larger tonnage of ore from which the concentrates were produced, even though the higher freight and treatment rates assessed against the concentrates, the cost of milling, and metal losses in milling partially offset the advantage of reduction in tonnage. Upgrading of ore that will return little or no profit as mined is commonly practiced to remove as much barren or gangue mineral as possible and thus produce a concentrate that can be shipped profitably.

Milling is a term that covers upgrading or otherwise processing raw ores to produce a more valuable product. In the nonmetallic mineral field, milling may constitute the only processing necessary to prepare a marketable industrial product, but in the metal-mining industry, milling generally is just one of a series of necessary steps in conversion of metallic minerals to salable products. Milling is particularly important in base- and precious-metal mining because few available ores would be profitable without this upgrading step.

Milling can be divided into two categories, ore dressing (concentration or beneficiation) and hydrometallurgy (leaching). Ore dressing consists of upgrading an ore by making a physical separation of valuable and barren minerals. In hydrometallurgical processing, ores or ore products are leached with chemical solvents, extracting valuable constituents for subsequent precipitation in metallic form. The many ore-dressing techniques that have been developed have one thing in common--they make only a physical separation of ore minerals without any chemical changes. Ore constituents that are in chemical combination with one another in a single mineral are not separable by ore-dressing techniques. The zinc-iron sulfide mineral, marmatite, is an example of such a mineral. Ore dressing will not effect a separation of chemically combined zinc, iron, and sulfur in marmatite.

Ore dressing can be further defined as manipulation of a mixture of ground ore in water. Such a mixture is called a mill pulp or simply a pulp, not to be confused with sample pulp. The proportions of solids and water in pulps have a wide range depending on process requirements. The raw ore entering a milling plant is called the mill heads or heads. The products of milling are concentrates, which should contain most of the valuable minerals and a minimum of gangue minerals, and tailings, which should contain most of the gangue minerals and as little as possible of the valuable minerals.

Texts on milling are listed in the bibliography (4, 27, 29, 30).

Ore Sorting

Upgrading ore probably dates from the bronze age. Even then the advantage of discarding worthless material before further processing must have been obvious. Primitive upgrading attempts probably involved no more than picking out pieces of ore from a pile of rock, with separation aided by splitting rocks containing both ore and waste into fragments with skillful hammer blows--cobbing in mining terminology.

Ore sorting has remained a simple first step in upgrading. The efficiency of ore sorting sometimes can be improved by the use of crushing and screening equipment, conveyor belts, and other mechanical aids, but considerable labor is still necessary. Even simple mechanisms may be unjustified in some small operations, and upgrading by hand-sorting and cobbing, using nothing more than a sorting plat and a cobbing hammer, is still practiced occasionally.

Ore Washing or Primitive Gravity Concentration

Another advance in mineral concentration, was the invention of washing processes to recover gold, gem stones, and minerals of tin or other relatively heavy metals from gravel deposits (placers). By agitating placer gravels in water, the heavy, normally valuable minerals could be separated from light minerals that usually had no value. An early discovery was the fact that mercury combines on contact with native gold and silver to form an alloy or amalgam. Thus, recovery of precious metals in ore washing is often improved by the addition of mercury as a collector. The mercury can be removed from the amalgam later by distillation, leaving the gold and silver as a fairly pure product.

It was only a step from placering natural gravels to milling crushed ores won from solid deposits, using devices that were the prototypes of modern jigs, concentrating tables, and other gravity devices. De Re Metallica (1), the 16th century treatise on mining and smelting by the German teacher and scientist, Agricola, describes sorting procedures and ore-dressing equipment that are recognizable prototypes of present day practices and machines. A modern cobbing hammer or gold pan is little different in basic design from tools used centuries ago. Early sluice boxes for recovering placer gold, stamp mills, and related equipment for crushing and treating gold ores, and washing equipment used at the time of the discovery of America for concentrating lead ores functioned in much the same manner as similar items in current or recent use. So far as gravity milling is concerned, the advances in equipment have been largely in design, capacity, and efficiency rather than in principle of operation.

Regardless of the milling process used, all ores are prepared by crushing and grinding. An ore pulp must be ground to a degree of fineness at which ore-mineral particles have been unlocked, that is, liberated from adhering gangue minerals. This point differs widely, depending on the intimacy of the association of the contained minerals with one another. Complete unlocking of ore minerals from barren minerals is never possible, but the success of a process depends in large measure on the degree to which the grinding step makes a separation. However, overgrinding is undesirable for several reasons. One reason is that undesirable colloidal material, slimes, that interferes with all milling processes is produced. Another reason is that the cost of grinding, a major expense of milling, rises rapidly with increase in fineness of grind, particularly for hard ores.

The same general types of crushing, grinding, classifying, pumping, and auxiliary equipment are common to all ore-milling plants. The specialized aspects of mill design begin with the concentration process itself. A wide selection of equipment and plans is provided in flowsheets that have been developed for gravity, flotation, and leaching processes to be applied singly or in combinations on many types of ore.

Gravity Milling

The oldest of the milling methods, gravity concentration, continues to be used in the metal-mining industry because it offers advantages in simplicity and economy, even though mineral recovery may be lower than with other processes. Common items of equipment in gravity mills are concentrating tables, used for sands, and jigs, used for coarser material.

Gravity concentration depends on the fact that metallic minerals are usually heavier than barren gangue minerals, and a separation can be effected by agitating ore-water mixtures (pulps). Gravity and inertia acting on mineral particles subjected to some type of pulsating motion in a water medium cause the heavier particles to separate from the lighter ones. Gravity milling is effective on comparatively coarse mill pulps, that is, sands and larger sizes, provided the minerals have been unlocked by sufficient grinding; gravity milling is not efficient on finely ground ore. If fine grinding of ore is unavoidable or is necessary to unlock minerals, other milling processes are more suitable.

Gravity separation works for both sulfide and oxide minerals, provided the differences in specific gravity of ore and waste minerals are significant. Specific gravity differences in minerals of copper, iron, and zinc in a complex ore are not sufficient to permit complete gravity separation of such minerals. Even lead minerals, which differ considerably in specific gravity from the others, cannot be separated completely from them by gravity because ore minerals generally are not unlocked completely in the relatively coarse particle sizes on which gravity methods work effectively. Moreover, when minerals are not unlocked, gravity methods alone do not produce high-grade concentrates or high mineral recovery.

The Wilfley sand table, introduced in 1895, was an improved gravity concentrating device that not only made a fair separation of galena and sphalerite but also permitted partial elimination of iron pyrite from a zinc concentrate. Jigs and tables have remained in ore dressing flowsheets as standard items of equipment, although, in current milling practice, they serve best in an auxiliary capacity. Used with flotation, they provide an economical means of producing a low-grade concentrate for later regrinding and flotation without the necessity of fine-grinding an entire mill feed.

Other Gravity Processes

Two other processes that take advantage of gravity differences in minerals to effect a separation have been developed. One of these, the heavy media or sink-float process, has found some application in lead-zinc ore milling in the Coeur d' Alene district of Idaho and the tristate district of Kansas, Missouri, and Oklahoma. The process recently was installed in the Old Dick copper-zinc flotation mill of Cyprus Mines Corp. in Yavapai County, Ariz., to remove barren and low-grade material from the mill feed after coarse crushing but before grinding.

The process makes use of a fluid medium of controlled density in which substances of lower density than the medium will float, and heavier substances will sink. In ore milling, a medium of high specific gravity is required. Normally, heavier ore minerals are to be separated from lighter gangue minerals, and a medium having a density between the two is provided. In testing and experimental work, liquid organic chemicals such as tetrabromoethane or other heavy hydrocarbon derivatives are suitable, but in commercial applications, satisfactory separating mediums are simulated fluids formulated to the desired density by suspending quicksand or finely ground magnetite, ferrosilicon, or similar heavy material in the proper amount of water.

Heavy-media separation is efficient only on comparatively coarse particles and cannot be used alone in base-metal milling because base-metal minerals generally are not completely unlocked in the coarse sizes. Thus, heavy-media separation on base-metal ores is limited to preliminary treatment of ores in which coarse crushing produces large pieces of extremely low-grade material or waste that can be eliminated before the grinding stage with a saving in grinding costs.

Spiral concentrators separate minerals of different specific gravity by centrifugal forces acting on an ore pulp traveling downward in a spiral launder. The process has had little application in base-metal milling.

Flotation

The flotation process, first used commercially in the United States about 1911, perhaps has revolutionized the science of ore dressing more than any other single development. The process has found application throughout the mineral industry for the beneficiation of many types of simple and complex ores. Mill flowsheets can be tailored to use flotation in any size plant, on a wide variety of ore types, and in conjunction with other treatment processes. A flowsheet for a widely used selective flotation application, milling of complex lead-zinc sulfide ore, is shown in figure 5.

Flotation is defined in A. F. Taggart's text on ore dressing (29) as a "process for rendering a mixture of finely ground minerals susceptible to gravitational separation." From this standpoint, it is a specialized type of gravity concentration, but any relationship between flotation and other gravity processes is not readily apparent because, at first glance, flotation seems to defy gravity. The many aspects of flotation as currently developed

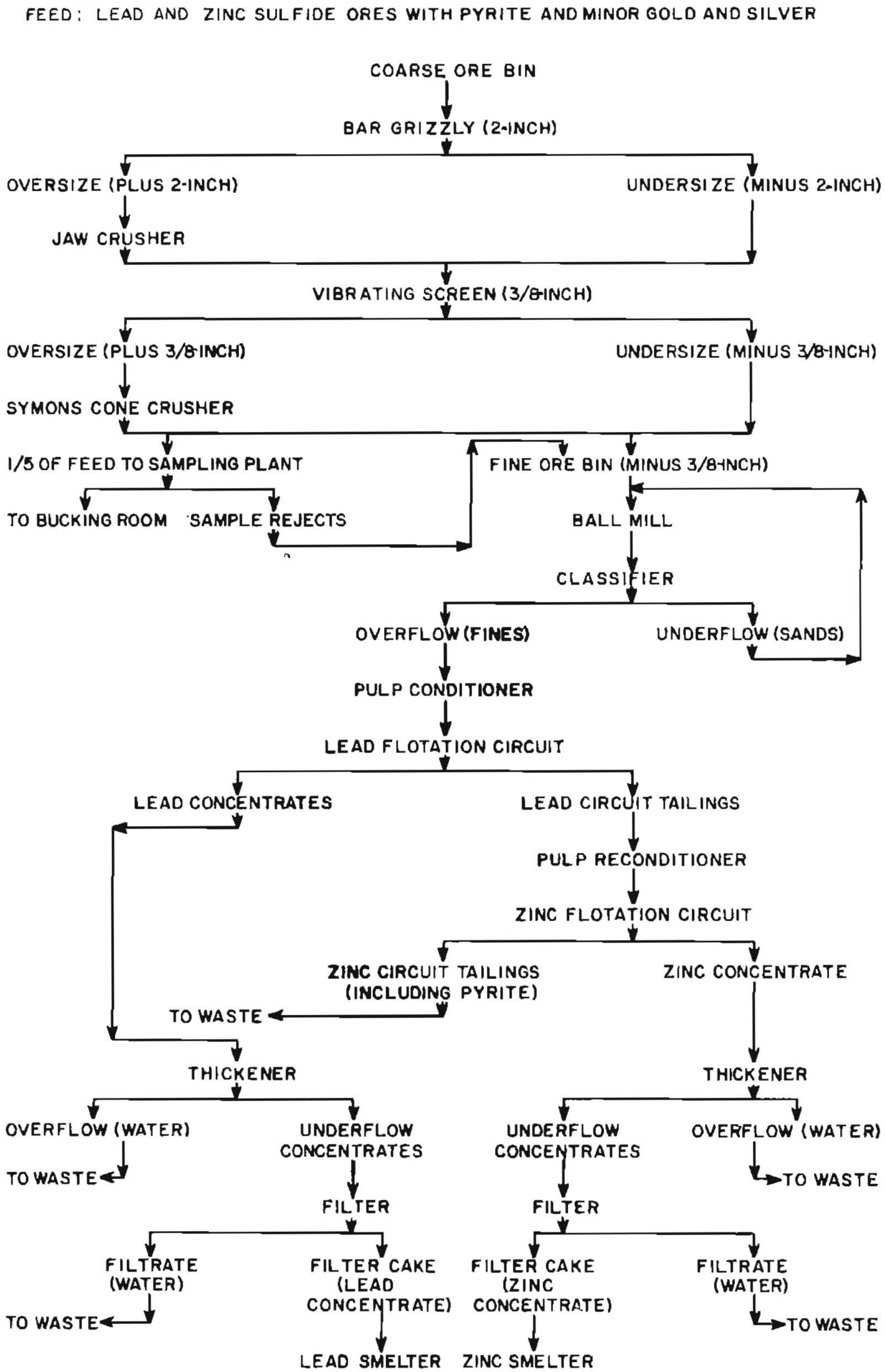


FIGURE 5. - Typical Flowsheet for a Selective Flotation Mill.

involve application of physical-chemical principles that can only be touched on in a brief discussion. Moreover, the basic theories are still somewhat controversial after more than fifty years of research and operational use.

The flotation principle is based on the relative affinity of different substances for air or water. Particle surfaces of certain substances are wetable; that is, do not repel water. This is true of many minerals including most metal sulfides. Other substances, including such minerals as sulfur, graphite, and molybdenite, are not naturally wetable and their surfaces tend to repel water.

In applications of the principle to ore dressing, a gas (air) is introduced into a tank (flotation cell) in which a finely ground ore-water mixture (pulp) is agitated. Nonwetable mineral particles, having a greater affinity for bubbles of air than for water, attach themselves to air bubbles formed in the pulp by pneumatic or mechanical agitation while wetable minerals do not. In order to form stable air bubbles, a frothing agent, such as steam-distilled pine oil, is added to strengthen bubble walls. Bubbles with attached particles rise to the pulp surface and collect as froth, which is skimmed off as a concentrate of the floatable (nonwetable) minerals. Wetable minerals collect in the bottom of the cell where they are drawn off.

Flotation would have limited application in ore dressing if only the naturally nonwetable minerals could be floated, but many other minerals can be floated under proper conditions. The affinity of different substances for water or air is related to particle surface characteristics. By adding appropriate conditioning reagents (collectors, depressants, activators, and others) to mill pulp, particle surfaces of many minerals can be modified, regardless of natural characteristics, to make them react like wetable or nonwetable minerals, either enhancing or suppressing natural surface characteristics as desired. The interior of mineral particles is not affected and does not enter into the flotation effect. By the proper choice of reagents, pulps can be conditioned so that certain minerals will be floated and others will not. Different minerals can be floated successively in several stages to produce separate concentrates of each mineral. This is the basis of selective, or differential, flotation, which has increased the usefulness of the flotation process so greatly. Complex sulfide ores of copper, lead, and zinc can be milled by selective flotation not only to produce separate concentrates of each valuable mineral but to remove iron pyrite, a common undesirable constituent in certain smelter feeds, as a separate concentrate, if desired.

Mineral separation and concentration by flotation is not perfect. Whereas excellent recovery and satisfactory separation are possible on amenable ores, some valuable minerals are lost because they enter tailings or the wrong concentrate. Flotation has a limitation common to other concentration processes: Before ore minerals can be separated, they must be unlocked from gangue minerals. However, in this respect, flotation has an advantage over other processes in that it is effective on finely ground pulps in the range of from 10 to 100 micron particle size. The treatment of colloidal particles of less than 10 microns (slimes) is a problem that may be solved eventually through research.

Oxide and silicate minerals of copper and zinc have not been concentrated satisfactorily by flotation. Lead sulfate and carbonate minerals have been treated with limited success, but more complicated mill circuits than needed for sulfide lead ores are necessary, recovery and concentrate grade are lower, and treatment costs are higher. Sulfide minerals often acquire an oxide coating through alteration by weathering, which, if not removed, causes mineral particles to act like oxides with respect to floatability. This coating is removed, at least partially, in the grinding step, but the oxides component of such an ore is recoverable only at extra cost or not at all. For this reason, the oxide lead and zinc content of mixed complex ores is not paid for at a custom mill (appendixes C and D).

The abundance of lead-zinc sulfide ores that comprise most of the world's current reserves and the comparative scarcity of oxidized zinc or lead ores have not made development of flotation for oxide ores vital, nor has the level of zinc and lead prices in recent years given much incentive for research. Eventually, milling research on oxidized ores of copper, lead, and zinc may lead to development of economical processes (2, 8, 10, 25).

Hydrometallurgical Processes

Cyanidation

Until about 1890, no practical alternative for gold and silver recovery by gravity and amalgamation methods had been perfected. In the late eighties and early nineties, the short-lived chlorination process for the extraction of gold and the successful cyanidation process for gold and silver were introduced. Cyanidation gives metal recoveries up to 95 percent, superior to that obtained by any other process in 1890. It remains a standard method for many gold and silver ores.

Cyanidation is a leaching process based on the solubility of gold and silver in a solution of potassium or sodium cyanide. Gold and silver leached from ores is precipitated from this solution by adding zinc or activated carbon. Thus, a cyanidation mill requires some of the specialized equipment of chemical processing plants as well as standard ore-milling equipment.

The process is applicable primarily to straight gold and silver ores. Some ores containing lead, zinc, or copper minerals are amenable, provided the content of these metals is insignificant or can be removed before cyanidation. If the gold and silver content is locked up in the crystal structure of minerals such as gold and silver tellurides and auriferous pyrites, ores must be conditioned to make them amenable to cyanidation. The standard method is roasting, although some pyritic ores have been leached after extremely fine grinding. Flotation can be used as a preliminary step to make a concentrate from gold telluride or pyrite ores; then only concentrate need be roasted rather than the entire mill feed. The low-grade flotation tailings are leached without further preparation. Amalgamation and tabling are sometimes used before cyanidation to recover any free gold promptly, particularly coarse gold, which dissolves slowly in a cyanide solution.

Copper Leaching

Another hydrometallurgical advance of the late 1800's was the introduction of practical leaching processes for extracting copper from some low-grade ores not amenable to concentration or direct smelting (3, 21, 34). Of possible solvents, only sulfuric acid and, to a limited extent, ammoniacal solutions have been practical. Copper oxide minerals, carbonates, chlorides, sulfates, silicates, and certain sulfides (bornite and covellite) are soluble in one or another of commonly used acid-leaching solutions: Weak or strong sulfuric acid; sulfuric acid-ferric sulfate; or water alone, in the case of sulfates. The ferric sulfate, needed to assist in dissolution of some minerals, is not added to the leaching solution but comes from action of sulfuric acid on iron minerals normally present in copper ores. Copper sulfides other than bornite and covellite are amenable to leaching after an oxidizing roast, but the cost of roasting would be prohibitive on low-grade ores. Furthermore, sulfide ores can be treated economically by flotation.

Preparation of ore for treatment in leaching plants consists of crushing to about 3/8-inch maximum size with production of as few fines as possible. An excess of slimes prevents efficient sand leaching, the preferred method from a cost standpoint. Sand leaching can be done in open vats and require simple equipment compared to the classifiers, agitators, thickeners, and extra solution-handling equipment necessary to handle slimes. Equipment that comes in contact with leaching solutions must be impervious or at least highly resistant to acid. Materials commonly used in leaching equipment, perhaps only as an acidproof lining, are lead, rubber, asphalt, mastic, glass, porcelain, and more recently some types of stainless steel and plastics. Wood is acid-resistant but fails eventually.

Heap leaching and leaching in place, either in dumps or underground, are special applications that eliminate vats and much of the other equipment needed in complete plants, thus lowering the cost of leaching enough to make treatment of very low-grade material profitable. Advantage is taken of natural weathering processes with water, air, and ferric salts to break down any sulfide content to sulfates or other copper compounds soluble in water or weak acid-ferric sulfate solutions. Sulfuric acid is generated in the system and need not be added. The leaching solutions are circulated through heaped ore piles on the surface or through permeable, filled stopes or caved areas underground, taking up the soluble copper compounds formed by the action of weathering. The process is very slow and may take months or years to complete.

Copper is recovered from strong acid-leaching solutions by electrolytic precipitation in equipment similar to that used in electrolytic refining. Acid is regenerated and used over. This is the normal procedure for ores that require strong acid. In leaching processes that need only weak solutions from which the acid need not be recovered, copper is recovered by chemical precipitation with iron supplied in the form of shredded, detinned, scrap tin cans. Sponge iron has been used experimentally and may replace scrap cans to a greater extent eventually. The depleted leach solution is discarded. Chemical precipitation produces impure cement copper, or mud, which is smelted. Electrolytic precipitation from leaching solutions produces a metal that approaches the purity of electrolytically refined copper. Leaching by weak acid solutions followed by chemical precipitation generally is preferred, when applicable, because corrosion of equipment and costs are less.

Whereas a limited content of iron minerals in copper ores is essential to supply the ferric sulfate needed for efficient leaching, an excess of iron is detrimental because the iron consumes the acid. Moreover, an excess of iron salts in leaching solutions interferes with efficient electrolytic precipitation. The presence of calcite or dolomite in copper ores also is detrimental because these carbonate gangue minerals consume acid. Ores that are primarily basic in character cannot be leached successfully with acid.

Ammoniacal leaching, with ammonium carbonate as the solvent, is limited to ores containing copper carbonates or native (metallic) copper. Copper enters solution as a copper ammonium salt and is precipitated as copper oxide by boiling the solution. However, the process has found little application in the United States and is not currently in use.

Ammoniacal leaching was used at one time on a copper carbonate ore from the Kennecott mine in Alaska having a carbonate gangue that precluded acid leaching. However, most copper carbonates are soluble in acid, few copper ores have such a high carbonate gangue, and acid leaching is preferable. Ammoniacal leaching, once practiced on low-grade native copper ore and mill tailings in the Lake Superior district, was superseded by flotation, a superior process.

Experimental work on other basic copper-leaching processes has been carried on for some years. Economic treatment of some heretofore unprofitable ores may be realized as the result of a process under development by a Tucson, Ariz. firm, the Banner Mining Co.

A major limitation of copper-leaching processes is cost in relation to the low value of the ores normally treated. To keep costs per unit of copper produced low enough for economic operation, large tonnages must be treated. Because leaching plants usually operate with a small margin of profit, slight changes in plant efficiency, costs, or copper prices may make the difference between profit and loss.

Zinc Leaching

The zinc leaching process is not used on raw ores but as a substitute of zinc retorting on concentrates. The process therefore is considered in the section of this circular on smelting as an alternate method for producing zinc metal rather than as a means of ore beneficiation.

The Copper Segregation Process

In 1923, during experiments on roasting oxide copper ores with coal to reduce copper to the metallic state, it was discovered that, in certain tests, the copper segregated into friable agglomerates containing carbon and gangue minerals instead of remaining disseminated in the calcine as expected (26).

It was finally determined that, in the presence of heat, an involved sequence of chemical reactions took place between sodium chloride (salt), clay gangue minerals, carbon from coal, moisture, and copper minerals, producing agglomerate metallic copper.

The process was developed to the practical stage before 1931 and used briefly in two African plants before abandonment because of economic conditions at that time. Nothing further was done until about 1958 when the Federal Bureau of Mines undertook research on the process. Recently a prototype plant was put into operation at the Lake Shore mine near Casa Grande, Ariz., treating a chrysocolla ore containing too much iron, clay, and calcite for economical leaching (9, 11). In the process, crushed ore, salt, and pulverized coal or coke are mixed and charged into a gas-fired rotary kiln. The charge roasted at about 725° C., producing a calcine containing segregated copper agglomerates. The metallic copper is recovered by flotation of reground calcines, producing a concentrate marketable at a smelter. Ore mined at Lake Shore contains about 2 percent copper and makes a concentrate containing 45 to 50 percent copper.

The segregation process may be applicable to other oxidized copper ores and perhaps to some mixed oxide-sulfide ores as well.

Other Milling Processes

A number of other concentrating processes for minerals have been developed. Among them are magnetic separation, which has had limited application in concentrating oxide zinc ores, electrostatic separation, differential grinding, and air classification. Some of these might have further application in base-metal ore dressing.

Factors Governing Mill Performance

Before cyanidation, flotation, and improved gravity concentration methods were introduced, perhaps no more than 50 or 60 percent of the valuable minerals in a mill feed was recovered. With advances since 1890, recoveries in the 90 to 95 percent range are common with flotation and cyanidation. Recoveries with modern gravity equipment are generally better than with older equipment, but tend to be lower than with flotation, if a satisfactory ratio of concentration is maintained.

The efficiency of a milling operation is gaged by a number of factors, among them:

(1) Mineral recovery: the amount of valuable minerals entering a concentrate compared to the amount of the same minerals in the mill feed, expressed as a percentage ratio; and conversely, mineral losses in tailings (100 percent less recovery ratio).

(2) Ratio of concentration: the total weight of mill feed compared to the weight of concentrates produced from it, expressed as a ratio.

730-683 O-64—5

(3) The degree to which minerals that are undesirable impurities in a concentrate can be removed.

(4) Comparative milling costs.

The importance of high mineral recovery and low content of impurities in concentrates is obvious. A high-concentration ratio is desirable to effect the maximum reduction in the amount of concentrate that must be subsequently processed. The attainment of both the highest possible mineral recovery and concentration ratio would seem to be the most desirable result in milling, but practical achievement of both in the same operation is not feasible. An exceptionally high recovery or, conversely, a very low tailing loss may be possible, but probably only at the expense of concentrate grade. This is particularly true of gravity concentration. A good concentration ratio for precious metal ores is about 100 to 1 or more; for copper ores, 30 to 1, for lead-zinc ores, 10 to 1 or less. Ratio of concentration is not used as a measure of the efficiency of leaching processes. Better mill performance may result from increased processing time or from installation of additional equipment. Either course tends to raise treatment costs. The correct balance between mineral recovery, concentrate grade, and cost of milling is usually a compromise. The following table illustrates a good metallurgical balance for a selective flotation circuit (similar to that shown in fig. 5) of a lead-zinc sulfide ore with concentration ratios (weight of heads to weight of concentrates produced) of 8.4 to 1 for lead concentrates and 17.3 to 1 for zinc concentrates:

Item	Relative weight	Content			
		Lead, percent	Zinc, percent	Silver, ounces per ton	Gold, ounces per ton
Product analysis:					
Feed (millheads).	100.0	8.73	4.80	8.98	0.063
Lead concentrates	11.9	68.78	2.24	53.46	0.229
Zinc concentrates	5.8	0.84	60.13	4.63	0.024
Tailings.........	82.3	0.60	1.22	2.86	0.042
Metal recovery.....		[1] 93.8	[2] 72.5	[3] 70.9	[4] 42.9

[1] Based on lead reporting in lead concentrate.
[2] Based on zinc reporting in zinc concentrate.
[3] In percent; based on silver reporting in lead concentrate.
[4] In percent; based on gold reporting in lead concentrate.

In planning and operating any milling facility to produce a maximum return to the operator, all factors concerned with actual mill operation must be weighed and balanced; but more than this, the mining and milling operation as a whole must be considered in the light of mining and marketing factors as well. Methods and formulas for analyzing and balancing milling performance and selecting appropriate processes and equipment are included in a number of textbooks and handbooks on ore dressing (27, 29, 30). However, design, construction, and operation of mills should be placed in the hands of experienced personnel. Many manufacturers of mining machinery and mill construction firms are prepared to make beneficiation tests and design milling plants. A number of commercial laboratories and mineral research organizations also test ores on a fee basis.

The Smelting Process

General

Smelting, simply defined, is any process for reducing metals from their ores by some means that includes fusion. In base- and precious-metal production, copper and lead smelting fulfill this definition. Zinc retorting, although commonly referred to as smelting, does not, because complete fusion of the charge does not take place in a zinc retort. Some standard reference works on smelting are listed in the bibliography (3, 5, 7, 21, 34, 35).

The process of smelting lead and copper ores, including any associated gold and silver and sometimes minor base metals, consists of heating in a refractory-lined vessel (furnace) a charge of ore or concentrates, roasted or sintered if necessary, mixed with fluxing material and added fuel. Heat is furnished by combustion of the fuel, which may be coke, pulverized coal, gas, oil, or in part, sulfur in the ore. The necessary oxygen is supplied by air under pressure, sometimes supplemented in recent practice with the pure gas.

Carefully controlled chemical reactions take place within the furnace between ore, flux, carbon, and carbon monoxide in the fuel, and oxygen in the air. The valuable ore minerals are reduced to a metal or metallic product that collects as a heavy molten bath in the base of the furnace (hearth or crucible). Gangue minerals, which include zinc minerals in the case of lead and copper smelting, combine with flux to form a lighter fluid slag that is insoluble in and floats on top of the metal bath. Metal and slag are tapped off separately. The gaseous products of combustion include sulfur dioxide and carry fine material from the furnace charge (flue dust) and fume (metallic oxides).

The metallic products of primary smelting are base bullion, in the case of lead, copper matte (copper-iron sulfide) in the case of copper, and occasionally speiss, an artificial arsenide of iron, copper, and lead. All three products contain, as impurities, most of the gold, silver, and minor metals in the original ore; these must be removed by refining.

Charge constituents entering the slag are iron silicates carrying oxides of basic gangue constituents, most of any zinc in the furnace feed, and as little as possible of valuable metallic products. Lead furnace slags containing enough zinc can be treated in a fuming furnace to recover zinc as an oxide. Slags are also utilized as a source of iron, in cement manufacture, and for construction materials. Imperfect separation of slag and metal tapped from a furnace will produce some material with a content of valuable metals that must be retreated.

Flue dust and fume are separated from furnace gases in settling chambers (flues), cloth filters in baghouses, and electrostatic precipitators (Cottrell treaters). The materials saved are processed to recover arsenic, antimony, lead, zinc, gold, silver, and perhaps other metals by appropriate refining processes or by adding them to furnace charges for retreatment. Sulfur dioxide in copper furnace and roaster gases may be used in sulfuric acid production, and the heat in such gases may be used in waste heat boilers.

Roasting

Ore roasting may be defined as a heating process for treating ore products at temperatures below the fusion point. The purpose is to change ore minerals chemically and/or physically by driving off uncombined moisture (drying), chemically combined water and carbon dioxide (calcining), or sulfur and possibly arsenic, antimony, or other volatile metals such as tellurium (roasting). By these means, valuable metallic minerals are converted to a form more amenable to treatment. For some requirements, the roasting temperature is purposely raised to the point of incipient fusion, in which case the process is called sintering, although roasting reactions are involved. At one time, the ores marketed at base-metal smelters required little or no preparation before smelting, but as the bulk of smelter feeds changed from oxide to sulfide ores and from raw ore to finely divided concentrate, the ores and ore products required conversion to a form suitable for further processing.

Drying as a separate step is seldom necessary on base- or precious-metal ore shipments. Unless it is necessary to prepare extremely wet or frozen ore as received for sampling, the drying step normally is accomplished as the first stage of calcining or roasting.

A primitive roasting procedure (heap roasting) requires only a flat surface on which coarse ore is piled up on stacked wood in a pyre. The heat from burning wood plus sulfur in the ore does the roasting. The labor cost is high, roasting is not complete, noxious fumes are released without control, and fine materials cannot be treated by this means.

A reverberatory roaster, in which the ore is spread out on a flat enclosed hearth and heated by the gases of combustion from a firebox at one end, is a more efficient means of calcining or roasting. The ore can be spread on the hearth and stirred at intervals by hand-raking or, in improved equipment, by systems of mechanical rakes (rabbles) that move the materials through the furnace.

Calcining or roasting can be accomplished in firebrick-lined rotary kilns of the type used in cementmaking. However, this method is not ideal because large amounts of dust are formed, and heat losses from radiation are high. Before retort smelting, oxide zinc ores sometimes are calcined in the type of open-shaft kiln used in burning limestone to quicklime. In this method, ore and crushed coal or coke are charged through the top of the kiln in alternating layers, while air is introduced through tuyères near the bottom. Any fine material in the charge impedes free passage of air through the furnace and must be removed before calcining.

Another type of roasting furnace in general use is the multiple hearth roaster in which as many as 13 hearths are arranged one above another, each with a mechanical rabbling device for moving and stirring the ore as it passes by gravity from one hearth to the next. Raw ore or concentrate, entering at the top of the roaster, is dried on the top hearth. Material passes from hearth to hearth, finally reaching calcining or roasting temperatures, and leaves the bottom hearth as a roasted or calcined product ready for a copper-smelting furnace, zinc retort, or zinc-leaching plant. In roasting straight sulfide ores or concentrate, very little, if any, supplementary fuel is necessary after ignition to augment heat requirements. Coal can be mixed with the charge or pulverized coal, oil, or gas blown into the furnace.

Flash roasting can be used to prepare zinc sulfide concentrate for leaching. Dry, fine concentrate containing at least 40 percent sulfur is fed with air into a roasting chamber near the top through a burner of the type used for burning pulverized coal. Additional air is fed in at the bottom of the chamber at a rate adjusted to effect complete combustion and to control the rate at which burning particles fall through the chamber. Waste gases, leaving the furnace through the top at rather high temperature, contain enough sulfur and heat for worthwhile recovery in an acid plant and waste-heat boiler. The roasted concentrates collect below the combustion chamber from which they pass to leaching. A flash-roasting furnace may be designed with multiple hearths with several hearths both above and below the main roasting chamber. Waste heat is used to dry wet concentrate on the upper hearths so that it can be dry-ground before roasting. In this design, the waste gases pass downward through the hearths below the roasting chamber to use the heat for burning a small percentage of the sulfur remaining after flash roasting.

In flash roasting, concentrate particles come into free contact with gases at roasting temperature for no more than a few seconds, and the material must be extremely fine to bring about a complete or nearly complete roasting. A recent development, Fluosolid Roasting, a patented process,[8] employs suspension roasting on sulfide concentrate without the extremely fine grinding necessary for flash roasting. A Fluosolid Reactor contains a roasting chamber into which concentrate is fed at the bottom by a screw conveyor. The floor of the chamber is a perforated plate through which air and fuel, if needed, are introduced under enough pressure to keep the concentrate in suspension in a fluidized bed as roasting proceeds. The length of the roasting period is adjustable by controlling the rate of feed. The thoroughness and period of roasting can also be controlled by adjusting the depth of the fluidized bed. Roasted concentrate flows out through a discharge opening at the top of the fluidized bed as it is displaced by material entering at the bottom. Roasted concentrate can be discharged into quenching tanks or sent directly to other processing. Waste gases are discharged through the top of the reactor for recovery of dust, sulfur, and waste heat as desired. Close control of the thoroughness of the roast and production of a gas discharge with a high concentration of sulfur dioxide is possible. This comparatively new process now has application in roasting copper, zinc, and gold concentrates; other uses will no doubt be developed.

Sintering, or blast-roasting, is an extension of roasting into the region of incipient fusion for the purpose of making a hard, porous clinker or sinter

[8]Reference is for information only, and does not imply endorsement by the Bureau of Mines.

that will permit free passage of furnace gases through the charge in a blast furnace. A sintering machine consists of a traveling cast-iron grate that slowly carries a 4- or 5-inch bed of a prepared charge of sulfide ore or concentrate mixed with flux and possibly solid fuel over a suction box that pulls an airblast downward through the charge. The charge first passes under an ignition muffle fired by gas or fuel oil and continues to burn during passage over the suction box. The roasted charge emerges from the machine as a porous sinter suitable for blast furnace or zinc retort. A considerable amount of dust entrained by the airblast as it passes through the charge is recovered and mixed with the entering feed. The operation of a sintering machine is flexible; process time, temperature, and completeness of roast can be controlled by adjusting the rate of grate travel and the airblast. The process sometimes is carried on in two steps with roasting first, followed by sintering. The Dwight-Lloyd sintering machine perhaps is the best known of several types that have been developed.

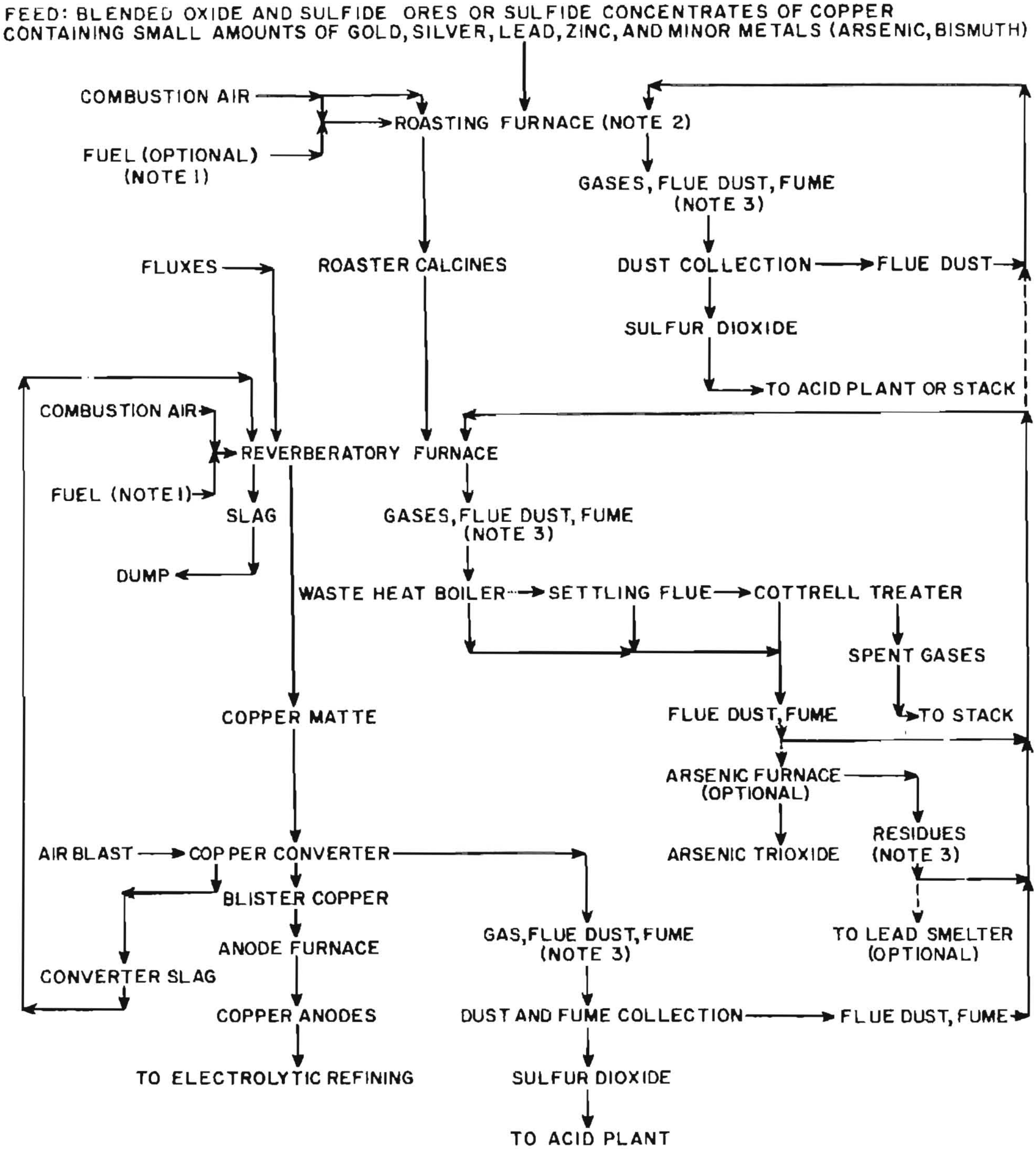
Copper Smelting

The product of primary copper smelting in current U.S. practice is not metallic copper, but matte, an artificial alloy of cuprous and ferrous sulfides. Thus, furnace charges must contain sulfur and iron in order to form matte. This is no problem because present day smelter feeds are largely concentrates of natural sulfides, which contain more than enough sulfur and iron to form a matte. Figure 6 is a typical flowsheet for a copper smelter.

Roasting at a temperature below fusion before smelting once was common practice on sulfide ores and concentrates in order to burn off excess sulfur in advance of smelting, thus lowering the processing time in the smelting furnace and increasing throughput. More recent smelter practice permits charging of green unroasted concentrates--wet charging--directly into smelting furnaces and disposing of excess sulfur in this furnace instead of in a roaster. This method has been adopted at many smelters, most recently at the Garfield, Utah, plant of the Kennecott Copper Corporation.

Copper can be smelted in a blast furnace similar to a lead or iron blast furnace. This was at one time standard practice on oxide and native copper ores, producing metallic copper. It was the process used in treating Lake Superior native copper ores, which required little more than melting to separate copper from gangue minerals. The blast furnace also has been used on sulfide ores to produce matte or metallic copper, but the reverberatory furnace, a development of the early Welsh copper-smelting industry similar to the open-hearth steel furnace, is now generally used. Blast furnaces were suitable for high-grade crude, oxidized ores, native copper ores and concentrates, and even crude, coarse sulfide ores, but not for the finely divided sulfide concentrates that have largely replaced other smelter feeds. It is possible to make blister copper directly in either blast and reverberatory furnaces using any type of feed, but the process is uneconomical.

A modern reverberatory furnace is an enclosed, refractory-lined oblong vessel up to 30 feet wide and 100 feet or more in length covered by an arched roof. The bottom and lower walls form a hearth or crucible in which metallic



NOTE 1 NATURAL OR MANUFACTURED GAS, FUEL OIL, OR POWDERED COAL MAY BE USED FOR FUEL.
NOTE 2 THE ROASTING STEP IS OFTEN BYPASSED IN MODERN SMELTER PRACTICE.
NOTE 3 FURNACE GASES ALSO CARRY FLUE DUST (FINE PARTICLES OF FURNACE FEED) AND FUME (VOLATILE OXIDES OF LEAD, ZINC, ARSENIC AND POSSIBLY BISMUTH OR OTHER MINOR METALS OCCASIONALLY PRESENT IN SMALL AMOUNTS IN COPPER SMELTER FEEDS)

FIGURE 6. - Simplified Flowsheet for a Copper Smelter.

constituents of the charge collect in a molten bath. Heat for the process is furnished by combustion of gas, fuel oil, or pulverized coal in the space above the hearth enclosed by the upper walls and roof of the furnace (combustion chamber). Fuel and combustion air are introduced through burners set in one end wall of the furnace, travel the length of the furnace, and are discharged as spent gases through ports in the other end wall. The charge is heated by reflection of the heat generated in the combustion chamber.

Smelting takes place on the hearth, where metallic and gangue minerals and fluxing materials in the charge segregate into a molten bath of copper matte covered by an immiscible slag composed of barren gangue minerals and flux. The matte and slag are drawn off separately as they accumulate. Reverberatory smelting is essentially a melting process with chemical reactions limited to conversion of the metallic constituents in the charge to the desired copper matte and elimination of excess sulfur. In roasted sulfide ores or concentrates, the natural high-sulfur copper and iron minerals already have been converted largely to the cuprous and ferrous sulfides needed for matte, and most of the excess sulfur has been burned off. Green concentrates, however, still contain high-sulfur minerals that must be disposed of in the smelting furnace. At furnace temperature, high-sulfur minerals are not stable and break down into matte-forming cuprous and ferrous sulfides and elemental (free) sulfur. The free sulfur enters combination gases,burning to sulfur dioxide to the extent that free oxygen is available.

Whereas copper smelter feeds are largely concentrates, the charge also may contain copper leaching precipitates (cement copper) and, rarely, oxide ores. The sulfur needed to produce mattes from a mixed charge is furnished by the excess in sulfide concentrates. Some metallic copper may form in smelting oxide and metallic ores and report in the matte as inclusions.

Ore products in copper smelter feeds usually contain iron minerals in excess of matte requirements as well as other gangue minerals such as silica, lime, magnesia, alumina, and zinc, all of which must be disposed of in slag. A furnace charge must have the proper balance of fluxing materials to form a suitable slag. Silica, iron, and lime are necessary ingredients of slags; any content of alumina and zinc in smelting charges requires extra fluxing materials to form a fluid slag. Fluxing materials used to balance gangue minerals in the feed are silica or limestone. Sufficient iron, a necessary fluxing ingredient, is normally present in ore products. Essentially, a slag is a molten solution of ferrous silicates in which smaller amounts of basic oxides (alumina, lime, magnesia, and perhaps zinc) are dissolved. Slags have somewhat the characteristic of an alloy and consequently can have a wide range of fluidity, mutual solubility of constituents, and freezing points. In making up a furnace charge, an attempt is made to balance flux and ore feed to produce a fluid slag that will not carry off valuable metals or attack furnace linings, using the least possible amount of barren flux. Desirable reverberatory slags have generally been siliceous, and siliceous ores of gold, silver, and copper, ores that sometimes could not be smelted profitably for metal content alone, have been in demand to balance a silica deficiency in other furnace feed without using barren silica flux. More recently, the trend is toward less siliceous slags, and the demand for siliceous ores has lessened correspondingly. The composition of reverberatory slags generally ranges between 30 and 38 percent silica (SiO_2), 45 to 52 percent iron oxide (FeO), 5 to 8 percent alumina (Al_2O_3), and 1 to 5 percent lime and/or magnesia (Ca(Mg)O).

A charge is fed through ports into the furnace by some type of semiautomatic feeder whereby the blended constitutents are discharged in piles along the walls beneath the ports. The piles absorb heat and gradually melt down as the charge components separate into matte and slag. Reverberatory smelting is a continuing process. A pool of matte covered by slag is maintained continuously during the life of a furnace, and the charge is fed at short intervals to replenish the charge piles as they melt down. Matte and slag are tapped off as they accumulate according to the rate at which excess sulfur in the charge is removed. Mattes, being metallic sulfide alloys, can have a wide range in the proportions of cuprous and ferrous sulfides and therefore an equally wide range in copper content. Mattes produced at different plants have ranged between 20 and 80 percent copper content. An optimum content would appear to be 40 to 50 percent.

In addition to copper and iron compounds, mattes carry metallic impurities that were present in the original ores. These may be gold, silver, arsenic, antimony, bismuth, lead, zinc sulfide, or other base metals in small amounts. Mattes may also have minor inclusions of metallic copper or slag-forming substances. Speiss will form if arsenic or antimony are present in the charge in excess of the small quantities of these metals soluble in matte. However, formation of speiss is uncommon in copper smelting.

Zinc and copper oxides are soluble in slags, and copper losses on oxide ores tend to be high because some copper will enter the slag before it is reduced to metal or matte. Matte is slightly soluble in slag, but losses by mechanical entrainment in the slag are more important. Good slag fluidity and settling basins to allow matte and slag to separate during tapping operations reduce entrainment losses.

The gaseous discharge from reverberatory smelting carries valuable materials such as sulfur dioxide, flue dust (mechanically entrained material from the charge) and fume (volatile oxides of arsenic, antimony, lead, zinc, or minor metals). Sulfur dioxide is used in sulfuric acid manufacture. Gases are also processed to recover any valuable constituents in flue dust and fume. Heat carried out of roasters or furnaces in gases can be used in waste-heat boilers, and in a few instances has been used in preheating blast air.

Copper matte is processed to metallic copper in a converter, a refractory-lined vessel that can be tilted to discharge the contents. Modern converters are cylindrical in shape, up to 13 feet in diameter and 30 feet long, with a charge capacity of about 60 tons of matte. The copper converter is similar to the bessemer converter of the steel industry in operation but not in appearance. Copper converting is a batch process with a cycle of operation consisting of charging with molten matte and silica flux and blowing with air in two stages. All of the heat necessary for the process is furnished by oxidizing the sulfur in the matte. Additional heat normally is necessary only to keep the converter hot in the event of delay between blows or to correct errors of operation that otherwise might cause the charge to freeze.

The process takes place in two stages because oxygen combines preferentially with ferrous sulfide, and a reaction with cuprous sulfide does not occur until all of the ferrous sulfide has been converted to iron oxide, leaving essentially pure cuprous sulfide (white metal). In the first, or slag-forming stage, the iron oxide combines with silica flux to form an iron silicate slag, which is poured at intervals as it forms. Elemental sulfur is released, burning immediately to sulfur dioxide in the oxidizing converter atmosphere. In the second, or blister-forming stage, oxygen combines with sulfur in the white metal, releasing copper as the element.

Completion of the blister-forming stage is carefully determined because overblowing produces undesirable copper oxide and, if prolonged, will chill the charge. Not enough heat to keep copper molten evolves after all the cuprous sulfide is converted to copper.

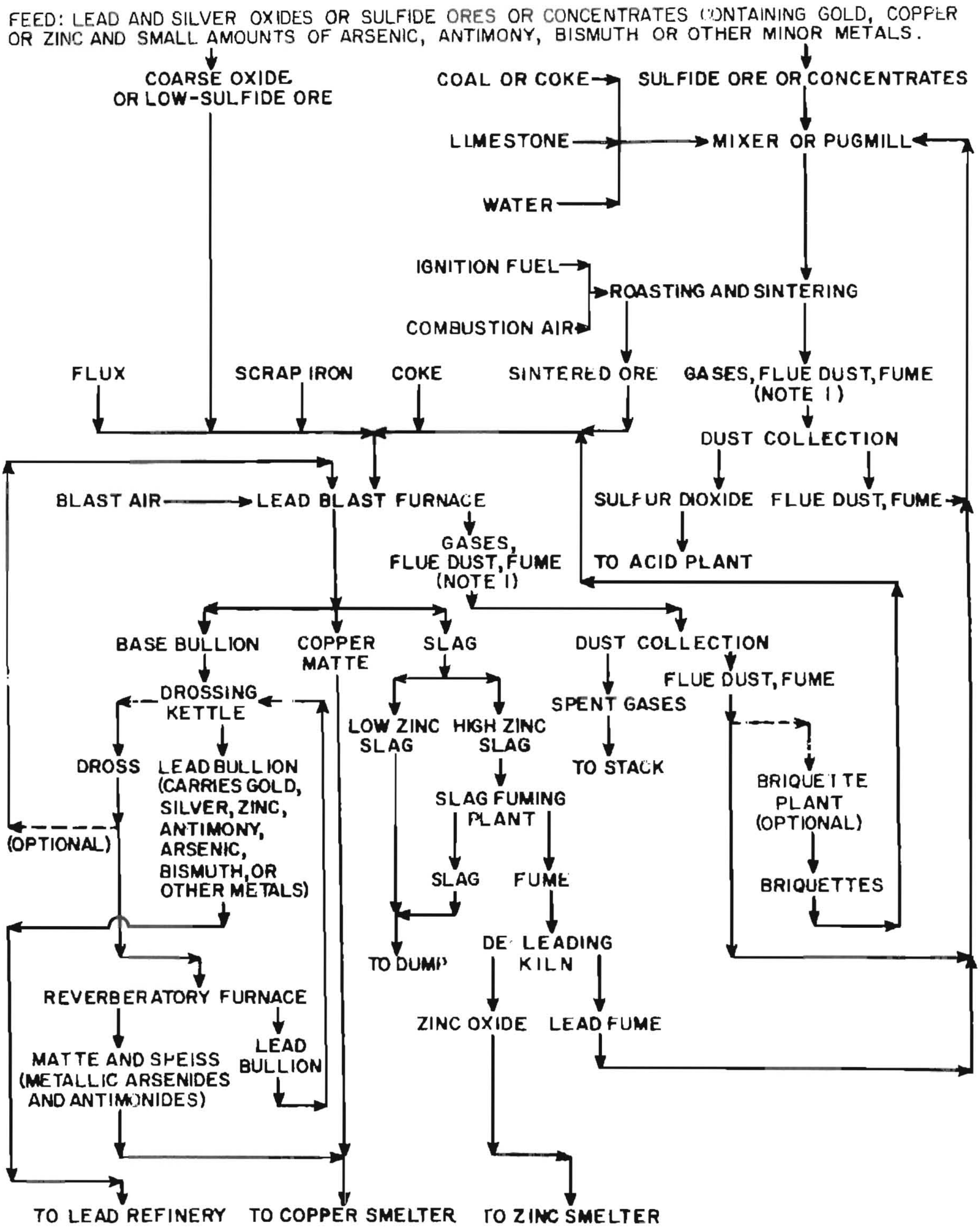
Blister copper contains 98 percent or more copper plus most of the metallic impurities that were in the matte, including practically all of any gold and silver that is present and possibly minute quantities of the platinum group metals. To produce pure copper for the market, the blister copper must be refined to remove impurities whether valuable or not. Oxygen in the blister copper can be eliminated by poling after the charge is removed from the converter, a process whereby green wood poles are repeatedly plunged into the molten copper, causing oxygen in the charge to combine with wood carbon. Natural gas, processed (reformed) so as to increase the content of hydrogen and carbon monoxide, has replaced wood as a purifying agent at some plants, and the practice of poling probably will die out. Poling is in effect the first step in copper refining, a process that is continued by fire-refining to remove volatile impurities, and may be completed by electrolytic refining to remove nonvolatile impurities, including the precious metals. Molten copper discharged from the reverberatory furnace may be transferred directly to be refined or cast into ingots for shipment to another plant.

Copper is sometimes marketed as fire-refined, particularly if the precious metal content is insignificant. Copper from the Lake Superior region, Lake copper, is exceptionally pure as it comes from the refining furnace, and is superior to fire-refined copper from other sources. A small amount of silver in Lake copper does not detract from the quality and in fact is considered to improve electrical conductivity.

The gaseous products of the copper converter contain usable sulfur dioxide and small amounts of any volatile metals that were present in the matte (arsenic, antimony, lead, zinc). These products are used in the same manner as reverberatory gases and fumes. Converter slags contain significant amounts of copper and are returned to the reverberatory furnace for retreatment.

Lead Smelting

The product of lead smelting are base bullion, matte, speiss, slag, flue dust, fume, and gases. Figure 7 is a typical flowsheet for a lead smelter.



NOTE 1: FURNACE AND ROASTER GASES CARRY SULFUR DIOXIDE, FLUE DUST (FINELY DIVIDED PARTICLES OF ORE), AND FUME (VOLATILE OXIDES OF LEAD, ZINC, AND MINOR AMOUNTS OF SOME OF THE FOLLOWING METALS: ARSENIC, ANTIMONY, BISMUTH, CADMIUM, SELENIUM, TELLURIUM, AND TIN).

FIGURE 7. - Simplified Flowsheet for a Lead Smelter.

The standard process requires a blast furnace, a refractory-lined rectangular vessel set on end with a vertical length up to 24 feet and a horizontal cross section of up to 60 by 180 inches. In the base of the furnace is the hearth or crucible in which molten lead bullion collects as it is formed. The lead blast furnace is similar to the copper blast furnace in operation and general design but operates at a generally lower temperature. Both copper and lead blast furnaces are similar in operating principle to the iron blast furnace.

The chief metallurgical reaction in the blast furnace is formation of metallic lead by reducing lead oxide with carbon or carbon monoxide in a reducing atmosphere. Oxidized lead ores and concentrates can be charged directly into a blast furnace. Few such ores are available, and present day feeds are largely preroasted sulfide ore products. Lead sulfides are not broken down efficiently in the blast furnace, a necessary reaction before metallic lead will form. Instead, lead sulfides, together with any copper sulfides in a furnace charge, tend to form a lead-rich matte that must be given additional treatment. Therefore, most of the sulfur in lead ores is removed before smelting, leaving only enough to make matte out of any copper in the ore. The hearth-roasting procedure used on copper concentrates would eliminate sulfur from lead sulfides, but the friable product of hearth roasting is too fine to make a desirable, hard, porous furnace charge. A nonporous charge prevents uniform passage of furnace gases at desirable low velocity throughout the charge column, but instead, causes their rapid passage through restricted channels. Under this condition, the charge is not uniformly or completely smelted, and dust losses occur through entrainment of fine material in restricted, high-velocity gas streams.

Blast-roasting (sintering) is used to prepare lead sulfides for smelting. A dead roast, that is eliminating practically all the sulfur, is possible, but leaving enough sulfur to combine with any copper in the furnace feed is desirable.

The normal blast furnace charge consists of sintered sulfide ore or concentrates, lime or silica flux, and coke intimately mixed in carefully controlled proportions. The charge enters the top of the furnace and is spread in uniform layers. Air under pressure enters the furnace through tuyères (nozzles) just above the hearth and passes upward through the charge, combining with coke to heat the charge and form the required reducing atmosphere. The charge gradually absorbs heat during its descent through the furnace shaft as smelting proceeds but remains dry; that is does not soften, until it approaches the lower end. However, metallurgical reactions start before melting occurs. The rate of descent depends on the rate at which the charge is melted and discharged through the bosh, a constriction in the lower end of the shaft just above the tuyères that marks the bottom of the smelting zone. Molten lead, the first metallic product formed in the process, trickles down through the smelting zone. This action, called the lead fall, collects precious metals in the charge, and enough lead must be present in the charge to insure a generous lead fall, if collection of precious metals is to be complete. Matte, slag, and perhaps speiss also form in the smelting zone but do not melt completely until they reach the bosh. All products then drop into the hearth where they accumulate in mutually insoluble layers of molten base bullion, matte, and slag. As they accumulate, matte and slag are tapped off into a settling basin from which slag overflows and is sent to a zinc-fuming plant or the dump, perhaps granulated for later sale as a commercial product. Matte is tapped from the settler and can be charged, still molten, into a copper converter or a special furnace, or cast into pigs for shipment to a copper smelter. As it collects, base bullion, containing speiss and other metallic impurities, flows continuously from the hearth into a well through a siphoning tube. This bullion is transferred to a drossing kettle, where speiss separates out as dross and is returned to the blast furnace. Bullion may be cast into pigs for later treatment, or still molten, started through the refining process. If produced from pure ores, base bullion is soft, that is, comparatively free from impurities, and sometimes is marketed without refining. However, most bullion contains some copper, iron, arsenic, antimony silver, gold, or other metals and must be softened (refined) to remove deleterious impurities and recover valuable ones.

Furnace gases carry fume and entrained dust that are diverted through a flue to reduce their velocity and condense volatile matter by cooling. Some flue dust and fume condense and settle out in the flue, and the balance is recovered by filtering in a baghouse or precipitating in an electrostatic (Cottrell) treater. Temperatures in lead smelting are kept as low as possible, particularly in the upper part of the furnace, in order to minimize the formation and discharge of lead oxide fume.

Satisfactory lead furnace slags have a reasonably wide range of acceptable compositions, so the slags used may be basic or siliceous within limits, depending on the available ores and fluxes. As in copper smelting, iron must be present to form iron silicate, a necessary slag constituent. Any iron deficiency in the feed usually is made up by adding scrap iron to the charge. Enough fluxing material must be used to form a fluid slag with the zinc present in the charge. Typical slags may contain 22 to 35 percent silica (SiO_2), 28 to 36 percent iron (manganese) oxide, and 17 to 22 percent lime (magnesia). In current practice, slags that will accommodate 20 percent or more zinc oxide may be used. However, a lead furnace charge with a high zinc content is costly to treat for several reasons: More flux is necessary; zinc tends to increase slag accretions within the furnace shaft and on the hearth, thus lowering capacity and increasing maintenance; zinc tends to carry silver into the slag; and zinc tends to form viscous slags, with the danger that the charge may freeze in the furnace. High viscosity also inhibits free separation of metal and slag, with resultant loss of metal in the slag by entrapment. Although higher operating temperatures are partial cures for the difficulties brought about by a high zinc content, high temperatures also tend to increase operating costs and fume losses.

Zinc Smelting

Zinc smelting does not involve complete melting or fusing of the charge, so, in that sense, is not a smelting process; rather it is a distillation process carried on in sealed retort (5, 7, 35). Economic ores or concentrates suitable for zinc retorting contain more than 50 percent zinc. However, regardless of the zinc content, ore products must be prepared for use.

Oxidized zinc ores are given a calcining roast to drive off carbon dioxide and moisture. Sulfide ores and concentrates are given a sintering roast to remove sulfur and form a porous retort charge. Calcined oxides and sintered sulfides are retorted separately.

The older type of zinc retort is a horizontal ceramic cylinder into which are charged calcines or sintered material intimately mixed with coal. The retort is sealed to exclude air and fired externally with natural gas to heat the charge to the point (2,200° F.) at which metallic zinc is formed by reacting the zinc oxides in the charge with carbon monoxide generated from the coal. Zinc metal, volatile at the temperature of formation, leaves the retort with the gas. The gas passes through a condenser, in which cooled zinc vapor condenses to a liquid that is cast into the commercial slab zinc (spelter). The waste gases contain considerable recoverable heat that can be used in waste-heat boilers.

Smelting in horizontal retorts is a batch process. The ore and coal are charged into the retort, fired until zinc vapor ceases to form, and then removed. Material is handled in part by mechanical equipment that has supplanted earlier hand methods, but considerable labor is still necessary.

The fuel efficiency of the horizontal retorting process is poor, partly because of heat losses in batch processing, and large amounts of fuel, both coal and gas, are required. Even under the most advantageous conditions, the cost of retorting per ton of ore treated is high, and high-grade ores must be used to keep the cost per unit of zinc produced at a reasonable level. Obviously, a cheap and abundant supply of natural gas is advantageous, if not essential, under competitive conditions.

Retort residues contain from 5 to 15 percent zinc, and some zinc is lost as aluminates and silicates absorbed in retort walls as a result of interaction between the charge and the ceramic material in the retorts. Residues also contain any lead, copper, gold, and silver present in the charge. Depending on the value and amount of metals contained, residues can be treated by ore-dressing methods to recover a metal concentrate, sent to a lead smelter, possibly after sintering, or used as feed for a Waelz kiln or similar type of fuming furnace to recover zinc oxide.

A vertical retort that operates continuously, introduced in 1925, has replaced horizontal retorts in several plants. In a vertical retort, the charge descends by gravity, as in a blast furnace, but never reaches fusion temperature. The charge consists of porous briquets of roasted ore or concentrates mixed with bituminous coal and coke or anthracite coal in excess of reaction requirements, plus a binder of sulfide liquor and clay, oil and clay, or pitch. After being formed in a press, the green briquets are heated in a coking retort; volatile matter is driven off, leaving strong, hard briquets that retain their shape and remain porous throughout the subsequent zinc-retorting process.

Vertical retorts are as high as 35 feet with a cross section of about 1 by 6 feet, constructed of silicon carbide. The charge is fed in at the top in batches and is gradually heated during descent at a rate governed by removal of the spent briquets through a water seal at the base of the furnace. The retort is heated externally by burning natural gas in combustion chambers adjacent to the retorts. Producer gas from the retort itself may be used along with the natural gas. The zinc-forming reaction and the temperature reached in the reducing zone are the same as in horizontal retorts. Zinc vapor from the retort is conducted into a condensing chamber and drawn off as liquid zinc. The waste heat in the retort gases is used in a heat exchanger to preheat combustion air for external retort heating.

Among the advantages of vertical retorts over horizontal retorts are: Better zinc recovery, mechanical charging and discharging with consequent lower cost, higher thermal efficiency through continuous operation and better use of waste heat, and long retort life (up to 5 years). Horizontal retorts eventually may become obsolete, but their use is being continued in older plants in the United States because economic conditions in some zinc-producing areas do not justify replacing them.

Electrothermic retorts that use resistance heating of the charge have also been introduced successfully at several plants. These units use a vertical retort and differ somewhat from thermal retorts in construction and operation, but they rely on the same basis metallurgical reaction for reduction of zinc to the vapor form.

Zinc Leaching

Although the principle of electrolytic precipitation of zinc metal from sulfuric acid solution had been known for many years (7, 34, 35), a successful process for leaching zinc ore products was not introduced until 1914. Zinc leaching, which requires large amounts of electrical energy for precipitation of the zinc, was developed in the Northwest as an alternate to smelting, particularly for low-grade concentrates (40 percent or less zinc) that could not be treated economically by retorting. Leaching is not used commercially on raw zinc ores, probably because such ores are now uncommon, although high-grade oxide ores presumably are amenable.

Sulfide zinc concentrates must be roasted to convert zinc sulfides to acid-soluble oxide and water-soluble sulfate--the sulfate providing the sulfuric acid needs of the leaching process. Either hearth or flash roasting is used under controlled temperature conditions to convert most of the zinc minerals to zinc oxide, to prevent formation of zinc sulfate in excess of the 2 or 3 percent needed for replenishing acid losses in the leaching circuit, and to minimize the formation of insoluble zinc-iron oxide (ferrite).

Zinc leaching and precipitation both require careful operating control because operating conditions and the composition of leaching solutions, both as to acid strength and contained impurities, are critical. The weak sulfuric acid solution used will dissolve not only zinc oxide and zinc sulfate from roasted concentrates but other compounds, some of which are undesirable. Among soluble salts that should be removed from the leaching solutions because they interfere with electrolytic precipitation of zinc are metallic compounds of antimony, arsenic, copper, and cadmium, possibly nickel and cobalt, and rarely, germanium, one of the most injurious of all. Soluble iron, silicon, aluminum, or fluorine compounds are also detrimental if they enter leaching solutions in excess. By carefully adjusting solution acidity and temperature and adding zinc dust or other chemicals in several stages of purification, most of the deleterious compounds can be precipitated chemically and filtered out before electrolysis. With efficient operation, a leaching plant will produce cathode metal with a zinc content exceeding 99.9 percent.

Residues are removed from the leaching circuit by thickening and filtering. They contain lead, silver, zinc in the form of ferrite, undissolved or inadvertently reprecipitated zinc oxide, plus antimony, arsenic, and copper, and perhaps other minerals. Leaching residues can be treated in several ways of which two are commonly used. Residues are processed directly in a fuming plant to recover zinc or, if copper, lead, and silver content justify it, sent to a lead smelter where these metals are recovered in bullion or matte, zinc being recovered indirectly by fuming high-zinc slags.

If present in the leaching solution, cadmium is precipitated chemically before electrolysis and later refined to a salable product.

Zinc leaching is done both in continuous circuits and in batches, and plants use different equipment, flowsheets, and procedures according to needs. Batch processing is said to be better for ore feeds that vary widely in mineral content because control of the composition of leaching solutions is easier. The corrosion problem in zinc leaching is minor because leaching solutions are maintained at low acid strength.

Zinc Fuming

Zinc fuming is a pyrometallurgical process that was developed for the manufacture of industrial zinc oxide (5, 7, 35). Because a marketable product must be free of impurities, high-grade oxide ores were used. These ores have been replaced largely by reasonably lead-free, sintered sulfide concentrates. Low-grade oxide ores, zinc retorting- and leaching-plant residues, and even molten lead-smelter slags can be fumed. However, the zinc oxide produced from these materials usually contains impurities that must be removed and is not marketable as an industrial chemical without further processing.

When used on solid materials, fuming processes have a superficial resemblance to calcining or roasting but are actually more similar to zinc retorting. Much of the equipment could also be used for calcining or roasting, but the basic metallurgical reaction involved is the reduction of zinc oxide to metallic zinc vapor by carbon monoxide just as in zinc retorting. The maximum temperature reached in the process, 2,200° F., is the same temperature reached in the zinc retort. Fuming differs from retorting in that the zinc vapor is not recovered as metal but is burned in an oxidizing atmosphere, either in the furnace or an attached combustion chamber, removed from the furnace as a fume with the gases of combustion, and condensed by cooling or filtered out in a baghouse.

Grate-type furnaces and revolving kiln retorts are used. The standard method for manufacturing industrial zinc oxide is the grate process in which an intimately mixed charge of calcined or roasted zinc ore or concentrates and coal or coke is gas-fired through a perforated grate on which the charge rests. In the original Wetherill grate furnace, the process is a batch operation requiring about 12 hours for a complete cycle of charging, baking of the charge, burning, reducing, and discharge. An improved furnace uses a traveling grate and operates continuously.

The Waelz process is used on both low-grade zinc ore and zinc retorting or leaching-plant residues. It uses a refractory-lined rotary kiln up to 150 feet long and 8 feet in diameter, fired at the charging end with gas or powdered coal. The charge is calcined or roasted ore or residues mixed with coal or coke, and the reactions are the same as in the grate process. Zinc-oxide fume is produced by burning zinc vapor in a combustion chamber at the discharge end of the kiln. Zinc ore or residue containing cadmium, lead, tin, and germanium can be treated by the Waelz process, recovering oxides of these metals as well as zinc. All fuming processes for solid materials produce a semifused clinker reject. The clinker from high-grade material treated by the grate process may contain enough zinc for retreatment in a Waelz kiln.

In recent years, lead smelters have been successfully treating furnace feeds with a higher zinc content than formerly, producing high-zinc slags. The increased zinc content of these slags is a valuable byproduct that can be recovered in a fuming furnace designed to treat molten slag. Slag fuming is a process in which a coal-air mixture is introduced into a crucible-type furnace through tuyères near the base. The reducing mixture bubbles up through a bath of molten slag, and zinc vapor is formed by reduction of zinc oxides and zinc silicates in the slag. Slag fuming is a batch process consisting of charging, blowing (about 2 hours) and tapping. The metallurgical reactions and recovery of the zinc oxide fume are the same as in grate and Waelz furnaces. Hot gases evolved in the fuming process are an excellent source of heat that can be utilized for other plant needs.

An electrothermic slag-fuming furnace in use at some plants since 1955 produces slab zinc instead of zinc oxide. The process is carried on in a sealed crucible by the reducing action of coke breeze floating on top of the molten bath. Heat to maintain the necessary temperature is furnished by resistant heating of the molten slag. Zinc vapor forms in the reducing atmosphere above the bath and is condensed and cast into slab zinc as in zinc smelting.

When the market price of zinc is low, there is very little profit in zinc fuming, but returns that plants get from zinc that would otherwise be lost undoubtedly contribute to the removal or lowering of zinc penalties charged shippers at lead smelters and to a better rate of payment for zinc at plants that pay for zinc content.

730-683 O-64—6

Recent Developments in Smelting

Metallurgical principles in smelting are based on fundamental laws of chemistry and physics, and basic smelting practices have changed very little over a long history of operation. Improvements have come in better operational control, advances in equipment design, and adaptation of new methods of bulk material handling and processing developed in other phases of industry. Some recent innovations indicate the possibility of radical changes in the future, but no new basic principles are involved.

A zinc blast furnace that will smelt complex, mixed, copper, lead, and zinc ores or concentrates in a continuing process without prior separation of ore constituents and with a minimum of ore preparation has been operated commercially in Great Britain (20, 35), and elsewhere in Europe and Africa. The only ore preparation necessary is bulk concentration, if the metal content of ores is low, and sintering of the feed to provide a porous furnace charge. Fluxing materials are added before sintering. The zinc content of the feed can be lower than in conventional zinc retorting. By close control of the temperature and gases within the furnace, a balanced atmosphere is maintained in which zinc metal, formed as a vapor as in conventional retorts, is condensed within the furnace by a molten lead spray. The molten, zinc-saturated lead is cooled outside the furnace, and zinc separates out. Simultaneously, base bullion and even copper matte are produced, thus recovering in one operation and with one smelting cost lead, copper, gold, silver, and minor metals. The process has possible applications for mixed sulfide and oxide ores that have been uneconomical and for complex sulfide ores currently milled at substantial cost to produce separate lead and zinc concentrates. The cost of fuel (coke) for the process is reported to be higher than in lead and copper smelting but less than in conventional zinc retorting.

Oxygen-enriched air is being tried in roasters, in copper converters, and even in reverberatory furnaces to improve efficiency and boost capacity. In Japan, smelting copper sulfide concentrates directly in a converter using oxygen-enriched air has proven feasible. A small fraction of the converter charge must be copper matte, but the remainder can be pelletized sulfide concentrates (20).

Control of Smelting Operations

The smelting process, like ore beneficiation, does not yield perfect results. Metal losses in slags are never completely eliminated, and close control of all plant operations is necessary to maintain the highest possible metal recovery at the lowest cost.

The composition of a smelter charge is critical because slight variations in the ingredients can cause critical differences in physical and chemical properties of the slag produced. Slag fluidity, metal recovery, and furnace capacity may be affected seriously. Slags of high viscosity will increase metal losses by entraining valuable products. In extreme cases, slag freezes in a furnace, necessitating complete and costly shutdown. Zinc tends to make slags viscous, and large amounts of fluxing materials are necessary to dilute them. This is the basis for zinc penalties in smelting.

The calculation of a furnace charge is a science in itself. On the basis of the content of silica, lime, iron, sulfur, zinc, and occasionally other ore constituents considered in conjunction with the cost and availability of fluxing materials, the optimum combination for a desirable slag with the use of as little barren flux as possible is determined. Frequent monitoring of the composition of the charge and of the slag is necessary to maintain the desired metallurgical balance, particularly in custom smelting where purchased ores may vary widely in mineral content. The perfect smelter charge would be a self-fluxing, self-smelting ore containing the right combination of fluxing material for a fluid slag and enough sulfur for fuel. Obviously this ideal is never realized.

Settlement of Ores at Custom Treatment Plants

Treatment Charges and Payments at Milling Plants

A buying schedule for a cyanidation plant is comparatively simple as shown in appendix B. In this example, all milling costs, including tailing losses and marketing charges, are covered by a single sliding-scale treatment charge based on the gross value of the ore.

Treatment charges assessed at base-metal milling plants that buy ores rather than treat them on a toll basis also reflect smelting or other costs that must be met when concentrates are sold. Schedules 18 and 19 of appendix A, appendix C, and appendix D apply to complex lead-zinc sulfide ores. Because the selective flotation circuits normally used in custom milling such ores are effective only on sulfides, any oxidized lead and zinc content, as determined by analyses at the time of purchase, is deducted from the total metal content before payment is calculated.

Metal Payments, Treatment Charges, and Penalties at Smelters

Smelting base metals is essentially a manufacturing operation in which raw materials (ores and concentrates) are processed, refined, and marketed. Smelter economics are based on the generation of an average profit per ton of material treated. This profit, then, along with treatment, refining, and marketing costs is a charge against the gross value of the refined products obtained from the material treated. The proposition can be stated another way: The entire cost of mining, milling, smelting, refining, and marketing an ore must be covered by the value of the contained minerals in their final marketable form if the overall operation from mining through marketing is to be profitable. However, to the producer, the value of an ore expressed as the amount the contained minerals are worth in the refined state is meaningless.

The price paid for the raw material depends, as it does for any commodity, on quality, as represented by the content of valuable minerals, the impurities, and the suitability of the ore to the treatment process used. No two ores, even lots of ore from the same mine, are exactly alike either in valuable metal content or the amount and character of waste constituents. An excess or deficiency of a certain constituent may call for a penalty at one plant and no penalty or even a premium at another. To provide for the range of ores that are offered to custom plants, many detailed treatment schedules are offered. The terms governing purchases at plants treating different base and precious metals are shown in appendix A, and examples of buying schedules and settlement sheets in appendixes B through L. Competition may be a factor in the terms offered a shipper if a demand for the same ore exists at more than one plant, but not if plants are so located with respect to the mine concerned that differences in ore freight are more important than treatment costs. This is particularly true of small ore shipments because smelters accept them largely as an accommodation. Competition for this class of ore is virtually nonexistent, and shipping costs control the choice, if a choice exists, of market for most small mining operations in the Western United States.

The structure of payments, deductions, treatment charges, and penalties in most smelter schedules is similar in principle, even though details will vary from ore to ore and from plant to plant. Except in the Tri-State District, methods of calculating metal payments and the assessment of penalties, treatment, refining, and marketing charges are generally uniform. The prices paid the shipper for metals depend on the value of the refined metal delivered to certain basing points shown in published metal quotations, as defined in smelter schedules and contracts. Definitions of methods of sampling and analysis, units of weight and percentage, conditions of ore delivery, and metal quotations governing payment are listed in examples of western smelter and mill buying schedules in appendixes B through L. Midwestern and eastern plants that accept custom ores do not issue open buying schedules but negotiate purchase terms with individual shippers on a contract basis.

Metal payments to the shipper are based not only on market quotations and cost of processing, including refining and transportation of products to market, but also on smelting losses. Normally, over 97 percent of the copper in an ore shipped to a copper smelter is recovered directly, but any lead content enters a residue as a fume or a byproduct of refining blister copper and must undergo further treatment, usually at another plant. Consequently, the lead content of copper ores, usually small, is paid for at a much reduced rate, if at all. Recovery of lead at a lead smelter as bullion averages around 96 percent. A good recovery is also made on any copper in such ores, but in the form of matte that must undergo further treatment, and payment for copper at a lead smelter is reduced accordingly. The recovery of silver and gold at lead and copper smelters approaches 100 percent, so the prices paid for these metals largely reflect refining and marketing costs. Zinc recovery at a zinc plant ranges from about 88 to 96 percent. Recoveries of copper, lead, silver, and gold in ores shipped to a zinc plant depend on the efficiency of subsequent processing to extract these metals from zinc residues. The price paid for these metals at a zinc plant reflects metal recovery and the cost of the retreatment.

The base treatment charge represents operating costs, including labor, fuel, flux, power, and other supplies at a price level defined in a schedule, and applies only to the ore for which the schedule is set up. Adjustments for any changes in labor and supply costs are provided for by additional charges or credits, also defined in the schedule. The base treatment charge applies only to ores up to a certain maximum value. Additional charges, computed as a percentage of metal payments above a defined maximum, are assessed for excess value. Presumably the charge for excess value compensates the smelter for interest on the capital tied up in stockpiled ore and metal in transit and gives protection against fluctuation of metal prices between the date of ore purchase and final sale of the finished product some months later. Assessment of extra charges for higher grade ore may enable custom smelters to offer lower treatment charges on low-grade ore, thus subsidizing the production of otherwise unmarketable low-grade ores, perhaps to assist mine development.

The penalty section of a lead or copper smelter schedule covers ore constituents that are detrimental because they increase smelting costs or because they enter smelter products as undesirable impurities. Examples are zinc, particularly sulfide zinc, arsenic, antimony, bismuth, tin, and sulfur in metal sulfides.

Zinc is always a detriment in conventional lead or copper smelting for the reasons given previously in descriptions of smelting processes, and an excess may incur a penalty. A high sulfur content in lead ores, which must be removed by roasting before smelting, usually incurs a penalty.

Arsenic, antimony, bismuth, or other minor metals are common ore impurities with a market value in refined form that will not compensate refiners for the full cost of removing them from copper or lead smelter products. Consequently, a penalty normally is charged to cover refining costs in excess of the return from sale of these minor metals. When any of these metals are present in smelter feeds in amounts that will justify special recovery facilities, payment may be made for them. For example, a plant purchasing lead ores with a substantial content of antimony pays for the antimony (schedule 14, appendix A). Another plant pays for cadmium content (schedule 17, appendix A). Selenium, tellurium, gallium, tin, and other metals may be present in smelter feeds, but while they may be recovered during copper and lead refining or from smelter residues, the amount present in most ores is too small to justify any payment to the producer for them.

Silica, alumina, lime, magnesia, and iron are constituents of ores and fluxing materials that have no market value as smelter products except as minerals that must be present in the correct proportions to make fluid slags. Whether they are subject to penalty in an ore because they require addition of barren fluxes to form suitable slags, or command a premium because they reduce the fluxing requirements for some other ore, depends on the requirements at each smelter. Copper smelters may penalize or give credit for excess silica, depending on the overall fluxing needs. Lead smelters penalize for silica and give credit for iron and lime because available lead ores usually contain an excess of silica and are deficient in iron and lime, necessitating addition of barren iron and lime flux. If the iron in an ore is present as a sulfide mineral, a penalty for sulfur may offset any credit for iron.

Deficiencies in the major base metals may, in special cases, incur a penalty: For example, copper deficiency in a gold-silver ore offered to a copper smelter (schedule 1, appendix A), or lead deficiency in ores purchased at a lead smelter (schedule 12, appendix A). The justification for such charges is that these deficiencies may be difficult to compensate for with the ore supply available to the smelter.

Computation of Metal Payments

As shown in appendix A, payment for the gold content of an ore is usually made on the full assay content, subject to a minimum content for which payment will be made. This minimum, ranging from 0.01 ounce per ton to 0.03 ounce per ton depending on the smelter, represents the gold lost in the treatment process. Payment is computed at a percentage of the U.S. Mint price for domestically mined gold as set by the Gold Act of 1934. Since 1935, this price has been \$35.00 per ounce, less a handling charge of one-fourth of 1 percent. The difference between the full mint price and the percentage of this price paid to the shipper represents a small smelting loss, the refining cost, the cost of delivery to the mint, and the profit. The range in percentage shown in appendix A, reflects the variations in these factors at different treatment plants. The highest deduction for gold is made at a zinc smelter (schedule 15, appendix A). At a few plants, the rate of payment for gold rises with increase in gold content of the ore. One custom cyanide mill (appendix B), used a simplified treatment schedule in which payment for gold was computed at the full mint price and for the full assay content.

In general, payment for silver follows the gold pattern; the minimum content paid for is 0.5 or 1.0 ounce. A portion of the silver content, usually about 95 percent, is paid for, subject to a minimum deduction of 0.5 to 1.0 ounce. The price paid for silver is the mint price or the Handy and Harman, New York, quotation, whichever is greater, less a refining and marketing deduction expressed either as a percentage of the market price or in cents per ounce. Only domestically mined silver, for which an affidavit of origin is furnished, is eligible for Government purchase. Since 1946, the mint price has been \$0.905 per ounce for silver 1.000 fine (technically \$1.2929, less 30 percent seigniorage accruing to the Treasury, or \$0.90505 cents per ounce). After 1947, the New York market quotation for silver 0.999 fine ranged between \$0.70 and \$0.91375 per ounce. In 1960 and 1961, the price remained steady at the latter figure until November 1961 when the New York quotations rose to more than \$1.00 per ounce after the Government suspended sales of U.S. Treasury silver stocks.

Payment for copper is based on a percentage of the assay content, subject to a minimum deduction paid for at the Engineering and Mining Journal of New York market quotations, averaged over the week of ore delivery, less a deduction for refining and marketing expressed as cents per pound of metal.

Payment for lead is based on the New York quotation for desilverized lead, less a refining and marketing deduction expressed in cents per pound of metal.

Payment for zinc at western plants is based on a percentage of the assay content, subject to a minimum deduction, paid for at the East St. Louis, Ill., quotation less a marketing deduction. The latter deduction may be computed as a percentage of the market price or as a net figure expressed as cents per pound of metal.

In treatment schedules applying to complex ores where lead, copper, and zinc are all paid for, a sliding-scale schedule for metal payments may be used whereby the deduction from market prices to determine rates of payment depends on the increase or decrease of the market price above or below a base quotation used as references. The rate of payment may also be affected by the metal content of the ore, rising with increase in grade. The relative level of market quotations on several metals may also enter into the calculation of metal payments. Calculation of metal payments can be very involved for schedules of this king (schedule 14, appendix A). Such schedules apply to complex ores that may be milled by the purchaser before smelting and treatment in an electrolytic zinc plant. Examples of settlement sheets illustrating methods of computation are given in the appendixes D, F, H, and K.

Tristate Ore Marketing

Schedules for purchase of ore in the Tri-State District of northeast Oklahoma, southeast Kansas, and southwest Missouri are set up on a different basis than elsewhere in the United States. Tri-State schedules have a background of milling and marketing practices antedating the history of smelting in the West. Tri-State ores are all purchased f.o.b. the mine, and the purchaser assumes all freight and handling charges, including loading and unloading.

In former years, nearly every one of the typical small mining operations in the Tri-State District included a gravity mill, perhaps only a simple jigging plant, in which lead and zinc concentrates were made. The product sold, therefore, was a concentrate rather than mine-run ore. Later, custom plants serving groups of mines replaced many of the individual mills. The smaller custom mills, operated on a toll basis, did not commingle ores but produced concentrates for the account of the shipper in separate lots corresponding to the ore shipments received. The larger custom mills sampled the ore shipments on delivery, processed the commingled ore, with settlements adjusted to the total concentrates produced during the previous months' operations. These concentrates were purchased by brokers or ore buyers for shipment to smelters or oxide plants where they were reduced to metal or oxide pigment. The ores, sampled as received, were converted to equivalent standard concentrates by calculation on the basis of the assay.

The standard method of settlement for Tri-State District ores used before the virtual shutdown in 1958-60, follows:

1. Settlements were usually made by telephone, the buyers represented by the brokers or smelter representatives, and the sellers agreeing on assay, tonnage, and delivery date. The ores were sold f.o.b. the mine, with the buyer doing the loading either in trucks or railroad cars. Mine weights were

accepted by both buyer and seller. Appendix Q is a list of Tri-State ore-buyer-representatives active in 1960.

2. Mine ore was hauled separately from each mine and sampled separately before commingling at the custom mills. Three samples were taken, one each for buyer and seller and one for an umpire. If buyers' and sellers' assays were not within settlement limits, settlement was made on the basis of an umpire assay made by a chemist agreeable to both parties.

3. Prices for concentrates were quoted on the basis of 60-percent zinc concentrates and 80-percent lead concentrates at Joplin, Mo. These concentrate prices for many years were based on 6.7 x 100 for zinc and 12 x 100 for lead; multiplied by the zinc and lead metal prices quoted at East St. Louis. These factors have declined in recent years because of mounting smelter costs. Carbonates and silicates, produced in minor amounts before 1944, were quoted on the basis of 40-percent zinc content. The following is an example of a price schedule for zinc and lead concentrates that illustrates the relation between payments and metal prices. The numerical values are not necessarily valid at the present time.

Zinc		Lead	
East St. Louis, Ill. metal price, cents per pound	Payment for 60 percent concentrate Joplin, Mo., per ton	New York metal price, cents per pound	Payment for 80 percent concentrate Joplin, Mo., per ton
10	$56.00	10	$112.92
10-1/2	60.00	10-1/2	120.12
11	64.00	11	127.32
12	72.00	12	141.72
13	80.00	13	156.12
14	88.00	14	170.52
15	96.00	15	184.92

Inspection of the table will show that for every cent change in the East St. Louis, Ill., price per pound for prime western zinc, there is a change of approximately $8.00 per ton in the Joplin zinc concentrate price; for every cent change in the New York quotation for lead, there is a change of approximately $14.40 per ton in the lead concentrate price. Specific penalties such as $1.00 per unit for iron content in excess of 1 percent and $1.50 per unit for lime in excess of 1 percent may be assessed, but milling, smelting, and marketing charges in general enter into the calculation of the concentrate payment schedule rather than appearing as separate deductions. A charge for fine concentrates, assessed after flotation concentrates appeared in the market in the thirties, was later removed as smelters devised methods for handling the finer material. The Central mill of The Eagle-Picher Co. has on occasion paid an extra premium of $4.00 to $6.00 per ton of zinc concentrates produced.

TRANSPORTATION OF BASE-METAL ORES AND CONCENTRATES

Transportation Patterns in the West

Transportation patterns for ores and concentrates produced in the West (Rocky Mountain States and west) have changed greatly in recent years, particularly in regard to base metals. Many factors, some dating back to the early 1900's, are responsible. Among these are decline of mining activity, abandonment of rail routes, improvement of highways, and development of large and reliable trucking equipment. In mining districts that no longer have direct rail connections, movement of mine products necessarily has been shifted to trucks for at least part of the haul to market. Examples include most of the older Colorado mining districts. Many of the recently discovered ore deposits, largely uranium mines, are in locations remote from rail routes. For new districts, the flexibility and comparatively low investment cost of trucking equipment favor use of truck transportation over railroads inasmuch as roads usually are built with some type of Government assistance.

When distances by rail and highway are comparable, transportation of ore products entirely by rail is invariably cheaper, provided that the shipper accumulates mine products in carload quantities. However, direct rail connections are now available at very few small mine operations. Ore shipments often are transferred from truck to rail, but if trucking costs over the road route for which rail haulage might be substituted are at all competitive, such a transfer may not be economical. In mountainous territory, highway routes between certain mines and markets may be much shorter than any truck-rail route. This was true of hauls from many mining districts in Colorado to the Leadville smelter of the American Smelting & Refining Co. When the shipper may either transfer products from truck to railroad cars at some point along the route from mine to market, or use truck haulage for the entire distance, the comparative length of truck and rail portions of the haul, as well as the difference between applicable truck and rail freight rates, enters into a choice of routes.

Appendixes M, N, O, and P show representative rail and truck freight rates compiled from published tariffs of 10 railroads operating in the West and from data furnished by truck carriers, truck tariff bureaus, and public regulatory bodies in several Western States. Rates in appendix M cover rail routes which are, or have been recently, in use for transportation of ore and concentrates. The carload (CL) freight rates quoted are commodity rates applicable between specific points. Less-than-carload (LCL) rates can be calculated by adding a percentage to the carload rate in some cases, and by applying general class rates in others. Few specific LCL rates on ores and concentrates are published because there is little or no rail traffic in less-than-carload lots of base- or precious-metal ores. LCL rates have been omitted from appendix M.

Appendix N covers trucking routes for which specific commodity tariffs on mine products have been established, and also routes to which distance commodity or class rates have been applied. Comparatively few commodity rates, either for truckloads (TL) or less-than-truckloads (LTL), between specific points have been set up for ore and concentrates. Most shipments are handled by contract carriers rather than common carriers, and freight rates are set by negotiation or by reference to distance-commodity tables.

Appendix O presents distance-commodity or class rates on truck haulage in effect in several Western States; from these, freight rates between specific points can be estimated if no point-to-point rates have been established.

Appendix P lists local hauling rates in effect in two mining districts where ore was hauled from mines in a small area to centrally located mills. There are no published tariffs covering this type of hauling.

Freight Rates

Relation of Railroad Freight Rates to Distance and Other Factors

Primarily, railroad freight rates are a function of the length of haul. However, calculated ton-mile rates are not the same over the entire range of distances. On short hauls the cost of other services, such as setting out and picking up cars, is large in comparison with the actual hauling cost, and the ton-mile rate is high. As the length of haul increases, the ton-mile rate decreases. Volume of traffic, type of terrain, and competition also enter into freight rates. Freight movements over branch lines or over lines of more than one railroad are usually subject to higher rates than haulage on main lines or on a single railroad system.

This range in rates is illustrated in appendix M. The highest ton-mile rate for a specific distance is as much as 50 percent more than the lowest rate.

In practice, rail hauls of less than 25 miles, or even 50 miles, are uncommon for small mine operations. Nearly all the short rail hauls being made today serve large, integrated mining operations, many of which include a private railroad system.

When volume of traffic is low, or shipments are made from new loading points or to new destinations, a freight rate may be set temporarily by use of distance-commodity or distance-class tables. Later, if the volume of traffic warrants, a commodity rate covering the specific haul is established. A point-to-point commodity rate is usually lower than a rate for the same haul derived from tables.

Railroad rate structures, subject to both State and Federal regulation, are complicated, particularly where more than one line, or competing lines, are involved. Freight rates applying to ore and concentrates, as well as to other commodities, are subject to modification if the traffic volume changes. Rates presented in this circular, believed to be current, are subject to change. Most of the freight rates applying to ores and concentrates result in a much higher ton-mile cost than 1.45 cents per ton-mile, the estimated average cost of shipping all commodities in carload lots in the United States in 1958. An upward nationwide trend in freight rates necessitates frequent revision of published tariffs.

Effect of Ore Valuation on Railroad Freight Rates

Rail freight rates are usually influenced by the value of the product shipped. The metal content of ores and concentrates is used, as determined by control assays that serve as a basis of settlement between ore shipper and buyer. The calculated valuation is an arbitrary figure. The actual price received by the producer for gold and silver is used, but the value of base metals is calculated from a set price schedule rather than by the actual market quotations:

	Price per pound
Metal:	
Copper......................	$0.14
Lead........................	.07
Zinc........................	.08

Published commodity tariffs usually contain specific freight rates on mine products carrying valuations up to $100 per ton and occasionally higher. For higher valuations, a percentage formula is used whereby increases in rates are calculated by adding a percentage of the rate on $100 ore. As an example, a method of calculation used by the Denver & Rio Grande Western Railroad is quoted.

> Basis for arriving at rates on ore and concentrates or other commodities when value exceeds $100.00 per ton:
>
> On Ore and Concentrates, or other commodities, when value is in excess of $100.00 per ton, except where specific rates are provided, apply the following percentages of rate applying on Ore and Concentrates, or other commodities, of $100.00 per ton in value:
>
> Value over $100.00, but not over $125.00 per ton, 109 percent
> Value over $125.00, but not over $150.00 per ton, 118 percent
> Value over $150.00, but not over $175.00 per ton, 127 percent
> Value over $175.00, but not over $200.00 per ton, 135 percent
> Value over $200.00, but not over $225.00 per ton, 144 percent
> Value over $225.00, but not over $250.00 per ton, 153 percent
> Value over $250.00, but not over $275.00 per ton, 162 percent
> Value over $275.00, but not over $300.00 per ton, 170 percent
> Value over $300.00, but not over $350.00 per ton, 185 percent
> Value over $350.00, but not over $400.00 per ton, 200 percent
> Value over $400.00, but not over $450.00 per ton, 215 percent
> Value over $450.00, but not over $500.00 per ton, 225 percent
>
> For Ore, value in excess of $500.00, the rate will be made by adding the following to the rate for $500.00 valuation:

Value over $500.00 and under $1,000.00 per ton of 2,000 pounds, add 2 percent of valuation above $500.00 per ton.
Value $1,000.00 and under $1,500.00 per ton of 2,000 pounds, add 3 percent of valuation above $500.00 per ton.
Value $1,500.00 and under $2,000.00 per ton of 2,000 pounds, add 4 percent of valuation above $500.00 per ton.
Value $2,000.00 and over per ton of 2,000 pounds, add 5 percent of valuation above $500.00 per ton.

Ore of greater value than $1,000.00 per ton is not properly subject to carriage by freight train, and if offered, agent will refer shippers to Express Company. If shippers prefer freight service however, the ore may be accepted.

Agents must notify the traffic department by wire at once when such shipments are tendered, in order that necessary arrangements may be made to properly care for same.

Basis for rates on less than carload lots:

In the absence of specific rates, the rates on less than carload lots will be 130 percent of the rates authorized herein as applicable to carload lots of the same valuation per ton.

Lots less than carload must in all cases be prepaid; prepayment on basis of lowest valuation will be sufficient, but in no case shall shipments be waybilled on valuation less than $100.00 per ton of 2,000 pounds, but in cases where rates are not provided for Ore of $100.00 valuation, shipment to be forwarded at highest valuation for which rates are provided.

In computing charges under this item, fractions will be disposed of in accordance with the provisions of Rule 36, of Western Classification.

Several versions of these formulas are used by different western railroads. Very little raw ore worth as much as $100 per ton is now mined in the West. Concentrates may exceed this value.

Carload and Less-Than-Carload Shipments

Freight tariffs covering carload (CL) shipments specify a minimum tonnage which may be a set figure; the rated capacity of the railroad car, or a percentage thereof; or the visible capacity of the car. The last limitation is seldom operative for ore or concentrates because of their high specific gravities. If the railroad furnishes, for its own convenience, a car having a marked capacity greater than ordered by the shipper, the minimum tonnage regulation applying to the car ordered governs.

Less-than-carload (LCL) shipments are costly. On bulk shipments, the minimum carload tonnage must be paid for to get the carload rates. If carried in cars with other commodities in mixed freight service, a shipment must be packed in containers (bags, barrels, or boxes), and a much higher LCL rate is charged. Formerly, LCL shipments of mine products of high value were made occasionally in less-than-carload lots for the greater security this service afforded. Express service was and is available for the same class of products.

Because the volume of LCL rail traffic in mine products is low, very few point-to-point LCL commodity rates have been established. The methods of setting them up differ: Some railroads add a percentage of the carload rate to arrive at an LCL rate; in other cases, LCL rates are derived from distance-class tables, using specified percentages of the rates in the tables. If the total freight on a shipment computed at the LCL rate exceeds the cost computed for a minimum carload at the carload rate, the latter cost governs. Thus, if the weight of a shipment approaches a minimum carload, the total freight computed for the minimum carload tonnage is likely to be less than for the actual tonnage computed at the LCL rate. Because truck transportation is normally available, a rail shipment of ore at an LCL rate would be unusual. For this reason, LCL rates are omitted from appendix M.

Railroad tariffs make provision for shipment for several bulk LCL lots in one car. A bulkhead or other divider between lots may be necessary. Under such an arrangement, the freight on each lot is billed at the applicable carload rate, but the minimum carload tonnage specified for the commodity must be paid for even though the combined weight of the several lots is less. Such rail shipments usually incur extra handling and switching charges and are avoided, if possible.

Relation of Truck Freight Rates to Distance and Other Factors

Ton-mile freight rates for truck haulage vary inversely with the length of haul as do rail rates. Also, as in rail transportation, factors other than length of haul enter into trucking costs: Volume of traffic, type of terrain, condition of roads, loading and unloading facilities, and distances from the carriers' bases of operations to loading or unloading points. Most of the cost of trucking ore over short distances consist of the cost of loading, unloading, and possibly deadhead travel from the carriers' bases of operations. Truck tariffs usually state that the rates quoted cover loading ore from bins by gravity or by the shipper's equipment, unloading at destination by dumping or mechanical devices, and a definitely limited amount of deadhead travel (not over 15 miles for a contract carrier operating in Arizona). An extra charge is made for use of additional labor or equipment or for loading and unloading delays beyond the control of the carrier.

In a few instances, mine operators have found it advantageous to haul ore in their own trucks, but, in general, the required investment is not justified unless reasonably full use of the trucking equipment can be made. Normally, in the case of small operations, it is cheaper to contract hauling to established carriers.

Few point-to-point commodity rates applying to the truck movement of ore and concentrates have been established. This condition is particularly true for base-metal shipments because the volume of traffic is low. Truck rates on ores are commonly the subject of negotiation between shipper and carrier. A distance-commodity table can be used, at least temporarily, if it applies to the type of hauling operation under consideration. Distance-class tables have been set up in some States to cover cases where no specific rates are in effect, and a rate to cover a particular commodity can be calculated from them. However, such rates are high, particularly in the low mileage range (example 4, appendix O), and a contract would undoubtedly be negotiated if possible.

Many trucking firms in common-carrier service also transport ores and concentrates, but they normally operate as contract carriers because special equipment, not adaptable to general freight service, is employed.

Short Truck Hauls

Short hauls of ore and concentrates are almost invariably made by local truckers on contract. Distance-commodity tables issued by some truck operators presumably cover the short distance range, but an examination of examples of such rates in appendix O will reveal that freight costs based on such tables are not realistic in the distance range under 15 miles. Some schedules result in an impossibly low cost for short hauls, and others in an equally impossible high cost. Investigation shows that local conditions, for which these particular rates were set up, do not require any short hauls. Therefore, the tables are inoperative in this range. Actually, a realistic freight rate for hauls under 10 or 15 miles must be based more on volume of traffic, loading and unloading facilities, and other factors, rather than on distance. Appendix P gives examples of short hauls to a centrally located Colorado gold mill, and one example in a base-metal district. These unpublished rates represent negotiated rates based on the conditions prevailing in each instance. For the gold mining district, the contract carrier was a subsidiary of the company that operated the mill and most of the mines, and the hauling operation probably yielded only a nominal profit. A Bureau of Mines publication (13) on the cost of trucking and packing ore in western gold mining districts is of historical interest.

Less-Than-Truckload Shipments

Less-than-truckload (LTL) shipments of ore and concentrates are uncommon. Such shipments must be in containers for acceptance in general freight service. LTL rates can be derived from a distance-class table but result in a prohibitive cost (example 4, appendix O). LTL service might be used for trial shipments to prospective buyers for appraisal or testing, but not for transporting ore on a continuing basis.

Effect of Ore Valuation on Truck Freight Rates

Truck freight tariffs normally make no mention of the value of ore. However, the probable value is no doubt considered when a freight rate for a particular haul is set. Some rates increase for valuations over $50 or over

$100, but these are uncommon. Two examples have been listed in appendix O: The truckload and less-than-truckload rates in example 4 apply to ore having a value up to $100 per ton; ore of higher valuation is subject to higher rates. In example 8, the tariff provides for a 5-percent increase in freight rate for each $10 increase in ore valuation above the $50 per ton.

Governmental Regulation of Ore Hauling by Truck

Freight rates for intrastate ore-trucking operations in the Western States are subject to a minimum of regulation. Regulations in the different States differ in detail but, in general, are concerned chiefly with assignment of franchises covering routes and territories. Contract carriers are not required to file rates in most States, and the few published rates are issued by carriers' cooperative tariff bureaus. At least two States have a requirement that a contract rate offered by a carrier must not be less than an approved commodity rate issued by a common carrier, but no limit is set on the maximum charge. One State issues a distance-commodity rate table which represents the minimum rates truckers may charge (example 8, appendix O). The rates in this table are below actual rates currently in effect.

Comparison of Railroad and Truck Freight Costs

By reference to freight rate tables, a comparison can be made of the truck and railroad freight rates applying to certain ore-hauling routes. In nearly every case, the cost of an all-rail haul on any ore or concentrate in carload quantities over a given route is less than for an all-truck haul, the advantage of rail shipments over truck shipments increasing with the distance, but decreasing with increase in ore valuation. Two exceptions appear to be shipments from Placerville and Colfax, Calif., to the Selby, Calif. smelter, distances of 105 and 113 miles, respectively (appendix M and appendix N). In both cases the truck rate is less than the rail rate. LCL rates for a given haul are always higher than truck rates in truckload lots. Truckload quantities range from 5 to 20 tons and occasionally more, depending on road conditions, length of haul, available equipment, and shippers' requirements.

The high freight rates applying to less-than-carload and less-than-truckload lots show conclusively that shipment of less than minimum carload or truckload quantities is uneconomical for most base-metal ores. For high-grade ores or concentrates, such shipments may be economically feasible but are probably avoided if there is a possibility of accumulating a carload or truckload.

Figure 8 shows ton-mile rail shipping costs for ore products in carload lots based on point-to-point commodity rates published by four western railroads. The data, plotted according to length of haul, cover a distance range up to 250 miles. A value of $50 per ton is assumed for all shipments. An average curve has been constructed to show the relation between ton-mile cost and distance. An extension of this curve into a distance range over 250 miles would show that the ton-mile cost continues to level off, approaching a lower limit of about 1.5 cents per ton-mile. The different ton-mile costs reported

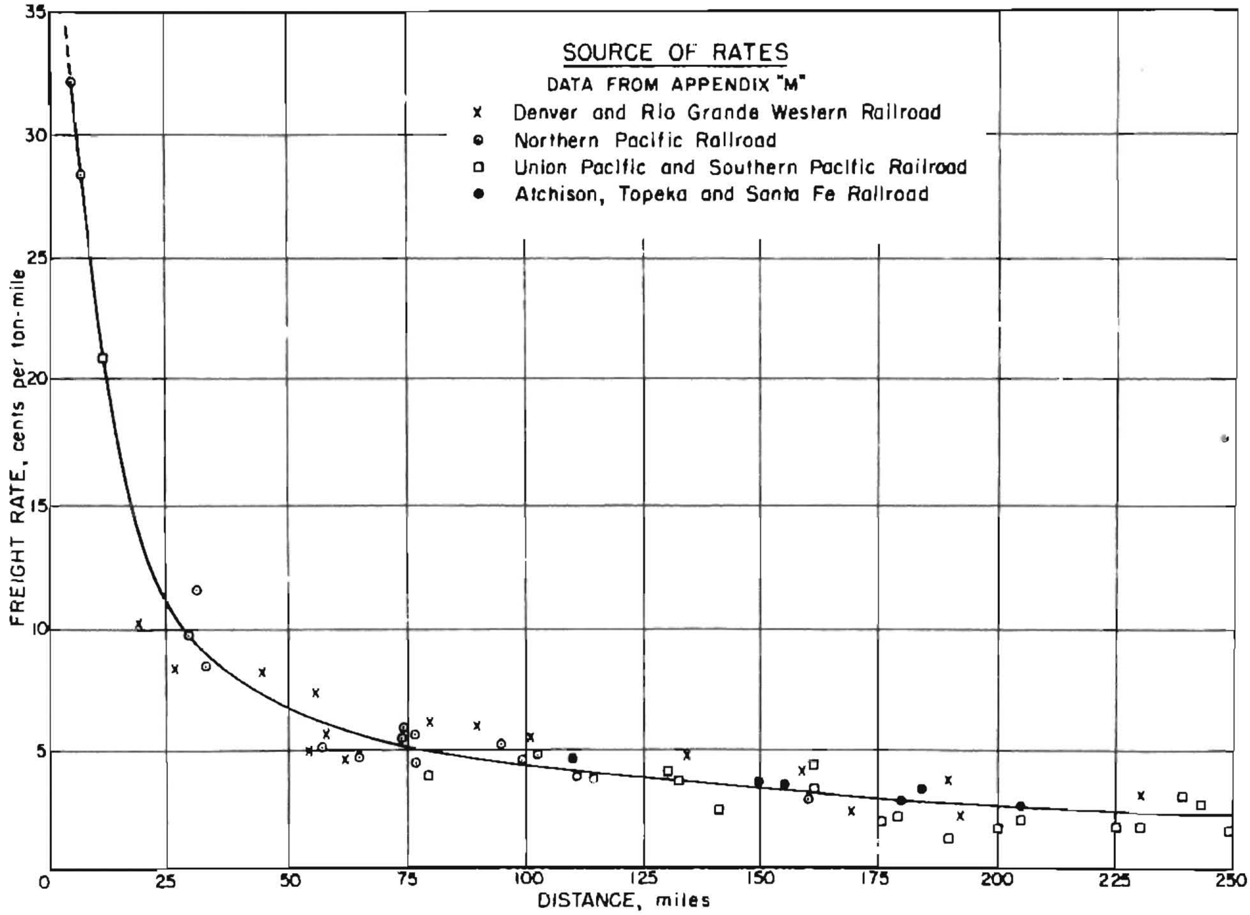


FIGURE 8. - Freight Rates for Ores and Concentrates on Four Western Railroads.

for the same distances are caused by the operation of such factors as type of terrain traversed by the rail routes, branchline or mainline operation, volume of traffic, and competition.

Figure 9 is a graphic comparison of rail and truck ton-mile costs based on the railroad rate data used in figure 8 and truck-distance-commodity rates in examples 2 and 3 of appendix O. This graph shows clearly the rise in both truck and rail ton-mile rates with decreasing distance and the rapidly increasing rate of rise below 25 miles. Although the curves are extended into the distance range under 10 miles, based on a few railroad rates and truck-distance-commodity tables, the values are misleading for estimates because this distance range generally is in the field of local truck hauling where rates are governed by local conditions and set by contract rather than by published tariffs.

When all-rail facilities are not available, a shipper may have a choice between all-truck haulage and combined truck-rail haulage, assuming good highway conditions. Under normal conditions, truck-rail haulage for distances over 50 miles tends to be cheaper than trucking alone, unless the necessary

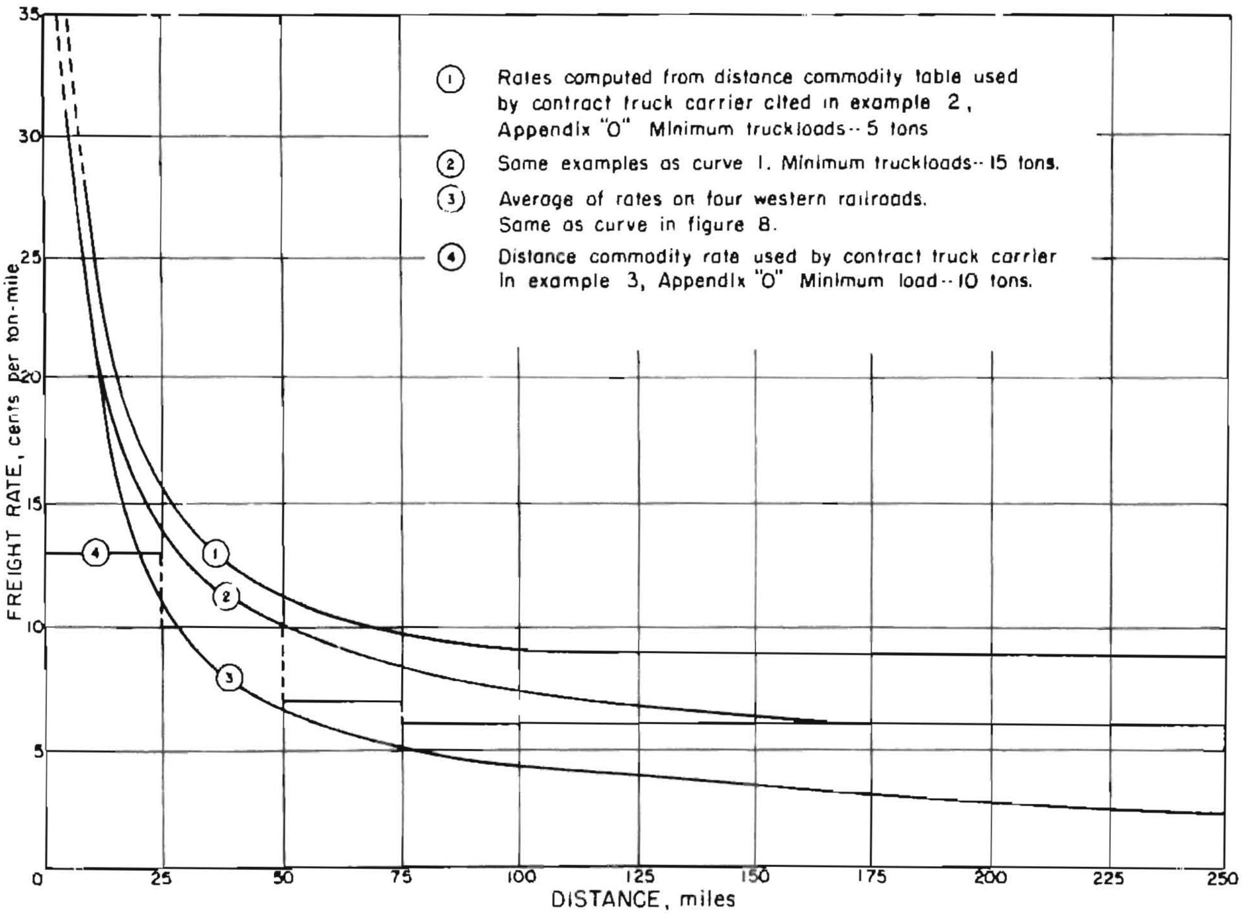


FIGURE 9. - Comparison of Railroad and Truck Freight Rates.

truck portion of the haul approaches or exceeds the possible rail portion. For total distances under 50 miles, straight truck haulage normally is cheaper. Each case must be considered individually in the light of all the factors involved. Some of these factors may be: The cost of transferring ore from trucks to railroad cars; additional charges, if any, for unloading trucks at destination; disparities in total hauling distances due to differences in the routes followed by railroads and highways; and limitations on size of trucking equipment because of the road or other conditions.

Freight costs applying to shipments of a mine product to different markets may have a wide range. The distance, and consequently the shipping cost, to one market may be lower than to any other; when the differences are large, the market requiring the shortest haul is more likely to bring the highest return to the shipper. Possible exceptions are cases where treatment rates at a more distant plant are favorable enough to compensate for the greater shipping cost.

Obviously a shipper's choice of transportation routes is limited to the means available. After a survey of possible routes, an estimate of the probable cost of delivering ore or concentrates to market can be made, based on distance, comparison of truck and rail routes, readiness of suitable trucking firms to serve, and perhaps other factors. If the prospective haul is in an active mining district, freight rates can be ascertained quickly from truck operators or railroads. If a new hauling operation, perhaps remote from the territory served by active carriers, is proposed, a preliminary cost estimate can be made, for which data included in this circular may be helpful. Carriers who will undertake the hauling operation must then be found, and the freight rates quoted by them will, of course, govern. Such rates may not necessarily agree with previously estimated rates but ought to be in the same general range. A rate for a new haul quoted by a carrier may be experimental and will probably be subject to revision, if later experience and volume of traffic require a change.

Transportation Patterns in the East

Few small base-metal mines are in operation east of the Rocky Mountains, and an increase in this type of operation is not anticipated. Consequently, the problems of hauling ore from such operations are minor, and detailed analysis of transportation patterns in these States, as affecting small mines, is not warranted.

Most of the production of base metals in the Midwestern and Eastern States is in the hands of large operators. An exception is in the Tri-State District of Missouri, Kansas, and Oklahoma, where small lead-zinc mines are common. However, few of these remain in operation, and in any case transportation of ore constitutes no problem because ore is traditionally sold f.o.b. the mines. The buyer furnishes truck transportation to centrally located concentrating plants.

In general, the factors affecting the transportation of ores in the Western States are also operative in the States east of the Rocky Mountains. The ton-mile rates should, however, be lower. Few point-to-point rail or truck freight tariffs have been established by common carriers to cover movement of base-metal ores over eastern routes that might be used for shipping the product of small mines to markets. Most rates quoted by common carriers would probably be derived from distance-class schedules or set by negotiation, subject to later revision.

BIBLIOGRAPHY

1. Agricola, G. (George Bauer). De Re Metallica, transl. by Herbert Clark Hoover and Lou Henry Hoover. Dover Publications, Inc., 1950, 638 pp.

2. Aitkenhead, W. C., and J. A. Jaekel. Flotation of Some Oxidized and Nonmetallic Ores. Min. Cong. Jour., v. 46, May 1960, pp. 50-54.

3. American Institute of Mining, Metallurgical, and Petroleum Engineers. Copper Metallurgy. Trans., v. 106, 1933, 740 pp.

4. _____. Milling Methods. Trans., v. 112, 1934, 977 pp.

5. _____. Metallurgy of Lead and Zinc. Trans., v. 121, 1936, 748 pp.

6. Bell, J. E., and H. M. McBreen. Gold. BuMines Minerals Yearbook 1954, v. 1, 1958, pp. 507-509.

7. Bray, John L. Non-Ferrous Production Metallurgy. John Wiley and Sons, Inc. New York, 1941, 430 pp.

8. Engel, A. L., and H. J. Heinen. Experimental Treatment of Base Metal Ores From California and Nevada. BuMines Rept. of Inv. 5566, 1960, 9 pp.

9. Engineering and Mining Journal. Arizona Copper Silicates Respond to Segregation. V. 161, November 1960, pp. 86-87.

10. Fergus, A. J., and W. C. Aitkenhead. The Flotation of Oxidized Zinc Ores From Washington. Washington State Inst. Technol., Bull. 245, 1958, 42 pp.

11. Freeman, G. A., Carl Rampacek, and L. G. Evans. Copper Segregation at the Lakeshore Mines. Pres. at the ann. meeting of the Extractive Metallurgical Division, AIME, St. Louis, Mo. Feb. 27, 1961, 13 pp.

12. Gardner, E. D. Gold and Silver Custom Plants. BuMines Inf. Circ. 6842, 1935, 4 pp.

13. _____. Cost of Trucking and Packing Ore in Western Gold Mining District. BuMines Inf. Circ. 6898, 1936, 17 pp.

14. Gardner, E. D., and P. T. Allsman. Open Schedules for Gold and Silver Ores and Concentrates at Western Custom Smelters. BuMines Inf. Circ. 6926, 1936, 25 pp.

15. Henderson, C. W. Mining in Colorado. Geol. Survey Professional Paper 138, 1926, 263 pp.

16. Jackson, C. F., and J. B. Knaebel. Sampling and Estimating Ore Deposits. BuMines Bull. 356, 1932, 155 pp.

17. Jaekel, J. A. New Guides to Chrysocolla Flotation. Mining World, v. 21, July 1959, pp. 44-46.

18. Kaufman, Alvin. Southeastern Alaska's Mineral Industry. BuMines Inf. Circ. 7844, 1958, 37 pp.

19. Lamb, Graham. Marketing Concentrates. Denver Equipment Company, Denver, Colo., Bull. 3713-B, 1937, 12 pp.

20. Morgan, S. W. K., and J. Lumsden. Zinc Blast Furnace Operation. J. Metals, April 1959, pp. 270-275.

21. Newton, Joseph, and Curtis L. Wilson. Metallurgy of Copper. John Wiley and Sons, Inc., New York, 1942, 516 pp.

22. Parsons, A. B. Marketing of Metalliferous Ores and Concentrates. Eng. and Min. J., v. 114, Dec. 23, 1922, pp. 1109-1114; v. 114, Dec. 30, 1922, pp. 1155-1162.

23. Peele, Robert. Mining Engineer's Handbook. John Wiley and Sons, Inc., New York, 3d ed., v. I, 1941, pp. 10-81 - 10-533.

24. _____. Mining Engineer's Handbook. John Wiley and Sons, Inc., New York, 3d ed., v. II, 1941, pp. 29-01 - 29-17, 31-02 - 33-31.

25. Powell, H. E. Beneficiating a Complex Sulfide-Oxide Lead-Zinc Ore From Missouri. BuMines Rept. of Inv. 5564, 1960, 10 pp.

26. Rampacek, Carl, W. A. McKinney, and P. F. Waddleton. Treating Oxidized and Mixed Oxide-Sulfide Copper Ores by the Segregation Process. BuMines Rept. of Inv. 5501, 1959, 28 pp.

27. Richards, R. H., and C. E. Locke. Textbook of Ore Dressing. McGraw-Hill Book Co., Inc., New York, 1940, 608 pp.

28. Spurr, J. E., and F. E. Wormser. Marketing Metals and Minerals. McGraw Hill Book Co., Inc., New York, 1925, 674 pp.

29. Taggart, A. F. Elements of Ore Dressing. John Wiley and Sons, Inc., New York, 1951, 595 pp.

30. _____. Handbook of Ore Dressing. John Wiley and Sons, Inc., New York, 1927, 1679 pp.

31. Tsuromato, Tamon. Copper Smelting in the Converter, J. Metals, November 1961, pp. 820-824.

32. Wright, C. W. Mining Methods and Costs at Metal Mines in the United States. BuMines Inf. Circ. 6503, 1931, 39 pp.

33. _____. Essentials in Developing and Financing a Prospect Into a Mine. BuMines Inf. Circ. 6839, 1935, 22 pp.

34. Van Arsdale, George D. Hydrometallurgy of Base Metals. McGraw-Hill Book Co., Inc., New York, 1953, 370 pp.

35. Zinc, the Science and Technology of the Metal, Its Alloys and Compounds. Am. Chem. Soc. Monograph Series No. 142, ed. by C. H. Mathewson. Reinhard Pub. Corp., New York, 1959, 721 pp.

APPENDIX A. - TYPICAL OPEN PURCHASE SCHEDULES AT SELECTED COPPER AND LEAD SMELTERS, ZINC PLANTS, AND CONCENTRATING MILLS IN THE WEST[1]

Schedule	Plant type	Mine products covered	Metal payments[2]: Metals paid for	Metal payments[2]: Minimum metal content paid for	Metal payments[2]: Payments based on assay content of material treated, less any deductions, computed at applicable market or Government prices, less marketing and/or refining charges for refining metal	Treatment charges: Base charge per ton[3]	Treatment charges: Charges or credits added to or subtracted from the base charge per ton	Debit or credit for other mineral content: Mineral or metal[4]	Debit or credit for other mineral content: Debit for undesirable content above the maximum allowed free or credit for desirable content for which premium is paid
1	Copper smelter A (Arizona)	Copper ore	Copper	0.5 percent[5]	Pay for 95 percent of assay content[2] at market less 3.5¢ per pound (subject to a minimum deduction of 8 pounds per ton).	$5.50	Add 10 percent of metal payments in excess of $15.00 up to a maximum of $7.50.	Zn	Debit for content above 5 percent at $0.30 per unit.[7]
								Sb, As, Bi	Not acceptable.
								Al_2O_3	Debit for content above 10 percent of SiO_2 content at $0.25 per unit.
			Gold	0.03 ounce/ton[6]	Pay for 100 percent of assay content at $32.3185 per ounce.				
			Silver	0.5 ounce/ton	Pay for 95 percent of assay content at market or mint price less 1.5¢ per ounce (minimum deduction of 0.5 ounce per ton).				
2	do.	Copper concentrates	Copper		Deduct 1 percent from assay content and pay for 100 percent of remainder at markes less 3.5¢ per pound.	13.50	None.	Al_2O_3	Debit for content above 10 percent of SiO_2 content at $0.25 per unit.
			Gold	0.03 ounce/ton	Pay for 100 percent of assay content at $32.3185 per ounce.			Zn	Debit for content above 5 percent at $0.30 per unit.
			Silver	0.5 ounce/ton	Pay for 95 percent of assay content at market or mint price less 1.5¢ per ounce (minimum deduction of 0.5 ounce per ton).			Ab, As, Bi	Not acceptable.
3	do.	Gold and silver ore or concentrates with minor base metals	Copper	1.0 percent	Deduct 1 percent from assay content and pay for 100 percent of remainder at market less 3.5¢ per pound.	10.00	None.	Zn	Debit for content above 7 percent at $0.30 per unit.
								Sb	Debit for content above 1 percent at $1.50 per unit.
			Gold	0.03 ounce/ton	Pay for 91.14 percent of assay content at mint price.			As	Do.
			Silver	1.0 ounce/ton	Pay for 95 percent of assay content at market or mint price less 1.5¢ per ounce (minimum deduction of 1.0 ounce per ton).			Bi	Debit for all at $0.50 per pound.
			Lead		No payment.				
4	do.	Dry gold-silver ore	Gold	0.03 ounce/ton	Pay for 100 percent of assay content at $32.3185 per ounce.	5.50	Add 10 percent of metal payments in excess of $15.00 up to a maximum of $7.50 total treatment.	Cu	Debit for the difference in pounds between the actual content and 8 pounds per ton computed at the terms applicable for copper payment. (Schedule not applicable if copper content exceeds 8 pounds per ton).
			Silver	0.5 ounce/ton	Pay for 95 percent of assay content at market or mint price less 1.5¢ per ounce (minimum deduction of 0.5 ounce per ton).				
5	Copper smelter B (Arizona)	Copper ore and concentrates	Copper	0.8 percent	Pay for 90 percent of assay content (deduction to be not less than 10 pounds or more than 20 pounds per ton) at market less 4.0¢ per pound.	9.00	Add 10 percent of metal payments in excess of $15.00 up to $40.00 and an additional 5 percent of payments in excess of $40.00	SiO_2	Credit $0.05 per unit of SiO_2 in excess of a content equal to the sum of 10 times Al_2O_3 content plus Fe content plus lime content.
			Gold	0.03 ounce/ton	Pay for 100 percent of assay content at $32.20 (92 percent of U.S. Treasury price of $35.00).				
			Silver	1.0 ounce/ton	Pay for 95 percent of assay content at market or mint price.				

See footnotes at end of table.

Schedule	Plant type	Mine products covered	Metal payments[2]: Metals paid for	Minimum metal content paid for	Payments based on assay content of material treated, less any deductions, computed at applicable market or Government prices, less marketing and/or refining charges for refining metal	Treatment charges: Base charge per ton[3]	Charges or credits added to or subtracted from the base charge per ton	Debit or credit for other mineral content: Mineral or metal[4]	Debit for undesirable content above the maximum allowed free or credit for desirable content for which premium is paid
6	Copper smelter B (Arizona)	Siliceous gold-silver ore (minimum silica content 70 percent)	Gold	0.03 ounce/ton	Pay for 100 percent of assay content at $32.20 per ounce.	$5.50	Add 10 percent of metal payments in excess of $15.00 up to $40.00 and an additional 5 percent of payments in excess of $40.00	Cu	Debit for the difference in pounds between actual content and 8 pounds per ton computed at the terms applicable for copper payment. (Not applicable if copper content exceeds 8 pounds per ton).
			Silver	1.0 ounce/ton	Pay for 95 percent of assay content at market or mint price.				
			Copper	0.8 percent	Pay for 90 percent of assay content (deduction to be not less than 10 pounds or more than 20 pounds per ton) at market less 4.0¢ per pound.			SiO_2	Credit $0.05 per unit of SiO_2 in excess of a content equal to the sum of 10 times Al_2O_3 content plus Fe content plus CaO content.
7	Copper smelter C (Arizona)	Copper ore	Copper	1.0 percent	Pay for 90 percent of assay content (deduction to be not less than 10 pounds or more than 30 pounds per ton) at market less 3.5¢ per pound.	6.00	Add 10 percent of metal payments in excess of $15.00 up to $30.00 and an additional 5 percent of payments in excess of $30.00 up to a maximum of $20.00 total treatment.	Al_2O_3	Debit for content of Al_2O_3 above 10 percent at $0.25 per unit.
								CaO	Credit for CaO content above 10 percent at $0.04 per unit up to a maximum of 25 units, if SiO_2 content is less than 40 percent and Al_2O_3 content is less than 10 percent.
			Gold	0.03 ounce/ton	Pay for 100 percent of assay value at $32.20 per ounce.				
			Silver	1.0 ounce/ton	Pay for 95 percent of assay content at market or mint price.				
8	Copper smelter D (Montana)	Copper, gold, and/or silver ore	Copper	0.5 percent	Pay for 96 percent of assay content (minimum deduction 10 pounds per ton) at market less 3.5¢ per pound.	4.00	Add 10 percent of metal payments in excess of $15.00.	Fe	Debit $0.12 per percent per ton.
								SiO_2	Credit $0.025 per percent per ton in excess of Al_2O_3 content.
			Gold	0.01 ounce/ton	Deduct 0.01 ounce per ton from assay content and pay for 100 percent of remainder at $31,81825 per ounce.				
			Silver	1.0 ounce/ton	Pay for 95 percent of assay content at market or mint price less 6.0¢ per ounce (minimum deduction of 1.0 ounce per ton).				
			Lead		No payment.				
9	Lead smelter A	Lead ore or concentrates (zinc content recovered but not paid for)	Lead	3.0 percent	Deduct 1.5 percent from assay content and pay for 90 percent of the remainder at market less 2.0¢ per pound.	7.50 (30 percent Pb content)	Add 10¢ per ton per unit of Pb under 30 percent content. Deduct 10¢ per ton per unit of Pb over 30 percent.	Zn	Debit for content above 10 percent at $0.30 per unit.
								As, Sb, Sn (combined)	Debit for content above 1 percent at $0.50 per unit.
			Copper	1.3 percent	Deduct 1.3 percent from assay content and pay for 100 percent of the remainder at market less 9.0¢ per pound.			Bi	Debit for all at $0.50 per pound.
			Gold	0.03 ounce/ton	Pay on the following percentage of mint price: 0.03 ounce or over and less than 5.00 ounce/ton--91.14 percent; 5.00 ounces or over and less than 10.00 ounces/ton--92.57 percent; 10.00 ounces or over and less than 15.00 ounces/ton--93.28 percent; 15.00 ounces per ton or over--94.00 percent.				

			Silver	1.0 ounce/ton	Pay for 95 percent of assay content at market or mint price less 1.0¢ per ounce.				
10	do.	Gold-silver ores or concentrates	Lead	3.0 percent	Payment same as in preceding lead ore schedule 9.	$10.00	Add 10 percent of metal payments over $20.00 per ton up to a maximum of $17.50 per ton.	Zn	Charge same as in preceding lead ore schedule 9.
			Copper	1.3 percent	do.			As, Sb, Sn (combined)	Do.
			Gold	0.03 ounce/ton	do.				
			Silver	1.0 ounce/ton	do.			Bi	Do.
11	Lead smelter B (with zinc recovery plant)	Lead ore or concentrates (zinc content recovered but not paid for)	Lead	3.0 percent	Pay for 90 percent of dry assay (wet assay less 1.5 percent) at market less 2.65¢ per pound.[a]	11.00 (30 percent Pb content dry assay)	Add 10¢ per ton per unit of Pb under 30 percent content. Deduct 10¢ per ton per unit of Pb over 30 percent content.	Zn As	Debit for content above 12 percent at $0.30 per unit. Debit for all at $2.25 per unit.
			Copper	0.75 percent	Pay for 80 percent of assay content (minimum deduction 15 pounds per ton) at market less 9.5¢ per pound.			S	Debit for content above 2 percent at $0.25 per unit (maximum charge $2.25).
			Gold	0.02 ounce/ton	Pay for 100 percent of the content at the following rate based on a mint price of $$34.9125 per ounce: 0.02 ounce or over and up to 5.00 ounces per ton--$31.8183; over 500 ounces and up to 10.00 ounces per ton--$32.3183; over 10.00 ounces per ton--$32.8183.			$SiO_2+Al_2O_3$ CaO	Debit for all at $0.10 per unit. Credit for all at $0.05 per unit if 5 percent or more is contained.
			Silver	1.0 ounce/ton	Pay for 95 percent of assay content (minimum deduction 0.5 ounce per ton) at market or mint price.				
12	Buying station C for lead smelter	Less-than-carload lots of load concentrates	Lead	1.5 percent	Deduct from the wet assay 1.5 percent and pay for 90 percent of the remainder at the market less 2.4¢ per pound.	15.00 (25 percent Pb content)	Add to base charge 10¢ per ton for each unit of lead (by wet assay) under 25 percent. Add freight to smelter at minimum carload rate and $25.00 sampling charge.	-	
			Copper	1.0 percent	Deduct from the wet assay 1.0 percent and pay for 95 percent of the remainder at market less 9.0¢ per pound				
			Gold	0.03 ounce/ton	Pay for all at 91.14 percent of mint price ($35.00 less 0.25 percent) when assay content is over 0.03 ounce or over and less than 1.0 ounce per ton. Pay for all at 92.57 percent of the mint price when assay content is 1.0 ounce per ton or over.				
			Silver	1.0 ounce/ton	Pay for 95 percent of the assay content (minimum deduction 1.0 ounce per ton) at the market or mint price less 1.5¢ per ounce.				
13	Lead smelter D (with lead-zinc concentrator and zinc recovery plant)	Lead-zinc ore or concentrates with recoverable zinc	Lead	3.0 percent	Deduct 1.5 percent from assay content and pay for 90 percent of remainder at market less 2.4¢ per pound.	12.00		As Sb	Debit for all at $1.00 per unit. Debit for all at $0.75 per unit.
			Copper	0.75 percent	Deduct 0.75 percent from assay content and pay for 100 percent of the remainder at market less 6.7¢ per pound.				
			Zinc	8.0 percent	Pay for 75 percent of the assay content at 30 percent of the market.				
			Gold	0.02 ounce/ton	Pay for 91 percent of the assay content at the mint price.				
			Silver	1.0 ounce/ton	Pay for 95 percent of the assay content (minimum deduction 0.5 ounce per ton) at the market or mint price.				

See footnotes at end of table.

			Metal payments[2]			Treatment charges			
Schedule	Plant type	Mine products covered	Metals paid for	Minimum metal content paid for	Payments based on assay content of material treated, less any deductions, computed at applicable market or Government prices, less marketing and/or refining charges for refining metal	Base charge per ton[3]	Charges or credits added to or subtracted from the base charge per ton	Debit or credit for other mineral content: Mineral or metal[4]	Debit or credit for other mineral content: Debit for undesirable content above the maximum allowed free or credit for desirable content for which premium is paid
14	Lead smelter E (with lead-zinc concentrator and zinc recovery plant)	Direct smelting lead ore, lead-zinc milling ore, lead concentrates, zinc concentrates	Lead	2.5 percent	Pay on the following percentages of assay content at market less 1.5¢ per pound when lead quotation is 15¢ per pound: 2.5 percent or over and less than 25 percent--90 percent, 25 percent or over and less than 50 percent--91 percent, 50 percent or over--92 percent. For each 1.0¢ per pound increase or decrease in the lead quotation of 15¢ per pound increase or decrease the marketing deduction charge of 1.5¢ per pound by 0.033¢ per pound.	\$8.00 (50 percent Pb content or over)	Add 10¢ per ton per unit of Pb under 50 percent content. (Treatment charge covers milling cost, if any)	Fe do. SiO_2 CaO As Bi	Debit \$0.40 per unit for Fe content under 1.8 times the Zn content. Credit \$0.40 per unit of Fe over 1.8 times the Zn content. Debit \$0.08 per unit for SiO_2 content under Fe content. Credit \$0.08 per unit for SiO_2 content over Fe content. Debit \$0.10 per unit for CaO content under Fe content. Credit \$0.10 per unit for CaO content over Fe content. Debit for content above 1 percent at \$1.00 per unit. Debit for content above 0.1 percent of the wet lead assay at \$0.50 per pound.
			Copper	0.5 percent	Pay for 85 percent of the assay content at 60 percent of the applicable copper quotation less 30 percent of the applicable lead quotation, negative values applying.			S	Debit for content above 16 percent at \$0.10 per unit.
					Pay for 85 percent of the assay content at 60 percent of the applicable copper quotation less 30 percent of the applicable lead quotation, negative values applying.				
			Gold	0.03 ounce/ton	Pay for 100 percent of the content at the following rate: 0.03 ounce or over and less than 3.0 ounces per ton--\$31.81825/ounce; 3.0 ounces per ton and over--\$32.81825/ounce.				
			Silver	1.0 ounce/ton	Pay for 95 percent of the assay content at the market or mint price less than 1.5¢ per ounce.				
			Zinc	2.5 percent	Pay for 50 percent of the assay content at 25 percent of the applicable zinc quotation.				
			Antimony	1.0 percent	Pay for 70 percent of the content at 50 percent of the applicable antimony quotation less the applicable lead quotation, negative values applying.				
[illegible]	Zinc smelter	Zinc concentrates and zinc-lead concentrates (sulfide) (Horizontal retorts)	Zinc		If content is 40 percent or more, pay for 85 percent of the assay content at market less 57.5¢ per 100 pounds of zinc accounted for. If content is less than 40 percent, deduct 8 units and pay for the remainder at the same rate.	38.00	Add \$1.00 for each 1.0¢ increase in the St. Louis zinc quotation over 6.0¢ per pound. Add \$0.15 for each 1.0¢ increase in hourly labor rate	Fe-Mn (combined) As-Sb (combined) CaO-MgO (combined)	Debit for content above 70 percent at \$0.50 per unit. Debit for content above 0.5 percent at \$1.00 per unit. Debit for content above 1.0 percent at \$1.00 per unit.
			Lead	4.0 percent	Deduct 4 percent from the wet assay content and pay for 80				

					percent of the remainder at market less 2.0¢ per pound.		over $1.677/hour. Add $0.40 for each 1.0 increase in natural gas cost over 7.0¢ per M.C.F.		
			Copper	1.0 percent	Pay for 65 percent of assay content at the market less 6.0¢ per pound of Cu accounted for.				
			Gold	0.03 ounce/ton	Pay for 80 percent of the assay content at 92.57 percent of the mint price.				
			Silver	1.0 ounce/ton	Pay for 80 percent of the assay content (minimum deduction 1.0 ounce per ton) at market or mint price.				
16	Electro-lytic zinc plant A	Zinc con-centrates (lead content acceptable)	Zinc		Deduct 3.0 percent from assay content and pay for 80 percent of remainder at market.	16.00 (45 per-cent Zn content)	Add $2.50 for each 1.0¢ increase in the zinc quota-tion over 4.0¢. Add $0.05 per ton per unit of Zn under 45 percent.	Fe	Debit for all at $0.30 per unit.
								Pb	Debit $1.00 per ton for each unit of lead under 3 units.
			Lead	3.0 percent	Deduct 3.0 percent from assay content and pay for 80 percent of remainder at market.				
			Gold	0.01 ounce/ton	Pay for 80 percent of assay content at $34.2425 per ounce.				
			Silver	1.0 ounce/ton	Pay for 80 percent of assay content at market or mint price.				
17	Electro-lytic zinc plant B	Zinc ore or con-centrates (lead content acceptable)	Zinc		Payment on sliding scale from 80 to 85 percent of market for assay content from 50 to 55 percent and over. Payment for assay content under 50 percent at 75 percent of market.	45.00	Add $2.00 per ton for each 1.0¢ increase in the zinc quotation above 10¢ per pound	Fe	Debit for content above 2 percent at $0.40 per unit.
								$SiO_2+Al_2O_3$	Debit for content above 4 percent at $0.60 per unit.
								CaO	Debit for content above 0.5 percent at $0.50 per unit.
			Lead	3.0 percent	Deduct 3 percent of assay content and pay for remainder at market less 2.0¢ per pound.			MgO	Debit for content above 0.1 percent at $2.50 per unit.
								As	Debit for content above 0.1 percent at $1.00 per unit.
			Cadmium	0.25 percent	Deduct 0.25 percent from assay content and pay for remainder at market less 50.0¢ per pound.			Sb	Debit for content above 0.1 percent at $3.00 per unit.
			Gold	0.03 ounce/ton	Pay for 80 percent of assay content at $34.2425 per ounce.				
18	Selective flotation mill A	Complex sulfide lead-zinc ores with or without minor copper, gold, and/or silver	Lead-copper	3.0 percent (sulfides only)	Pay for 70 percent of the combined sulfide lead and copper content at the market quotation for lead less 3.15¢ per pound.	4.00	Deduction made in computing metal payments cover all smelting and refining costs that will be incurred in further proc-essing of mill products.	Oxide Pb, Cu, Zn	Only sulfide Pb, Cu, and Zn content is paid for, so content of these metals present as oxides must be deducted from total metal content before computation of metal products.
			Zinc	do.	Pay for 60 percent of the sulfide zinc content at 40 percent of the market. Special payment: For each percent zinc in excess of 15 percent add 1 percent to the zinc percentage paid for up to a maxi-mum of 70 percent. For each per-cent of zinc in excess of 15 per-cent add to the payment for such metal $0.0005 per pound, but in no event shall the additional payment exceed $0.005 (5 mills) per pound.				
			Gold	0.02 ounce/ton	Pay for 50 percent of the assay content at $22.4643 per ounce while mint price is $34.9125.				
			Silver	1.0 ounce/ton	Pay for 70 percent of the assay content (minimum deduction 1.0 ounce per ton) at market or mint price.				

See footnotes at end of table.

Schedule	Plant type	Mine products covered	Metal payments[2]: Metals paid for	Metal payments[2]: Minimum metal content paid for	Metal payments[2]: Payments based on assay content of material treated, less any deductions, computed at applicable market or Government prices, less marketing and/or refining charges for refining metal	Treatment charges: Base charge per ton[3]	Treatment charges: Charges or credits added to or subtracting from the base charge per ton	Debit or credit for other mineral content: Mineral or metal[4]	Debit or credit for other mineral content: Debit for undesirable content above the maximum allowed free or credit for sedirable content for which premium is paid
19	Selective flotation mill B	Complex sulfide lead-zinc ores with or without minor gold, and/or silver	Zinc	3.0 percent	Pay for 70 percent of the sulfide zinc content (minimum deduction 3 percent) at the market less 5.3¢ per pound when the zinc price is 10.0¢ per pound. The deduction is increased by 0.4¢ for each 1.0¢ increase in the market price above 10.0¢ per pound, or decreased 0.4¢ for each 1.0¢ decrease in the price below 10.0¢ per pound.	$4.00	Deductions made in computing metal payments cover all smelting and refining costs that will be incurred in further processing of mill products. Treatment charge and payments are based on labor cost of $19.56 and $26.52 bullion freight.	Oxide Pb, Cu, Zn	Only sulfide Pb, Cu, and Zn content is paid for, so content of these metals present as oxides must be deducted from total metal content before computation of metal payments. Debit for content above 1.0 percent at $1.00 per unit.
			Lead	1.0 percent	Pay for 80 percent of the sulfide lead content (minimum deduction 1 percent) at the market less 3.0¢ per pound.				
			Gold	0.02 ounce/ton	Pay for 70 percent of the assay content (minimum deduction 0.02 ounce per ton) at the mint price.				
			Silver	0.5 ounce/ton	Pay for 80 percent of the assay content (minimum deduction 0.5 ounce per ton) at the market or mint price.				

[1]For calculation purposes only; purchase terms are subject to change without notice in accordance with variations in costs of labor, fuel, supplies, marketing, and refining charges. The examples given apply to minimum shipments (usually at least 10 tons) delivered to the buyers' plants in rail or truck equipment that can be unloaded into receiving hoppers by available mechanical facilities. Extra charges are made for material that does not meet the standard conditions specified by the ore buyer (see the section of the text covering general specifications of purchase and settlement).

[2]Payments for metals are based on the assay content of material as received, metal losses incurred in treatment, marketing and refining costs, and current market prices for refined metals (see section on basis of payments). The "assay content" of an ore product is the content with respect to any metal or mineral constituent expressed as a grade and is determined from a representative sample by analytical means. Assay content of gold and silver is expressed as ounce per ton and of base metals or other mineral constituents, as a percentage. The content of gold, silver, lead, antimony, and tin can be determined by fire assaying, a miniature smelting process carried on in the laboratory in a small furnace. Fire assaying is no longer used for the base metals but remains the standard method for gold and silver. Assaying for content of base metals and other minerals is now done by chemical analysis, referred to as wet assaying as contrasted with fire or dry assaying. For ore settlement purposes, 1.5 percent is subtracted from the wet lead assay or an ore before calculation of lead payment. This 1.5 percent represents smelting losses. At one time, lead payment was made on the basis of a lead content to fire assay which took into account smelting losses. One current smelter schedule, schedule 11, still related lead content to fire assay results, although this content is actually computed by subtracting 1.5 percent from the wet lead assay. Treatment schedules also allow for smelting or processing losses on other metals by specifying a deduction from the assay content before calculation of metal payments.

[3]Ton: The unit of weight used for bulk materials in the base-metal smelting industry is the short ton of 2,000 pounds avoirdupois. This unit should not be confused with the long ton of 2,240 pounds used in the steel industry.

[4]Chemical symbols

Compound of metal	Chemical symbol	Compound or metal	Chemical symbol
Gold	Ag	Tin	Sn
Silver	Ag	Iron	Fe
Copper	Cu	Silica	SiO_2
Lead	Pb	Alumina	Al_2O_3
Zinc	Zn	Insoluble ("Insol")	$SiO_2 + Al_2O_3$
Antimony	Sb	Lime	CaO
Arsenic	As	Magnesia	MgO
Bismuth	Bi	Sulfur	S
Cadmium	Cd		

[5]Percent: Base metal ore grades are commonly expressed as percentages.

[6]Ounce: The troy ounce is the weight unit used for precious metals. Gold and silver ore grades are expressed in ounces per ton.multiplied by the total weight of the lot in tons gives the total precious metal content in ounces. Precious metal market quotations in the United States are all in terms of the troy ounce. One short ton contains 29,166 troy ounces and 1 pound avoirdupois is equivalent to 14.583 troy ounces.

[7]Unit: In the smelting industry the word "unit" means 20 pounds, which is 1 percent of a short ton of 2,000 pounds. Therefore, 1 unit per ton of any base-metal or mineral constituent is equal numerically to a 1-percent content, and ore grades of 1 percent, 1 unit per ton, and 20 pounds per ton are equivalent. An ore grade expressed either in percent or in units per ton of any constituent multiplied by the total weight of an ore lot in tons gives the total content in units of that constituent. Units multiplied by 20 gives total content in pounds. Smelter treatment schedules may list penalties or premiums in terms either of units or pounds of the ore constituent concerned. An exception is cited in schedule 8, in which penalties and premiums are listed as cents per percent per ton.

APPENDIX B.- CYANIDATION PLANT TREATMENT SCHEDULE APPLICABLE TO DRY GOLD-SILVER ORES

Payments

Gold: No payment for gold when under 0.03 ounces per ton. When settlement is 0.03 ounces per ton or over, pay for all gold at $35 per ounce.

Silver: No payment for silver when under 1.0 ounce per ton. Payment for silver will be made, under the existing Government regulations on the basis of 90 cents per ounce, on the following schedule, providing, as required by the U.S. Treasury Department, miner's silver affidavits are promptly furnished; otherwise the following rule will be followed: Market quotation date immediately preceding date of settlement, excluding fractions of cents.

Silver contents: Pay for 50 percent of silver in ore containing 1 ounce and including 10 ounces. Pay 75 percent of silver in ore when over 10 ounces. The above payments subject to change without notice. No payment for metals other than gold and silver.

Note: The following products will not be accepted for treatment at this plant:

Concentrates, except by special agreement.
Ore containing copper in excess of 0.1 percent.
Ore containing zinc in excess of 0.3 percent.

Treatment Deductions

Base charge $3.00 per ton, on dry weight, when gross value does not exceed $5.00 per ton. When gross value exceeds $5.00 per ton, add to base charge 25 percent of excess over $5.00 per ton to a maximum rate of $12.00 per ton, when gross value does not exceed $100.00 per ton. When gross value exceeds $100.00 per ton, add to the $12.00 treatment charge, 5 percent of excess over $100.00 per ton.

An extra charge of $10.00 per lot when it contains less than 30 tons dry weight and not less than one ton dry weight; an extra charge of $25.00 per lot when lot contains less than one ton dry weight; an extra charge of 10 cents per ton if ore is sacked; an extra charge of 10 cents per ton if ore is frozen; an extra charge of 5 cents per ton for each 1 percent moisture in excess of 10 percent; Minimum moisture deduction of 1 percent. The above rates are exclusive of trucking rates, and are subject to change without notice.

General Conditions

All new shippers or shippers whose ore changes in character, or shippers who move from one mine to another, must send a 5-lb sample of new ore, charges prepaid, for testing purposes, before shipments are consigned, and must return to mill office an interrogatory signed by the owner of property before shipment is consigned.

Shippers are required to notify mill promptly of all shipments by written notice stating name of mine, owner, lessee (if any) and trucking company. Bin charges may accrue and settlements cannot be completed without such information.

Shipper agrees that after sampling, the shipment (with exception of sample held until settlement effected) may be commingled with other ores, or otherwise disposed of by this plant.

Shipper must agree to settle shipments in accordance with established practice at this plant at the time of shipment, and to insure prompt settlements, must compare assays promptly by telephone, assay certificate or letter to Settlement Clerk, or authorize settlement on mill assays at time of consigning shipment. In the absence of such information within 10 days after receipt of shipment, settlements will be made on mill assays.

No resamples on any shipments to this plant, on which the mill assay is less than 0.15 oz gold per ton. If an umpire is desired on a shipment on which the mill assay is less than 0.15 oz gold per ton, then shipper must pay umpire expense.

The weighing and sampling of any shipment may be inspected at this plant but shippers must pay for these services direct. No deductions for such services will be made on ore settlements.

Trucking charges must either be guaranteed or prepaid by shipper to the trucking company.

Shipment must be completed on the working day following the day on which bin was assigned.

APPENDIX C.- TYPICAL OPEN BUYING SCHEDULE FOR LEAD-ZINC SULFIDE MILLING ORE

Delivery: F.o.b. plant

Sampling: By buyer free of charge

Payments

Gold: Pay for 50 percent of the gold content at $22.4643 per ounce, as long as present U.S. Mint price of $34.9125 per ounce prevails. No payment if less than 0.02 ounce per ton.

Silver: Pay for 70 percent of the silver content (minimum deduction one ounce per ton) at the Handy and Harman New York official quotation, as published in the Engineering and Mining Journal Metal and Mining Markets of New York, for date of assay at plant, or if higher, at the realized U.S. Mint price, if silver qualifies for Government purchase. No payment if less than one ounce per ton.

Lead and copper: Pay for 70 percent of the sulfide lead and copper combined, at the average New York quotation for lead as published in the E & M J for the hournal week previous to date of receipt, less 3.15 cents per pound. No payment if less than 3 percent total lead and copper combined.

Zinc: Pay for 60 percent of the sulfide zinc content at 40 percent of the East St. Louis price for zinc as published in the E & M J for the journal week previous to date of receipt. No payment for zinc if product contains less than 3 percent zinc, total assay.

Special payment: For each percent zinc in excess of 15 percent add 1 percent to the percentage zinc paid for; but in no event shall the percentage zinc paid for exceed 70 percent.

For each percentage of zinc in excess of 15 percent add to the payment for such metal 0.05 cent per lb, but in no event shall the additional payment per pound exceed 0.50 cent per lb.

Charges

Treatment charge: $4.00 per ton

If lots of less than 10 tons are shipped there shall be a charge of $15.00 on the lot to cover sampling and assaying.

Above rates are subject to change without notice.

APPENDIX D.-EXAMPLE OF ORE SETTLEMENT CUSTOM LEAD-ZINC FLOTATION MILL

BOUGHT OF John Doe CLASS OF ORE Crude ore DATE Date of receipt

ADDRESS Blank, N. Mex. MINE LOT 2 MILL LOT 200

WEIGHT OF SHIPMENT				METAL PRICES AT SETTLEMENT				
WET WEIGHT POUNDS	MOISTURE PERCENT	NET DRY WEIGHT POUNDS	NET DRY TONS	METAL	QUOTATION IN DOLLARS	DEDUCTION	% PAID	NET PRICE PAID IN DOLLARS
155220	2.0	152018	76.0090	GOLD	34.9125/oz	none	100	34.9125/oz
				SILVER	.905/oz	none	100	.905/oz
				LEAD	.1200/lb	.03/lb	100	.09/lb
				ZINC	.1050/lb	.055/lb	100	.05/lb

FINAL SETTLEMENT ASSAYS

BY	Au oz./ton	Ag oz./ton	Pb %	Cu %	Zn %
MILL	.02	2.08	3.95		11.60
Non-sulfide			-1.35		-2.40
SETTLEMENT	.02	2.08	2.60		9.20

PAYMENT FOR METALS

METAL	ASSAY oz./ton or %	PERCENT OF ASSAY PAID FOR	LIQUIDATION SUBJECT TO MINIMUM DEDUCTION OF	NET ASSAY	EQUIVALENT CONTENT PER TON	RATE OF PAYMENT	PER DRY TON	TOTAL AMOUNT
GOLD	.02	70	.02 oz/ton	—	No pay			
SILVER	2.08	80	.50 oz/ton	1.58 oz/ton	1.58 oz	.905/oz	1.43	108.69
LEAD	2.60	80	1.0%	1.60%	32.00 lb	.09/lb	2.88	218.90
ZINC	9.20	70	3.0%	6.20%	124.00 lb	.05/lb	6.20	471.26
TOTAL PAYMENT FOR METALS							10.51	798.85

DEDUCTIONS	AMOUNT	
TREATMENT 76.0090 DRY TONS @ $4.00 PER TON	304.04	
RAILROAD FREIGHT 77.56 WET TONS @ $2.44 PER TON PLUS 3% TAX	194.93	
ROYALTY 10% of [854.34 − (304.04 + 194.93)] = 10% of 355.37	35.54	
TOTAL DEDUCTIONS		534.51
FINAL SETTLEMENT		264.34

Note:
Compare with mill schedule 19 Appendix A

APPENDIX E.-TYPICAL COPPER SMELTER BUYING SCHEDULE FOR WESTERN ORES

The following purchase terms are subject to the General Clauses attached, and are subject to change on 30 days notice. Unless shipments are begun within 30 days this quotation is automatically canceled.

Delivery: F.o.b. unloading bins at plant. The rates quoted are based upon shipment in gondola equipment. Extra unloading charges of $1.00 per dry ton will be assessed for products received in box cars.

Payments

Gold: If 0.03 of an ounce per dry ton or over, pay for 92.57 percent at the net realized price. Under present U.S. Mint price this is equivalent to paying for 100 percent at $32.3185 per troy ounce.

Silver: Pay for 95 percent (minimum deduction of 1/2 ounce) at the average Handy and Harman, New York, silver quotations for the calendar week, including date of delivery of last car of each lot at plant of buyer, or, if higher, at the realized U.S. Mint price provided silver qualifies for Government purchase and affidavit is furnished, less a deduction in either case of 1-1/2 cents per ounce.

Copper: Deduct from the wet copper assay 8 pounds and pay for 95 percent of the remaining copper at the Custom Smelter Copper Price, f.o.b. refinery, for electrolytic copper sold in standard shapes in the United States market as published in the E & M J Metal and Mineral Markets of New York for the 7-day period ending on the Wednesday following the calendar week including date of delivery of product at the plant of buyer less a deduction of 3.50 cents per pound of copper accounted for. Nothing paid for copper if less than 0.5 percent by wet assay.

No payment will be made for any metal or content except as above specified.

Deductions

Base charge: $6.50 per net dry ton of 2,000 pounds; provided the sum of payments for gold, silver, and copper does not exceed $15.00 per ton. Add to the base charge 10 percent of the excess over $15.00 to a maximum charge of $8.00 per dry ton. The base charge just specified is for ores containing at least 8 pounds of copper per ton; when a smaller quantity is contained, there will be added to the base charge a sum equivalent to the value of the deficiency between actual contents and 8 pounds per ton computed according to the terms specified herein for copper payment.

730-683 O-64—8

Insoluble:	Allow all units free; charge for excess at __ cents per unit, fractions in proportion.
Zinc:	Allow five units free; charge for the excess at 30 cents per unit, fractions in proportion.
Arsenic:	Allow two units free; charge for the excess at 50 cents per unit, fractions in proportion.
Antimony:	Allow one unit free; charge for the excess at $1.50 per unit, fractions in proportion.
Bismuth:	One-tenth of 1 percent (0.1 percent) by wet assay allowed free, excess charged at 50 cents per pound, fractions in proportion.
Taxes:	See clause 1 of general clauses governing open schedules.
Freight:	All railroad freight and delivery charges for account of shipper. Deduct from settlement freight and other advances made by buyer.
Tonnage:	Limited to __ tons per month except by special arrangement.

APPENDIX F.-EXAMPLE OF ORE SETTLEMENT CUSTOM COPPER SMELTER

BOUGHT OF John Doe CLASS OF ORE Crude ore DATE Date of receipt

ADDRESS Blank, Mont. MINE LOT 3 MILL LOT 300

QUOTATIONS ON Settlement date GOLD 35.00 SILVER .905 COPPER .2835

ASSAYS	GOLD Oz./ton	SILVER Oz./ton	LEAD %	COPPER %	SILICA %	ALUMINA %	IRON %	ZINC %	
SMELTER	.1450	3.70		4.00	65.6	6.4	8.0		
SHIPPER	.1500	3.60		3.40					
UMPIRE				3.92					
SETTLEMENT	.1475	3.65		3.92	65.6	6.4	8.0		

CAR INITIAL	CAR NUMBER	WET WGT. POUNDS
AB	72130	95450

GROSS WEIGHT	95450
WEIGHT OF SACKS	
WET WEIGHT	95450
LESS MOISTURE 3%	2863

PAYMENTS PER TON	
Gold, 100% of 31.81825/oz on 95% of .1475 oz (minimum deduction .01 oz) or .1375 oz	1/ 4.38
Silver, .905 less .06/oz on 95% of 3.65 oz (minimum deduction 1.0 oz) or 2.65 oz	2.24
Copper @ .2835 less .035/lb on 96% of 3.92% less 0.5 minimum deduction or 68.4 lbs @ 24.85/lb	17.00
GROSS VALUE OF METALS	23.62
LESS TOTAL DEDUCTIONS	4.34

DEDUCTIONS PER TON	
BASE CHARGE	4.00
EXCESS VALUE 15% of 23.62 less 15.00	.86
IRON 8 units @ .12	.96
SILICA 65.6 less 6.4 units or 59.2 units @ .025	(1.48)
TOTAL DEDUCTIONS	4.34

DRY WEIGHT 92587 or 46.2935 TONS 19.28 892.54

SAMPLING			
FREIGHT ADVANCED: WET WEIGHT 47.725 TONS @ 1.57	74.93		
FEDERAL TRANSPORTATION TAX 3%	2.25		
ROYALTY: Net value of ore is 892.54 less 77.18 freight or 815.36. Value per ton: 815.36 divided by 46.2935 or 17.61. Royalty rate on 17.61 per ton ore is 15% of 815.36	122.30	TOTAL OF OTHER CHARGES	199.48

NET PROCEEDS	693.06
LESS ADVANCES	
DUE John Doe	693.06

1/ Rate of payment for gold is computed on the basis of \$20.00 per ounce plus 90 percent of the Government premium in excess of \$20.67 per ounce. At the Mint price of \$35.00 per ounce less 1/4 of 1 percent (\$34.9125) this is equivalent to \$31.81825 per ounce.

Note:
Compare this settlement sheet with open smelter schedule 8 Appendix A.

APPENDIX G.-TYPICAL LEAD SMELTER BUYING SCHEDULE FOR WESTERN ORES APPLICABLE TO LEAD ORES AND CONCENTRATES

Delivery:	F.o.b. smelter
	<u>Payments for Metals</u>
Gold:	If 0.03 oz per dry ton and up to and including 3.0 ounces, pay for all at \$19.00 per troy ounce; if over 3.0 ounces per dry ton, pay for all at \$19.50 per troy ounce, plus 90 percent of the realized gold premium in excess of \$20.67 per troy ounce.
	(Under present Government prices, the above is equivalent to paying for gold at \$31.81825 per ounce when under 3.0 ounces, and \$32.31825 per ounce when over 3.0 ounces.)
Silver:	Pay for 95 percent at the average of the Handy and Harman, New York, silver quotations for the calendar week including date of arrival of the last car of each lot at the plant of the buyer, or at U.S. Mint price provided silver qualifies for Government purchase, and affidavit is furnished, minimum deduction one troy ounce per dry ton.
Lead:	If 3.0 percent or over by wet assay, deduct from the wet lead assay, 1.5 units and pay for 90 percent of the remaining lead at the average of the daily published quotations for common desilverized domestic lead for delivery in New York City for the calendar week including date of arrival of the last car of each lot at the plant of the buyer, less a deduction of 2.0 cents per pound of lead accounted for.
Copper:	If 1 percent or over, deduct from the wet copper assay one unit and pay for 100 percent of the remaining copper at the daily net refinery quotations for electrolytic cathodes as published in the E & M J Metal and Mineral Markets of New York averaged for the calendar week preceding date of arrival of last car of each lot at the plant of the buyer, less a deduction of 6 cents per pound of copper accounted for.
Bullion freight:	Lead and copper quotations are based on a bullion freight rate of \$24.24 per ton from smelter, to New York City.
	No payment will be made for any metal or content except as specified above.

Deductions

Base charge:	\$8.00 per net dry ton for ores having a settlement lead content of 20 percent or less; deduct 10 cents per ton for each unit of lead over 20 percent, fractions in proportion. \$7.00 per ton for ores having no payable lead content.
Arsenic and antimony: (combined)	2 percent free. Excess charged at 50 cents per unit. fractions in proportions.
Bismuth:	0.1 percent of the lead content by wet assay allowed free, excess charged at 50 cents per pound, fractions in proportion.
Zinc:	10 percent free. Excess charged at 30 cents per unit, fractions in proportion.
Sampling and assaying:	Charge \$10.00 per lot when ore is less the \$200.00 value and \$20.00 per lot when ore is over \$200.00 value, for shipments containing less than 5 tons dry weight.

Charge \$5.00 per lot when ore is less than \$200.00 value and \$10.00 per lot when ore is over \$200.00 value, for shipments containing less than 10 tons dry weight.

Weighing and sampling (at which seller or a representative may be present) as done by buyer according to standard practice, promptly after receipt of product, will be accepted as final. The absence of seller or a representative shall be deemed a waiver of the right in each instance. After sampling, the product may be placed in process, commingled, or otherwise disposed of by buyer. In case of disagreement on assays, an umpire shall be selected in rotation from a list mutually agreed upon whose assays shall be final if within the limit of the assays of the two parties, and if not the assay of the party nearer to the umpire shall prevail. Losing party shall pay cost of umpire. In case of seller's failure to make or submit assays, buyer's assays shall govern.

Seller should advise at the time shipment is made whether or not he desires to submit assays, also direct buyer where to send control pulp samples.

All rates quoted subject to change without notice. The Company reserves the right to reject any or all shipments.

APPENDIX H.-EXAMPLE OF ORE SETTLEMENT CUSTOM LEAD SMELTER

BOUGHT OF John Doe CLASS OF ORE Bulk Lead Conc. DATE Date of receipt

ADDRESS Blank, Colo. MINE LOT 1 MILL LOT 100

QUOTATIONS Settlement date SILVER 91.375 LEAD 16.00 COPPER 28.00

ASSAYS	Au oz./ton	Ag oz./ton	Pb %	Cu %	Insol %	Fe %	Zn %	S %	CaO %
SMELTER	.50	9.3	19.0	1.1	33.0	10.0	13.2	16.0	6.0
SHIPPER	.52	10.5	22.0	1.3			12.8		
UMPIRE		10.0	20.0						
SETTLEMENT	.51	10.0	20.0	1.2	33.0	10.0	13.0	16.0	6.0

CAR INITIAL	CAR NUMBER	WET WGT. POUNDS
AB	73414	18760
WEIGHT OF LOT		18760
WEIGHT OF SACKS		-
WET WEIGHT		18760
LESS MOISTURE 3%		563
DRY WEIGHT (POUNDS)		18197

PAYMENTS PER TON	
Gold @ 91.14% of $34.9125 or $31.81925/oz	16.23
Silver (less 1 oz) @ .91375/oz less .01/oz	8.13
Lead, 90% of (20.0-1.5) units @(.16-.02566)/lb or 2.6868/unit	49.70
Copper, 1.2% less minimum deduction of .75% @(.28-.095)/lb	1.67
GROSS VALUE OF METALS	75.73
LESS TOTAL DEDUCTIONS	17.55

DEDUCTIONS PER TON	
BASE CHARGE	11.00
INSOLUBLE 33% @ .10/unit	3.30
ZINC LESS 12% 1% @ .30/unit	.30
SULFUR LESS 2% maximum	2.25
EXCESS VALUE	
IRON CR or DR	
LIME CR or ~~DR~~ 6% @ .05/unit	(.30)
LEAD ~~CR~~ or DR 30%-20% @ .10/unit	1.00
TOTAL DEDUCTIONS	17.55

DRY WEIGHT 9.0985 TONS @ 58.18 PER TON 529.35

WET WEIGHT 9.38 TONS		
SAMPLING (less than 10 tons)	10.00	
FREIGHT ADVANCED @ 2.571 TON	64.25	
MINIMUM CARLOAD 25 TONS		
3% FEDERAL TRANSPORTATION TAX	1.93	
HAULING @ 1.50 TON	14.07	
3% FEDERAL TRANSPORTATION TAX	.42	
UMPIRE	5.00	
TOTAL HANDLING DEDUCTIONS	95.67	95.67
DUE John Doe		$433.68

Note: Compare this settlement with open smelter schedule II. Appendix A.

APPENDIX I.-TYPICAL LEAD-ZINC ORE SCHEDULE FOR SMELTER WITH ASSOCIATED ELECTROLYTIC ZINC PLANT

Metal Payments

Gold: No payment for gold when under 0.03 oz per ton
0.03 but under 3.0 oz per ton pay for 100 percent at $31.81825
3.0 oz per ton or over pay for 100 percent at $32.81825

Silver: No payment for silver under 1.0 oz per ton
1.0 oz per ton or over pay for 95 percent at the applicable quotation

Lead: No payment for lead when under 2.5 percent
2.5 percent but under 25.0 percent pay for 90 percent of wet assay[1]
25 percent but under 50.0 percent pay for 91 percent of wet assay[1]
50 percent or over pay for 92 percent of wet assay[1]

[1] At the lead quotation less 1.5 cents per pound when the lead quotation is 15 cents per pound. For each 1 cent increase or decrease in the lead quotation of 15 cents per pound, the refining and marketing deduction charge of 1.5 cents per pound shall be accordingly increased or decreased by 0.033 cents per pound. Fractional proportions applying.

Copper: No payment for copper when under 0.5 percent
0.5 percent or over pay for 85 percent of the contents at 60 percent of the applicable copper quotation less 30 percent of the applicable lead quotation, negative values applying

Example	Copper quotation	Lead quotation
(1)	$25.00 per cwt	$16.00 per cwt
(2)	10.00 per cwt	22.00 per cwt

(1) $0.85\left(0.60 \times \frac{25.00}{100} - 0.30 \times \frac{16.00}{100}\right) = \$0.0867$ payment per pound of copper contained

(2) $0.85\left(0.60 \times \frac{10.00}{100} - 0.30 \times \frac{22.00}{100}\right) = \$0.0051$ penalty per pound of copper contained

Zinc: No payment for zinc when under 2.5 percent
2.5 percent or over pay for 50 percent of the content at 25 percent of the applicable zinc quotation

Antimony: No payment for antimony when under 1.0 percent
1.0 percent or over pay for 70 percent of the content at 50 percent of the applicable antimony quotation less the applicable lead quotation, negative values applying

Example	Antimony quotation	Lead quotation
(1)	\$40.00 per cwt	\$16.00 per cwt
(2)	20.00 per cwt	16.00 per cwt

(1) $0.70\left(0.50 \times \frac{40.00}{100} - \frac{16.00}{100}\right) = \$0.0280$ payment per pound of antimony contained

(2) $0.70\left(0.50 \times \frac{20.00}{100} - \frac{16.00}{100}\right) = \$0.0420$ penalty per pound of antimony contained

Smelting and Refining Deductions

The minimum combined smelting and refining deduction will be \$11.00 per dry ton.

Smelting Deductions

Base charge:
\$8.00 per dry ton on products containing 50 percent wet lead or over.
Debit the base charge 10 cents per unit for wet lead under 50 percent.

Iron compensation:
Credit the base charge for percent iron over (percentage of zinc x 1.8) at 40 cents per unit.
Debit the base charge for percent iron under (percentage of zinc x 1.8) at 40 cents per unit.

Silica compensation:
Credit the base charge for percent silica over percent iron at 8 cents per unit.
Debit the base charge for percent silica under percent iron at 8 cents per unit.

Lime compensation:
Credit the base charge for percent lime over percent iron at 10 cents per unit.
Debit the base charge for percent lime under percent iron at 10 cents per unit.
The maximum net combined credits for iron, silica and lime will be \$3.00 per dry ton.

Refining Deductions

Silver: Debit the base charge for all silver in excess of 50 oz per ton at 1.5 cents per ounce.
Arsenic: Debit the base charge for all arsenic in excess of 1 percent at \$1.00 per unit.
Bismuth: Debit the base charge for all bismuth in excess of 0.1 percent of the wet lead content at 50 cents per pound.

Moisture: Debit the base charge for all moisture in excess of 10 percent at 20 cents per unit.

Sulfur: Debit the base charge for all sulfur in excess of 16 percent at 10 cents per unit. All fractional proportions applying.

Freight: This schedule is based on the lead freight rate from smelter to New York of $16.84 per ton, plus tax of 3 percent. Any increase or decrease shall be for account of the seller.

All freight on the product from shipping point to buyer's smelter shall be for account of the seller.

Quotations

Gold: As long as the Government pays the present fixed price for gold, the gold payments as indicated here, shall apply. If, at any time, the Government should change the present price paid for gold, or discontinue an established price for gold, the price to be paid for gold shall be 91.137 percent of the recognized gold price when the gold content is 0.03 ox but under 3.0 oz per ton. When the gold content is 3.0 oz, or over per ton, additional payment of $1.00 per ounce will be made.

Silver: Based on the fixed Government price for eligible domestic silver as indicated, or the official price for bar silver in New York as quoted by Handy and Harman, New York, and published in the E & M J Metal and Mineral Markets of New York, whichever price is the higher. For silver other than that eligible for the Government price supported by affidavits, the Handy and Harman quotation shall apply.

In the event the Government should discontinue purchasing silver at a fixed price, then the price paid for silver shall be the official New York price for silver as quoted by Handy and Harman, New York, as outlined above.

In the event, for any reason whatsoever, the Government shall refuse to accept silver covered by seller's affidavit, the difference between the price paid to seller for silver under this schedule and the price prevailing in the open market at the time of such refusal, shall be refunded to the buyer.

Lead: The New York quotation for lead as published in the E & M J Metal and Mineral Markets of New York.

Copper: The New York quotation for electrolytic cathode copper as published in E & M J Metal and Mineral Markets of New York.

Zinc: The St. Louis quotation for prime western zinc as published in the E & M J Metal and Mineral Markets of New York.

Antimony: The quotation for bulk antimony in carload lots f.o.b. Laredo, Tex., as published in the E & M J Metal and Mineral Markets of New York.

APPENDIX J.-TYPICAL ZINC SMELTER BUYING SCHEDULE APPLYING TO WESTERN ORES

Quotation for zinc concentrates for calculations only

<u>Payments</u>

Gold: If 0.03 of a troy ounce per dry ton or over, pay for 80 percent at 92.57 percent of the net price per ounce paid by U.S. Mints for gold recovered from domestic mine production on the 15th day following the rate of delivery of product at buyer's plant, provided however, that the payment to be made for the gold content of seller's product shall be subject to the terms and conditions of the Gold Schedule hereto attached and expressly made a part hereof. Nothing paid for gold if assaying less than 0.03 of a troy ounce per dry ton.

Silver: If 1.0 ounces per dry ton or over, pay for 80 percent on the basis of the mint price as defined in the Silver Schedule hereto attached and expressly made a part hereof, except as therein otherwise provided. Minimum deduction 1.0 ounces per dry ton. Nothing paid for silver if assaying less than 1.0 troy ounces per dry ton.

If however, the seller shall so elect, the price payable for the silver content of seller's product shall be based on the average of the Handy and Harman, New York, quotations for silver for the calendar week following date of delivery at the plant of the buyer, provided, however, that written notice of such election shall be given to the buyer prior to said date of delivery, and further, that if during said calendar week, in the sole judgment of the buyer, the market for silver for 3 months' forward delivery shall be inadequate, and the buyer shall so notify the seller, said price shall be based on the average of the Handy and Harman, New York, quotations for silver for the calendar week including the 19th day following said date of delivery. In case Handy and Harman, New York, shall discontinue publishing quotations for silver then the New York quotations for silver as published by the Engineering and Mining Journal shall govern.

Lead: From the wet lead assay deduct four units and pay for 80 percent of the remainder at the price for common desilverized domestic lead for delivery in New York City, as published in the Engineering and Mining Journal of New York, averaged for the calendar week including date of arrival of the last car of each lot at buyer's smelter, less a deduction of 2 cents per pound of lead accounted for. Nothing paid for lead if assaying less than 4.0 percent by wet assay.

Copper: If 1.0 percent or over wet assay pay for 65 percent of content at the daily net refinery domestic quotation for electrolytic cathodes, as published in the Engineering and Mining Journal of New York, averaged for the calendar week including date of arrival of the last car of each lot at buyer's smelter, less a deduction of 6.0 cents per pound of copper accounted for. Nothing paid for copper if assaying less than 1.0 percent by wet assay.

Zinc: If 40 percent or more contained pay for 85 percent of content, or, if assaying less than 40 percent deduct eight units and pay for remainder. Payment in either case shall be made at the East St. Louis price for prime western zinc as published by the Engineering and Mining Journal of New York, averaged for the calendar week including date of arrival of the last car of each lot at buyer's smelter, less a deduction of 57.5 cents per 100 pounds of zinc accounted for.

From the total of the above payments make the following deductions.

Deductions

Base charge: $38.00 per net dry ton of 2,000 pounds. (If the full East St. Louis quotations for zinc applicable under the above zinc payment clause if more than 6.0 cents per pound, there shall be added to the base charge $1.00 per net dry ton for each one cent increase above 6.0 cents, fractions in proportion.)

Iron: Plus manganese 7.0 percent free; charge for excess at 50 cents per unit, fractions in proportion.

Arsenic and antimony combined: 0.5 percent free; charge for excess at $1.00 per unit, fractions in proportion. In the event materials delivered hereunder contain in excess of 2.0 percent combined arsenic and antimony it shall be optional with the buyer to accept or refuse such material.

Lime and magnesia combined: 1.0 percent free; charge for excess at $1.00 per unit, fractions in proportion.

Moisture: Minimum deduction 1.0 percent.

Labor:[1] This quotation is based on an average hourly labor cost of $1.677 at buyer's plant, based on the wage rates, shift differentials, holiday, vacation, and overtime payments and payroll taxes paid to or on behalf of the employees (excluding foremen and other salaried employees and men on construction work) at said plant. Any increase or decrease in said average hourly labor cost in effect during the month prior to (including) date of delivery of product shall be for seller's account and to adjust, add 15 cents per dry ton for each 1 cent per hour that the average hourly labor cost shall be in excess of $1.677 and deduct 15 cents per dry ton for each 1 cent per hour that the average hourly labor cost shall be less than $1.677, fractions in proportion.

---

[1] Labor adjustment--Average labor cost December 1958 $2.327
Schedule 1.677
Increase at $0.15 .650 = $9.75 per dry ton

Spelter freight:	This quotation is based on the present freight rate on spelter from smelter, to East St. Louis, Ill., of 57.5 cents per 100 pounds. Any increase or decrease in this rate shall be for account of shipper and proper credit or deduction for zinc paid for shall be made accordingly.
Delivery:	Delivery under this schedule shall be made f.o.b. cars at unloading bins at buyer's smelter.
Other terms:	This quotation includes the provision of the complementary schedule hereto attached and expressly made a part hereof. Unless otherwise stipulated all quotations are for immediate acceptance only and unless shipments hereunder are made within 30 days from the date hereof, this quotation is automatically canceled.
Fuel:[2]	This schedule is based on a cost of natural gas at buyer's plant of 7.0 cents per Mcf.[3] Any increase or decrease in such cost in effect during and averaged for the calendar month prior to the date of delivery of product shall be for seller's account, and to adjust charge 40 cents per dry ton for each 1.0 cent per Mcf increase in such cost, and credit 40 cents per dry ton for each 1.0 cent per Mcf decrease in such cost, fractions in proportion.

[2]Average cost natural gas per Mcf December 1958 $08.3
Schedule 07.0
Increase at $0.40 01.3 = $0.52 per dry ton

[3]Thousand cubic feet.

APPENDIX K.- EXAMPLE OF ORE SETTLEMENT CUSTOM ZINC SMELTER

BOUGHT OF John Doe CLASS OF ORE Zinc conc. DATE Date of receipt

ADDRESS Blank, Ariz MINE LOT 4 MILL LOT 400

QUOTATIONAL PERIOD (Date) Zn 11.50¢ Ag 90 ¢ Cu 30.60¢

LOT	WET WEIGHT	MOISTURE %	DRY WEIGHT	SETTLEMENT ASSAYS % Zn	Oz. Ag	% Cu	TOTAL METAL CONTENT Lbs. Zn	Oz. Ag	Lbs. Cu
4	289536	2.0	283745 lbs	53.01	1.105	2.70	150,413	Less 1 oz/ton 14.93	Less .75% .5533

PAYMENT OR DUES

METAL	DEDUCTION	PAYABLE	AMOUNT PAID FOR	PRICE	AMOUNT PAYABLE
ZINC		85%	127,851 lbs	11.15 ¢	14,255.39
SILVER		100%	1490 oz	90 ¢	13.41
COPPER		70%	3873 lbs	20.59 ¢	797.45
	TOTAL METAL PAYMENT				15,066.25

TREATMENT CHARGE BASE, PER TON	45.50	
Zn PRICE VAR. BASE 13.50¢ QUOT 11.50¢ @ 1.25 (credit)	(2.50)	
Zn CONTENT VAR. BASE ACTUAL		
LABOR VARIATION BASE $18.367 ACTUAL $22.310 @ 18¢ per 10¢ 1/	7.0974	
141.8725 Short dry tons @	50.0974	7,107.44
NET VALUE		7958.81
OTHER DEDUCTIONS FREIGHT & TRANSPORTATION TAX	2058.67	
UMPIRE CHARGES		
OTHER		2058.67
		5900.14
ADVANCE PAYMENT		2000.00
DUE John Doe		$ 2900.14

1/ Labor variation charge is made at the rate of 18 cents for each 10 cents difference between base and actual labor costs per ton of ore treated.

730-683 O-64-9

APPENDIX L.-EXAMPLES OF GENERAL CLAUSES IN COMPLEMENTARY SCHEDULES ATTACHED TO AND MADE PART OF SMELTER SCHEDULES

Taxes

All taxes or other Governmental charges, national, local or municipal, now or hereafter imposed in respect to or measured by the product purchased hereunder, or the production, extraction, smelting, refining, sale, transportation, proceeds or value thereof, or of the metals derived therefrom, other than income taxes levied upon the buyer, shall be for account of the seller and shall be deducted from the purchase price payable hereunder.

All schedules on ore not under contract for a definite period of time are subject to change without notice, and subject also to the provision that neither buyer or seller shall be responsible for delays, failure, or omissions due to strikes, cessation of operation at smelter for failure of ore supply or other operating requirement or any cause or causes beyond its control, however arising, and which cannot be overcome by due diligence or by the means normally employed in performance.

Definitions

The date of delivery is the date of arrival of the last car or truckload of each lot at buyer's plant. The date of Sunday deliveries will be the following work day.

A calendar month means a named month in the calendar.
A calendar week begins with Sunday.

In this schedule where the word "ton" is used, it is understood to be a ton of two thousand pounds avoirdupois; where the word "ounce" is used, as referring to gold and silver, it is understood to mean the troy ounce; and where the word "unit" is used, it is understood to mean one percent of a ton, or twenty pounds avoirdupois.

Sampling and Assaying

Weighing, moisture, and ore sampling (at which seller or a representative may be present) as done by buyer according to standard practice, promptly after receipt of product, will be accepted as final. The absence of seller or a representative shall be deemed a waiver of the right in each instance. After sampling, the product may be placed in process, commingled, or otherwise disposed of by buyer. In case of disagreement on assays, an umpire shall be selected in rotation from a list mutally agreed upon, whose assays shall be final if within the limits of the assays of the two parties; and if not, the assay of the party nearer to the umpire shall prevail. Losing party shall pay cost of umpire. In case of seller's failure to make or submit assays, buyer's assays shall govern.

The rates quoted herein are for carload lots. A charge of $20.00 per lot will be made for sampling each lot containing less than 5 tons net dry weight. A charge of $15.00 per lot will be made for sampling lots weighing 5 tons or more, but less than 15 tons net dry weight. In the event metallics are recovered a melting charge will be assessed with a minimum of $5.00 per lot. The rates quoted apply only to ore, concentrates, etc., in bulk. A charge of $1.50 per ton will be charged for shipments received in sacks, and $2.50 per ton for shipments received in drums and other types of containers, to cover extra cost of handling.

In case any firm or publication whose quotations are the basis for pricing any metal under the principal agreement shall go out of business, cease publication, or discontinue the making of quotations, then the buyer shall establish a quotation or quotations which shall be used in making settlement in respect to the metal or metals in question.

In the event any quotation date should fall on a legal holiday or one upon which no quotation is issued, the next succeeding quotation will be used in settlement.

In order that delivery of shipments at our plant may not be unnecessarily delayed, we make it a general rule that THE FREIGHT CHARGES MUST BE PREPAID OR GUARANTEED BY THE SHIPPER.

The rates quoted herein are based on present existing scale for common labor at the plant. Any increase or decrease is for account of seller, and proper deduction or credit shall be made accordingly.

Representation

Representation is urged and welcomed. Every shipper is urged, especially for his initial shipment to be represented in person or by a member of his company while the shipment is being weighed and sampled. In lieu of this, the services of an independent professional representative are available. Because of limited storage space for individual shipments, it is impractical to hold shipments intact until assays and settlements are completed. The company, therefore, reserves the right to commingle all shipments immediately upon completion of weighing and sampling.

Advices and Shipments

Shippers shall notify the company promptly at time of shipment, advising number of lots in car (if more than one lot) and giving instructions as to how remittance is to be made, including the particulars of royalties, if such payments are called for.

Smelter schedules applying to ores purchased under contract usually include additional clauses illustrated by the following examples:

Force Majeure

Prevention or delay in the performance hereof caused by act of nature, strike, fire, flood, traffic interruption, delay in transportation, war, insurrection or mob violence, requirement or regulation of Government, financial crisis, cessation of operation at buyer's plant designated to receive product purchased hereunder for failure of ore supply or other operating requirement, or any disabling cause, without regard to the foregoing enumeration, beyond the control of either party, or which cannot be overcome by means normally employed in performance of the contract, including, without limitation upon the generality of the foregoing, any cause which would produce a financial loss to either party through performance hereof, in mining, smelting, refining or otherwise, shall entitle the party affected to suspend this contract. A suspension of performance pursuant to this clause shall not have the effect of abrogating the contract, but immediately upon the termination of the cause of disability this contract shall again come into full force and effect, and the time of performance of any obligation prevented or delayed as aforesaid, and the term of the contract shall be extended for a period equal to the period of suspension, but in no event shall such extended term of the contract be of longer duration than the unexpired term of the contract at the time of suspension.

Diversion

Buyer may sell or divert the product to any other smelter, and any increase or decrease in freight as against delivery as provided in the contract shall be for buyer's account. In case of such diversion, weighing and sampling shall be performed at the receiving plant and date of delivery shall be the date of arrival of the last car or truckload of each lot at the receiving plant. All other provisions of the contract shall apply in all respects as if no diversion had occurred.

Succession

This contract shall bind and inure to the benefit of the parties hereto, their executors, administrators, legal representatives, successors, or assigns, and shall be a covenant running with the land.

Waiver

Waiver of any breach of any provision hereof shall not be deemed to be a waiver of any other provision hereof or of any subsequent breach of such provision.

APPENDIX M. - REPRESENTATIVE FREIGHT RATES APPLYING TO RAILROAD SHIPMENTS OF BASE METAL ORES AND CONCENTRATES IN THE WEST

Item	From: Railroad loading point	From: Mining district served	From: Map reference symbol (fig. 1)	From: County	To: Location of smelter or mill: City and State	Map reference: Symbol	Map reference: Figure	Map reference: Table	Railroad[1]	Class of material shipped	Condensed schedule of carload rates in dollars per short ton for ore of a valuation[2] per short ton not over: $10	$20	$30	$40	$50	$100	Minimum carload short tons	Rail miles	Calculated carload rates in cents per ton mile for ore valuation: $50	$100
	ARIZONA																			
1	Dragoon	Cochise (Dragoon)	1	Cochise	Hayden, Ariz.	1	3	6	SP	Copper ore or conc.	2.25	3.01	3.39	3.77	4.16	5.68	30	251	1.7	2 7
2	do	do		do	Miami, Ariz.	5	3	6	SP	do	1.91	2.88	3.26	3.65	4.03	5.55	30	179	2.3	3.1
3	do	do		do	Superior, Ariz.	5	3	6	SP	do	[3]2.63	3.01	3.39	3.77	4.16	5.68	30	226	1.8	2.5
4	do	do		do	El Paso, Tex.	54	3	6	SP	do	[3]4.00	5.10	5.64	6.17	6.71	8.83	30	243	2.8	3.6
5	Tombstone	Turquoise	2	do	Hayden, Ariz.	1	3	6	SP	do	2.25	3.01	3.39	3.77	4.16	5.68	30	255	1.6	2.2
6	do	do		do	Miami, Ariz.	3	3	6	SP	do	2.25	3.14	3.52	3.90	4.28	5.81	30	229	1.9	2.5
7	do	do		do	Superior, Ariz.	5	3	6	SP	do	[3]2.63	3.04	3.39	3.77	4.16	5.68	30	231	1.8	2.5
8	do	do		do	El Paso, Tex.	5	3	6	SP	Lead ore or conc.	3.44	5.82	6.35	6.89	7.42	9.53	30	281	2.6	3.3
9	Cork	Aravaipa	6	Graham	Hayden, Ariz.	1	3	6	SP	Copper ore or conc.	[3]3.52	3.90	4.28	4.66	5.05	6.57	30	350	1.4	1.9
10	do	do		do	Miami, Ariz.	3	3	6	SP	do	[4]1.22	1.87	2.25	2.63	3.01	4.54	30	79	3.8	5.8
11	do	do		do	Superior, Ariz.	5	3	6	SP	do	3.52	3.90	4.28	4.66	5.05	6.57	30	326	1.6	2.0
12	do	do		do	El Paso, Tex.	55	3	6	SP	Lead ore or conc.	4.74	5.28	5.82	6.35	6.89	9.01	30	253	2.7	3.5
13	Clifton	Copper Mountain (Morenci)	7	Greenlee	Hayden, Ariz.	1	3	6	SP	Copper ore or conc.	[3]6.35	([5])	7.42	7.96	8.48	10.60	30	415	2.0	2.6
14	do	do		do	Superior, Ariz.	5	3	6	SP	do	[3]6.35	([5])	7.42	7.97	8.48	10.60	30	39.	2.2	2.7
15	do	do		do	Miami, Ariz.	3	3	6	SP	do	[3]4.74	([5])	5.82	6.35	6.89	9.01	30	254	2.7	3.6
16	Kingman	Wallapai	9	Mohave	Tooele (mill), Utah	29 58	2 3	5 6	SFE	Lead-zinc ore or conc.	([5])	[6]11.90	[7]12.87	([5])	[8]19.19	26.00	30	809	2.4	3.2
17	do	do		do	El Paso, Tex.	55	3	6	SFE	do	([5])	8.20	8.65	9.10	10.42	13.96	40	723	1.4	1.9
18	do	do		do	Deming (mill), N. Mex.	22 23	2 2	5 5	SFE	Copper, lead, or zinc ore	([5])	8.20	8.65	9.10	10.42	13.96	40	648	1.6	2.2
19	Sahuarita	Baboquivari, Helvetia, Pima	12, 14, 15	Pima	Ajo, Ariz.	8	3	6	SP	Copper fluxing ore	[3]2.65	([5])	([5])	([5])	([5])	([5])	50	190	1.4	([5])
20	do	do		do	do	-	-	-	SP	Copper-lead ore	7.85	7.85	7.85	7.85	7.85	7.85	30	190	4.1	4.1
21	do	do		do	do	-	-	-	SP	Copper conc.	8.45	8.45	8.45	8.45	8.45	8.45	30	190	4.4	4.4
22	do	do		do	Hayden, Ariz.	1	3	6	SP	Copper ore or conc.	1.48	2.37	2.76	3.14	3.52	5.05	30	200	1.8	4.4
23	do	do		do	Miami, Ariz.	3	3	6	SP	do	2.33	3.65	4.03	4.41	4.79	6.32	30	266	1.8	2.4
24	do	do		do	Superior, Ariz.	5	3	6	SP	do	[3]1.99	2.37	2.59	3.14	3.52	5.05	30	176	2.0	2.9
25	do	do		do	Douglas, Ariz.	6	3	6	SP	do	1.48	2.37	2.76	3.14	3.52	5.05	30	142	2.5	3.6
26	do	do		do	El Paso, Tex.	54, 55	3	6	SP	Copper, lead ore or conc.	[3]5.46	6.17	6.71	7.24	7.78	9.89	30	359	2.2	2.8
27	Patagonia	Harshaw, Oro Blanco, Patagonia	21, 22, 23	Santa Cruz	do	-	-	-	SP	do	4.19	6.35	6.89	7.42	7.96	10.07	30	320	2.5	3.2
28	do	do		do	Deming (mill), N. Mex.	22, 23	2	5	SP	Copper, lead, or zinc ore	[3]6.10	6.80	7.50	([5])	([5])	([5])	30	239	3.1	([5])
29	do	do		do	Hayden, Ariz.	1	3	6	SP	Copper conc.	2.76	3.26	3.65	4.03	4.41	5.94	30	290	1.5	2.1
30	Humboldt	Agua Fria, Big Bug	24, 25	Yavapai	Hayden, Ariz.	1	3	6	SFE	Copper ore or conc.	([5])	3.65	4.03	4.41	5.55	6.32	30	253	2.2	2.5
31	do	do		do	Miami, Ariz.	3	3	6	SFE	do	([5])	5.62	5.94	6.25	7.21	([5])	40	525	1.4	([5])
32	do	do		do	Superior, Ariz	5	3	6	SFE	do	([5])	3.65	4.03	4.41	5.55	6.32	30	229	2.4	2.8
33	do	do		do	El Paso, Tex.	55	3	6	SFE	Lead ore or conc.	([5])	8.20	8.65	9.10	10.42	13.96	40	590	1.8	2.4
34	Hillside	Eureka	27	do	Hayden, Ariz.	1	3	6	SFE	Copper ore or conc.	[3]2.76	3.65	4.03	4.41	4.79	6.32	30	186	2.6	3.4
35	do	do		do	Superior, Ariz.	5	3	6	SFE	do	[3]2.76	3.65	4.03	4.41	4.79	6.32	30	163	2.9	3.9
36	do	do		do	Miami, Ariz.	3	3	6	SFE	do	[3]5.62	5.94	6.32	6.70	7.08	([5])	30	([5])	([5])	([5])
37	do	do		do	El Paso, Tex.	54	3	6	SFE	do	[3]8.65	([5])	9.10	9.80	10.42	14.62	20	523	2.0	2.8
37a	do	do		do	do				SFE	do	[3]7.78	8.20	8.65	9.10	9.43	13.96	40	523	1.8	2.7
38	do	do		do	Deming (mill), N. Mex.	22, 23	2	5	SFE	Copper, lead, or zinc ore	8.65	([5])	9.10	9.80	10.42	14.62	20	([5])	([5])	([5])
38a	do	do		do	do				SFE	do	7.78	8.20	8.65	9.10	9.53	13.96	40	([5])	([5])	([5])

Item	From: Railroad loading point	From: Mining districts served	From: Map reference symbol (fig. 1)	From: County	To: Location of smelter or mill: City and State	Map reference: Symbol	Map reference: Figure	Map reference: Table	Railroad[1]	Class of material shipped	Condensed schedule of carload rates in dollars per short ton for ore of a variation[2] per short ton not over: $10	$20	$30	$40	$50	$100	Minimum carload short tons	Rail miles	Calculated carload rates in cents per ton mile for ore valuation: $50	$100
	ARIZONA--Continued																			
39	Dome	Castle Dome	29	Yuma	El Paso, Tex.	55	3	6	SP	Lead ore	8.65	9.18	9.71	10.25	10.78	12.91	30	542	2.0	2.4
40	do	do		do	Tooele, Utah	58	3	6	SP	Lead conc.	29.80	29.80	29.80	29.80	29.80	29.80	25	899	3.3	3.3
41	do	do		do	do				SP	Lead ore	21.60	21.60	21.60	21.60	21.60	21.60	30	899	2.4	2.4
42	Parker	Cienega	30	do	Hayden, Ariz.	1	3	6	SFE	Copper ore or conc.	(8)	3.65	4.13	4.61	5.83	7.95	30	258	2.3	3.1
43	do	do		do	Superior, Ariz.	5	3	6	SFE	do	(8)	3.65	4.13	4.61	5.83	7.95	30	235	2.5	3.4
44	do	do		do	Miami, Ariz.	3	3	6	SFE	do	(8)	8.42	9.22	10.04	(8)	(8)	30	530	2.5	(8)
45	do	do		do	El Paso, Tex.	54, 55	3	6	SFE	Copper, lead ore or conc.	[3]9.10	9.53	9.98	10.42	10.88	15.29	40	595	1.8	2.6
45a	do	do		do	do				SFE	Copper ore	8.20	8.65	9.10	9.53	9.98	14.42	40	595	1.7	2.4
46	do	do		do	Tooele, Utah	58	3	6	SFE	Lead ore or conc.	(8)	10.92	11.90	12.87	17.24	19.67	30	761	2.3	2.6
	CALIFORNIA																			
47	Placerville	(9)	42		Selby, Calif.	11	3	6	SP	Gold, silver ore	(8)	(8)	(8)	(8)	5.40	7.60	25	124	4.4	6.1
48	Lews	(9)	49		Hayden, Ariz.	1	3	6	SP	Copper ore or conc.	(8)	(8)	(8)	(8)	(8)	12.10	25	709	1.7	1.7
49	do	(9)			Anaconda, Mont.	32	3	6	SP	do	27.61	27.61	27.61	27.61	27.61	27.61	40	1,358	2.0	2.0
50	do	(9)			McGill, Nev.	37	3	6	SP	Copper ore	28.00	28.00	28.00	28.00	28.00	28.00	25	1,124	2.5	2.5
51	do	(9)			do				SP	Copper conc.	37.40	37.40	37.40	37.40	37.40	37.40	25	1,124	3.3	3.3
52	do	(9)			do				SP	Gold, silver ore	34.00	34.00	34.00	34.00	34.00	34.00	25	1,124	3.0	3.0
53	Lone Pine	(9)	44		Tooele, Utah	58	3	6	SP	Lead ore or conc.	10.42	10.42	10.42	10.42	10.42	10.42	50	812	1.3	1.3
54	do	(9)			Selby, Calif.	11	3	6	SP	do	6.25	6.25	6.25	6.25	6.25	6.25	40	509	1.2	1.2
55	do	(9)			Anaconda, Mont.	33	3	6	SP	Zinc ore	20.40	20.40	20.40	20.40	20.40	20.40	30	1,209	1.7	1.7
56	do	(9)			do					Zinc conc.	28.20	28.20	28.20	28.20	28.20	28.20	25	1,209	2.3	2.3
57	do	(9)			Silver King, Idaho	14	3	6	SP	Zinc ore	30.00	30.00	30.00	30.00	30.00	30.00	30	1,438	2.1	2.1
58	do	(9)			do				SP	Zinc conc.	41.20	41.20	41.20	41.20	41.20	41.20	25	1,438	2.9	2.9
59	Olancha	(9)	45	-	Tooele, Utah	58	3	6	SP	Lead ore or conc.	10.42	10.42	10.42	10.42	10.42	10.42	50	787	1.3	1.3
60	do	(9)	-	-	Selby, Calif.	11	3	6	SP	do	6.07	6.07	6.07	6.07	6.07	6.07	40	484	1.3	1.3
61	Mojave	(9)	47	-	do				SP or SFE	Gold, silver ore	15.00	15.00	15.00	15.00	15.00	15.00	(8)	353	4.2	4.3
62	Colfax	(9)	56	-	do				SP	do	(8)	(8)	(8)	(8)	5.60	(8)	25	117	4.8	6.8
63	Trona	(9)	48	-	Tooele, Utah	58	3	6	TRONA	Lead ore or conc.	10.65	10.65	10.65	10.65	10.65	10.65	30	752	1.4	1.4
64	do	(9)	-	-	Selby, Calif.	11	3	6	TRONA	do	10.65	10.65	10.65	10.65	10.65	10.65	30	479	2.2	2.2
65	Campo	(9)	48	-	do				SP	Gold, silver ore	(8)	(8)	(8)	(8)	[10]16.80	(8)	25	690	2.4	3.2
66	Hazel Creek	(9)	53	-	Tooele, Utah	58	3	6	SP	Lead ore or conc.	11.38	11.38	11.38	11.38	11.38	11.38	40	(8)	(8)	(8)
67	do	(9)	-	-	Selby, Calif.	11	3	6	SP	do	4.98	4.98	4.98	4.98	4.98	4.98	30	(8)	(8)	(8)
68	Redding	(9)	53	-	Hayden, Ariz.	1	3	6	SP	Copper ore	26.60	26.60	26.60	26.60	26.60	26.60	25	1,011	2.6	2.6
69	do	(9)	-	-	do				SP	Copper conc.	35.40	35.40	35.40	35.40	35.40	35.40	25	1,011	3.5	3.5
70	do	(9)	-	-	Anaconda, Mont.	32	3	6	SP	Copper ore or conc.	20.05	20.05	20.05	20.05	20.05	20.05	15	1,060	1.9	1.9
71	do	(9)	-	-	Tacoma, Wash.	62	3	6	SP	Copper ore	(8)	11.38	(8)	(8)	(8)	(8)	(8)	622	(8)	[12]1.8
72	do	(9)	-	-	do				SP	Copper conc.	(8)	(8)	(8)	(8)	(8)	13.78	(8)	622	2.2	(8)
73	do	(9)	-	-	McGill, Nev.	37	3	6	SP	Copper ore or conc.	15.29	15.29	15.29	15.29	15.29	15.29	40	769	2.0	2.0
74	do	(9)	-	-	do				SP	Gold, silver ore	27.20	27.20	27.20	27.20	27.20	27.20	25	769	3.5	3.5

	COLORADO																			
75	Texas Creek	Hardscrabble, Cotopaxi	87 90	Custer, Fremont	El Paso, Tex.	55	3	6	D&RGW	Lead ore	15.60	15.60	15.60	15.60	15.60	15.60	30	656	2.0	2.4
76	do	do	-	do	do				D&RGW	Lead conc.	21.20	21.20	21.20	21.20	21.20	21.20	25	656	3.2	3.2
77	do	do	-	do	Amarillo, Tex.	51	3	6	D&RGW	Zinc conc.[14]	5.50	5.50	5.50	5.50	5.50	5.50	([5])	386	( )	( )
78	Belden	Red Cliff	89	Eagle	Salt Lake Valley, Utah[15]	58 30	3 2	6 5	D&RGW	Gold, silver, or lead ore	3.30	4.05	6.54	([5])	7.45	11.02	([5])	438 488	1.7 1.5	2.5 2.3
79	Golden	Central City, Idaho Springs, Georgetown, Silver Plume	91	Gilpin, Clear Creek	Amarillo, Tex.	51	3	6	C&S	Zinc conc.	7.78	7.78	7.78	7.78	7.78	7.78	([5])	450	1.7	1.7
80	Leadville	California, Breckenridge, Montezuma.	93	Lake, Summit	do				D&RGW	do	5.51	5.51	5.51	5.51	5.51	5.51	40	475	1.2	1.2
81	do	do		do	Salt Lake Valley, Utah[15]	58	3	6	D&RGW	Lead-zinc conc.	6.61	6.80	7.39	([5])	7.49	11.02	([5])	460 500	1.7 1.5	2.4 2.2
82	do	do		do	do				D&RGW	Lead-zinc ore	4.67	6.80	7.39	([5])	7.45	11.02	([5])	460 500	1.7 1.5	2.4 2.2
83	Creede	Creede	94	Mineral	Amarillo, Tex.	51	3	6	D&RGW	Zinc conc.	7.78	7.78	7.78	7.78	7.78	7.78	40	522	1.5	1.5
84	do	do		do	El Paso, Tex.	55	3	6	D&RGW	Lead ore	15.40	15.40	15.40	15.40	15.40	15.40	30	792	1.9	1.9
85	do	do		do	do				D&RGW	Lead conc.	22.80	22.80	22.80	22.80	22.80	22.80	25	792	2.9	2.9
86	Salida	Bonanza, Monarch	96 85	Saguache, Chaffee	Salt Lake Valley, Utah[15]	58 30	3 2	6 5	D&RGW D&RGW	Lead-zinc do	([5]) ([5])	8.53 8.53	([5]) -	([5]) -	([5]) -	([5]) -	30 -	516 -	([5]) -	([5]) -
87	Salida	Bonanza, Monarch	85 85	Saguache, Chaffee	Amarillo, Texas	51	3	6	D&RGW	Zinc conc.	5.50	5.50	5.50	5.50	5.50	5.50	40	417	1.2	1.2
88	Ridgeway	San Juan districts	97 88	San Juan, San Miguel, Ouray, Delores	Salt Lake Valley, Utah[15]	58 30	3 2	6 5	D&RGW	Lead-zinc ore, bulk conc.	[3]5.18	5.51	5.96	5.35	7.00	8.62	30	385 425	1.8 1.5	2.2 2.5
89	Ridgeway or Montrose	do		do	Amarillo, Tex.	51	3	6	D&RGW	Zinc conc.	9.27 9.95	9.27 9.95	9.27 9.95	9.27 9.95	9.27 9.95	9.27 9.95	([19]) ([20])	724 750	1.3 1.3	1.3 1.3
90	Red Mountain Pass	Idarado mine	97	Ouray	El Paso, Tex.	54	3	6	RGMW	Copper conc.	13.05	13.05	13.05	13.05	13.05	13.05	([19])	1,030	1.3	1.3
91	do	do		do	Amarillo, Tex.	51	3	6	[21]RGMW	Zinc conc.	11.26	11.26	11.26	11.26	11.26	11.26	([19])	760	1.5	1.5
	IDAHO																			
92	Council	Seven Devils		Adams	Tacoma, Wash.	62	3	6	UP	Copper ore	([5])	([5])	([5])	12.28	[8]14.24	18.11	50	613	2.3	3.0
93	Gimlet	Warm Springs	111	Blaine	Anaconda, Mont.	33	3	6	UP	Zinc ore	([5])	([5])	([5])	7.51	[8]9.46	13.34	50	446	2.1	3.0
94	do	do		do	East Helena, Mont.	30	3	6	UP	Lead ore or conc.	([5])	([5])	([5])	8.56	[8]10.52	14.42	50	527	2.0	2.7
95	Hailey	Mineral Hill and Camas	111	do	Salt Lake Valley, Utah[15]	30	2	5	UP	Lead-zinc ore	([5])	6.06	([5])	7.51	[8]9.46	13.34	20	351	2.7	3.8
96	do	do		do	do				UP	do	([5])	5.56	([5])	7.04	[8]8.97	12.87	50	351	2.6	3.7
97	MacKay	Alder Creek, Bayhorse, Blackbird, Blue Wing	112 115	Custer, Lemhi	East Helena, Mont.	39	3	6	UP	Lead-zinc, copper ore or conc.	([5])	6.65	([5])	7.60	[8]9.53	13.44	40	417	2.3	3.2
98	do	do		do	Anaconda, Mont.	32	3	6	UP	do	([5])	([5])	([5])	[8]6.53	8.48	12.37	40	336	2.5	3.7
99	do	do		do	Salt Lake Valley, Utah[15]	30	2	5	UP	do	([5])	5.56	([5])	[8]7.04	8.97	12.87	20	295	3.0	4.4
100	do	do		do	do				UP	do	([5])	5.03	([5])	5.98	[8]7.92	11.80	40	295	2.7	4.0
101	Roberts	McDevitt	116	do	East Helena, Mont.	30	3	6	UP	Lead ore	([5])	([5])	([5])	5.98	[8]7.92	11.80	40	288	2.8	4.1
102	do	do		do	Salt Lake Valley, Utah[15]	58	3	6	UP	do	([5])	5.83	([5])	7.36	9.41	12.49	40	250	3.8	5.0
103	Osburn or Wallace	Coeur d'Alene	117	Shoshone	Kellogg, Idaho	13, 14	3	6	UP	Lead or zinc conc.	0.76	0.76	0.76	0.76	0.76	0.76	40	11	6.9	6.9
104	Dorn or Burke	do	117	do	do				UP	do	0.86	0.86	0.86	0.86	0.86	0.86	40	22	3.9	3.9
105	Bunn	do	117	do	East Helena or Anaconda, Mont.	30, 33	3	6	NP	do	([5])	([5])	6.59	7.13	[8]8.14	[11]10.20	30	261	3.1	3.9

See footnotes at end of table.

Item	From: Railroad loading point	From: Mining districts served	From: Map reference symbol (fig. 1)	From: County	To: Location of smelter or mill: City and State	Map reference: Symbol	Map reference: Figure	Map reference: Table	Railroad[1]	Class of material shipped	Condensed schedule of carload rates in dollars per short ton for ore of a valuation[2] per short ton not over: $10	$20	$30	$40	$50	$100	Minimum carload short tons	Rail miles	Calculated carload rates in cents per ton mile for ore valuation: $50	$100
	MONTANA																			
106	Dillon	Argenta	118	Beaverhead	East Helena, Mont.	30	3	6	UP	Lead ore	7.75	7.75	7.75	7.75	7.75	7.75	15	162	4.8	4.8
107	do	do		do	do				UP	do	(5)	3.78	(5)	4.47	(5)	6.33	40	162	3.2	3.9
108	Melrose	Bryant	118	do	do				UP	Lead-zinc ore	(5)	3.58	(5)	4.32	(5)	6.10	40	131	3.9	4.7
109	Townsend	Cedar Plains,		Broadwater	do				NP	Gold-silver or lead ore	[3]1.58	[6]1.77	[7]2.22	2.77			30	29	9.6	9.6
110	do	do		do	Anaconda, Mont.	32	3	6	NP	Gold-silver ore	[3]3.48	[6]3.88	[7]4.24	(5)	4.80	5.16	30	133	3.6	3.9
111	Drummong	Dunkleberg	119	Granite	East Helena, Mont.	30	3	6	NP	do	[3]2.51	[6]2.77	[7]3.32	(5)	3.88	4.07	30	73	5.3	5.6
112	Phillipsburg	Flint Creek (Phillipsburg)	119	do	do				NP	Gold-silver or lead ore	[3]2.99	[6]3.32	[7]3.70	(5)	4.45	4.62	30	99	4.5	4.7
113	do	do		do	Anaconda, Mont.	33	3	6	NP	Zinc ore or conc.	[3]3.48	[6]3.88	[7]4.24	(5)	4.98	5.16	30	95	5.2	5.4
114	Whitehall	Whitehall	120	Jefferson	East Helena, Mont.	30	3	6	NP	Lead or gold ore	[3]2.99	[6]3.32	[7]3.70	(5)	4.24	4.62	30	116	3.7	4.0
115	do	do		do	Butte, Mont. (Washoe Sampler)				NP	Gold ore	[3]2.51	[6]2.77	[7]3.14	(5)	3.70	3.88	30	32	11.5	12.5
116	Louisville	Beaver, Winston	(23)	Lewis & Clark	East Helena, Mont.				NP	Lead-zinc ore	[3]1.18	[6]1.35	[7]1.77	(5)	1.99	2.22	30	7	28.4	31.7
117	Twin Bridges	Tidal Wave, Rochester	(23)	Madison	do	30	3	6	NP	Gold-silver or lead ore	[3]3.15	[6]3.51	[7]3.88	(5)	4.45	4.80	30	(5)	(5)	(5)
118	Sheridan	Sheridan	(23)	do	do				NP	do	[3]3.15	[6]3.51	[7]3.88	(5)	4.45	4.80	30	(5)	(5)	(5)
119	Alder	Virginia City	(23)	do	do				NP	do	[3]3.15	[6]3.51	[7]3.88	(5)	4.45	4.80	30	161	2.8	3.0
120	do	do		do	Anaconda, Mont.	32	3	6	NP	Gold-silver ore	[3]3.48	[6]3.78	[7]4.24	(5)	4.80	5.16	30	103	4.7	5.0
121	Sheridan	Sheridan	(23)	do	do				NP	do	[3]3.48	[6]3.78	[7]4.24	(5)	4.80	5.16	30	(5)	(5)	(5)
122	Twin Bridges	Tidal Wave, Rochester	(23)	do	do				NP	do	[3]3.48	[6]3.78	[7]4.24	(5)	4.80	5.16	30	(5)	(5)	(5)
123	do	do		do	Butte, Mont. (Washoe Sampler)				NP	do	[3]2.99	[6]3.32	[7]3.70	(5)	4.24	4.62	30	77	5.5	6.0
124	Sheridan	Sheridan	(23)	do	do				NP	do	[3]2.99	[6]3.32	[7]3.70	(5)	4.24	4.62	30	65	6.5	7.1
125	Alder	Virginia City	(23)	do	do				NP	do	[3]2.99	[6]3.32	[7]3.70	(5)	4.24	4.62	30	77	5.5	6.0
126	Elliston	Elliston	(23)	Powell	do				NP	do	[3]2.99	[6]3.32	[7]3.70	(5)	4.24	4.62	30	74	5.7	6.2
127	do	do		do	East Helena, Mont.	32	3	6	NP	Gold-silver lead ore or conc.	[3]1.77	[6]1.99	[7]2.39	(5)	2.77	2.97	30	33	8.4	9.0
	NEVADA																			
128	Henderson	Searchlight	59	Clark	Salt Lake Valley, Utah[15]	58	3	6	UP	Lead ore	5.56	5.56	5.56	5.56	5.56	5.56	50	433	1.3	1.3
129	do	do		do	do	30	2	5	UP	Lead conc.	5.56	5.56	5.56	5.56	5.56	5.56	(5)	433	1.3	1.3
130	do	do		do	Selby, Calif	11	3	6	UP	Lead ore	13.57	13.57	13.57	13.57	13.57	13.57	50	656	2.1	2.1
131	do	do		do	do				UP	Lead conc.	15.17	15.17	15.17	15.17	15.17	15.17	50	656	2.3	2.3
132	do	do		do	Anaconda, Mont.	19	2	5	UP	Zinc ore	21.60	21.60	21.60	21.60	21.60	21.60	30	910	2.4	2.4
133	do	do		do	do	33	3	6	UP	Zinc conc.	29.80	29.80	29.80	29.80	29.80	29.80	25	910	3.3	3.3
134	do	do		do	Silver King, Idaho	14	3	6	UP	Zinc ore	25.60	25.60	25.60	25.60	25.60	25.60	30	1,239	2.1	2.1
135	do	do		do	do				UP	Zinc conc.	35.00	35.00	35.00	35.00	35.00	35.00	25	1,239	2.8	2.8
136	Carlin	Maggie Creek	67	Eureka	Hayden, Ariz.	1	3	6	WP or SP	Copper ore	31.80	31.80	31.80	31.80	31.80	31.80	25	1,288	2.5	2.5
137	do	do		do	do				WP or SP	Copper conc.	42.20	42.20	42.20	42.20	42.20	42.20	25	1,288	3.3	3.3
138	do	do		do	Anaconda, Mont.	32	3	6	WP or SP	Copper ore	9.33	9.33	9.33	9.33	9.33	9.33	50	547	1.7	1.7
139	do	do		do	do				WP or SP	Copper conc.	9.33	9.33	9.33	9.33	9.33	9.33	50	547	1.7	1.7

	NEVADA--Continued																			
140	Carlin	Maggie Creek	67	Eureka	McGill, Nev.	37	3	6	WP or SP	Copper ore	6.91	6.91	6.91	6.91	6.91	6.91	50	188	3.7	3.7
141	do	do		do	do				WP or SP	Copper conc.	6.91	6.91	6.91	6.91	6.91	6.91	50	188	3.7	3.7
142	Contact	Contact	60	Elko	Hayden, Ariz.	1	3	6	UP	Copper ore	31.80	31.80	31.80	31.80	31.80	31.80	25	1,269	2.5	2.5
143	do	do		do	do				UP	Copper conc.	42.20	42.20	42.20	42.20	42.20	42.20	25	1,269	3.3	3.3
144	do	do		do	Anaconda, Mont	32	3	6	UP	Copper ore	16.80	16.80	16.80	16.80	16.80	16.80	25	462	3.6	3.6
145	do	do		do	do	32	3	6	UP	Copper conc.	22.20	22.20	22.20	22.20	22.20	22.20	25	462	4.8	4.8
146	do	do		do	McGill, Nev.	37	3	6	UP	Copper ore	11.80	11.80	11.80	11.80	11.80	11.80	25	211	5.6	5.6
147	do	do			do				UP	Copper conc.	15.80	15.80	15.80	15.80	15.80	15.80	25	211	7.5	7.5
148	do	do		do	do				UP	Gold-silver ore	14.40	14.40	14.40	14.40	14.40	14.40	25	211	6.8	6.8
149	Elko or Montello	Merrimac or Delano	62	do	Tooele, Utah	58	3	6	SP or WP	Lead ore or conc.	6.91	6.91	6.91	6.91	6.91	6.91	50	193	3.6	3.6
150	Elko	do		do	Selby, Calif.	11	3	6	SP or WP	do	12.56	12.56	12.56	12.56	12.56	12.56	40	528	2.4	2.4
151	Palisade	Railroad	68	Eureka	do				SP or WP	do	12.56	12.56	12.56	12.56	12.56	12.56	50	279	2.5	2.5
152	Battle Mountain	Bullion	72	Lander	Hayden, Ariz.	1	3	6	SP or WP	Copper ore	30.40	30.40	30.40	30.40	30.40	30.40	25	1,237	2.5	2.5
153	do	do		do	do				SP or WP	Copper conc.	40.60	40.60	40.60	40.60	40.60	40.60	25	1,237	3.3	3.3
154	do	do		do	Anaconda, Mont.	32	3	6	SP or WP	Copper ore	9.33	9.33	9.33	9.33	9.33	9.33	50	646	1.4	1.4
155	do	do			do				SP or WP	Copper conc.	9.33	9.33	9.33	9.33	9.33	9.33	50	646	1.4	1.4
156	do	do		do	McGill, Nev.	37	3	6	SP or WP	Copper ore	6.91	6.91	6.91	6.91	6.91	6.91	50	288	2.4	2.4
157	do	do		do	do				SP or WP	Copper conc.	6.91	6.91	6.91	6.91	6.91	6.91	50	288	2.4	2.4
158	do	do		do	do				SP or WP	Gold-silver ore	4.29	4.29	4.29	4.29	4.29	4.29	40	288	1.5	1.5
159	Pioche	Pioche	74	Lincoln	Hayden, Ariz.	1	3	6	UP	Copper ore	([5])	([5])	([5])	12.62	[18]13.72	14.82	25	764	1.8	([5])
160	do	do		do	do				UP	Copper conc.	([5])	([5])	([5])	12.62	[18]13.72	14.82	25	764	1.8	([5])
161	do	do		do	Anaconda, Mont.	32	3	6	UP	Copper ore	23.00	23.00	23.00	23.00	23.00	23.00	25	801	2.9	2.9
162	do	do		do	do				UP	Copper conc.	30.60	30.60	30.60	30.60	30.60	30.60	25	801	3.8	3.8
163	do	do		do	McGill, Nev.	37	3	6	UP	Copper ore	19.00	19.00	19.00	19.00	19.00	19.00	25	577	3.3	3.3
164	do	do		do	do				UP	Copper conc.	25.00	25.00	25.00	25.00	25.00	25.00	25	577	4.3	4.3
165	do	do			do				UP	Gold-silver ore	23.00	23.00	23.00	23.00	23.00	23.00	25	577	4.0	4.0
166	do	do		do	Salt Lake Valley, Utah[18]	58	3	6	UP	Lead ore	3.93	3.93	3.93	3.93	3.93	3.93	55	324	1.2	1.2
167	do	do		do	do	30	2	5	UP	Lead conc.	3.93	3.93	3.93	3.93	3.93	3.93	55	324	1.2	1.2
168	do	do		do	Selby, Calif.	11	3	6	UP	Lead ore	9.57	9.57	9.57	9.57	9.57	9.57	50	756	1.3	1.3
169	do	do		do	do				UP	Lead conc.	9.57	9.57	9.57	9.57	9.57	9.57	50	756	1.3	1.3
170	do	do		do	Anaconda, Mont.	33	3	6	UP	Zinc ore	9.46	9.46	9.46	9.46	9.46	9.46	40	801	1.2	1.2
171	do	do		do	do				UP	Zinc conc.	9.46	9.46	9.46	9.46	9.46	9.46	40	801	1.2	1.2
172	do	do		do	Silver King, Idaho	14	3	6	UP	Zinc ore	24.00	24.00	24.00	24.00	24.00	24.00	30	1,146	2.1	2.1
173	do	do		do	do				UP	Zinc conc.	32.80	32.80	32.80	32.80	32.80	32.80	25	1,146	2.9	2.9
174	Wabuska	Yerington	75	Lyon	Hayden, Ariz.	1	3	6	UP	Copper ore	28.00	28.00	28.00	28.00	28.00	28.00	25	1,087	2.6	2.9
175	do	do		do	do				UP	Copper conc.	37.40	37.40	37.40	37.40	37.40	37.40	25	1,087	3.4	2.6
176	do	do		do	Anaconda, Mont.	32	3	6	UP	Copper ore	16.24	16.24	16.24	16.24	16.24	16.24	50	875	1.9	1.9
177	do	do		do	do				UP	Copper conc.	16.24	16.24	16.24	16.24	16.24	16.24	50	875	1.9	1.9
178	do	do		do	McGill, Nev.				UP	Copper ore	6.91	6.91	6.91	6.91	6.91	6.91	50	519	1.3	1.3
179	do	do		do	do				UP	Copper conc.	6.91	6.91	6.91	6.91	6.91	6.91	50	519	1.3	1.3
180	do	do		do	do				UP	Gold-silver ore	8.74	8.74	8.74	8.74	8.74	8.74	25	519	1.7	1.7
181	Mina	Candelaria	77	Mineral	Hayden, Ariz.	1	3	6	UP	Copper ore	28.80	28.80	28.80	28.80	28.80	28.80	25	1,176	2.5	2.5
182	do	do		do	do				UP	Copper conc.	38.40	38.40	38.40	38.40	38.40	38.40	25	1,176	3.3	3.3
183	do	do		do	Anaconda, Mont.	32	3	6	UP	Copper ore	16.24	16.24	16.24	16.24	16.24	16.24	50	964	1.7	1.7
184	do	do		do	do				UP	Copper conc.	16.24	16.24	16.24	16.24	16.24	16.24	50	964	1.7	1.7
185	do	do		do	McGill, Nev.	37	3	6	UP	Copper ore	6.91	6.91	6.91	6.91	6.91	6.91	50	606	1.1	1.1

See footnotes at end of table.

Item	From: Railroad loading point	From: Mining districts served	From: Map reference symbol (fig. 1)	From: County	To: Location of smelter or mill: City and State	Map reference: Symbol	Map reference: Figure	Map reference: Table	Railroad[1]	Class of material shipped	Condensed schedule of carload rates in dollars per short ton for ore of a variation[2] per short ton not over: $10	$20	$30	$40	$50	$100	Minimum carload short tons	Rail miles	Calculated carload rates in cents per ton mile for ore valuation: $50	$100
	NEVADA--Continued																			
186	Mina	Candelaria	77	Mineral	McGill, Nev.				UP	Copper conc.	6.91	6.91	6.91	6.91	6.91	6.91	50	606	1.1	1.1
187	do	do		do	do				UP	Gold-silver ore	8.74	8.74	8.74	8.74	8.74	8.74	50	606	1.4	1.4
188	East Ely	White Pine	82	White Pine	Salt Lake Valley, Utah[15]	58	3	6	NN	Lead ore	5.57	5.57	5.57	5.57	5.57	5.57	50	268	2.1	2.1
189	do	do		do	do	30	2	5	NN	Lead conc.	6.83	6.83	6.83	6.83	6.83	6.83	40	268	2.5	2.5
190	do	do		do	Selby, Calif.	11	3	6	NN	Lead ore	8.56	8.56	8.56	8.56	8.56	8.56	50	742	1.2	1.2
191	do	do		do	do				NN	Lead conc.	9.53	9.53	9.53	9.53	9.53	9.53	40	742	1.3	1.3
	NEW MEXICO																			
192	Hanover Junction (Vanadium) or Silver City	Central, Pinos Altos, and Swartz	82, 84, 85	Grant	El Paso, Tex.	54, 55	3	6	SFE	Copper, lead ore or conc.	2.84	2.84	2.84	2.84	2.84	2.84	([22])	177	1.6	1.6
193	do	do		do	do				SFE	do	([5])	([5])	([5])	([5])	([5])	11.60	25	177	6.6	6.6
194	do	do		do	Deming (mill), N. Mex.	22	2	5	SFE	Lead-zinc-ore	([5])	([5])	([5])	([5])	([5])	7.80	25	46	17.0	17.0
195	do	do		do	do				SFE	do	0.63	0.63	0.63	0.63	0.63	0.63	([22])	46	1.4	1.4
196	Hachita	Eureka	32	do	El Paso, Tex.	54	3	6	SP	Copper, lead ore or conc.	2.24	3.26	3.81	4.38	[10]6.00	7.06	30	110	4.5	6.4
197	do	do		do	Amarillo, Tex.	51	3	6	SP	Zinc ore or conc.	([5])	([5])	([5])	([5])	([5])	8.65	30	561	1.5	1.5
198	Lordsburg	Lordsburg	36	Hidalgo	El Paso, Tex.	54	3	6	SP	Copper ore conc.	2.24	3.81	4.38	4.91	5.46	9.71	30	149	3.7	6.5
199	do	do		do	do				SP	do	([5])	([5])	([5])	([5])	([5])	([5])	40	149	3.5	3.5
200	do	do		do	Hayden, Ariz.	1	3	6	SP	do	5.10	5.64	6.17	6.71	7.24	9.36	30	345	2.1	2.7
201	do	do		do	Miami, Ariz.	3	3	6	SP	do	3.80	( )	4.91	5.46	6.00	9.18	30	184	3.3	5.0
202	do	do		do	Superior, Ariz.	5	3	6	SP	do	5.56	6.19	6.82	7.46	8.11	10.65	30	321	2.5	3.3
203	Bernalillo	Cuba	37	Sandoval	El Paso, Tex.	53	3	6	SFE	Copper conc. and flux	5.07	5.27	[8]6.06	([5])	([5])	6.85	([22])	271	2.2	2.5
204	do	do		do	do				SFE	Copper conc.	5.07	5.56	[8]6.06	([5])	([5])	7.23	([22])	271	2.7	2.2
205	do	do		do	do				SFE	do	([5])	([5])	([5])	([5])	([5])	12.80	25	271	4.7	4.7
206	Los Cerrillos	Cerrillos, Cooper, San Pedro, New Placers	39	Santa Fe	do	54, 55	3	6	SFE	Copper ore	5.07	5.27	[8]6.06	([5])	([5])	6.85	([22])	305	2.3	2.3
207	do	do		do	do				SFE	Lead ore	5.07	5.56	6.06	([5])	([5])	7.23	([22])	305	2.4	2.4
208	do	do		do	do				SFE	Copper conc.	([5])	([5])	([5])	([5])	([5])	14.20	25	305	4.7	4.7
209	Socorro	Hansonberg	39	Socorro	do				SFE	Lead ore	3.53	3.84	5.27	([5])	([5])	6.85	([22])	179	3.8	3.8
210	do	do		do	do				SFE	Lead conc.	3.53	([5])	5.56	([5])	([5])	7.23	([22])	179	3.1	3.9
211	do	do		do	do				SFE	do	([5])	([5])	([5])	([5])	([5])	11.10	25	179	6.2	6.2
212	do	do		do	Deming (mill), N. Mex.				SFE	Lead-zinc ore	([5])	([5])	([5])	([5])	3.53	4.02	([22])	156	2.3	2.6
213	do	do	40	do	do				SFE	do	([5])	([5])	([5])	([5])	([5])	15.20	25	159	9.7	9.7
214	Magdalena	Magdalena		do	El Paso, Tex.	55	3	6	SFE	do	3.53	3.84	5.27	([5])	([5])	6.85	([22])	206	3.3	3.3
215	do	do		do	do				SFE	Lead conc.	3.53	([5])	5.56	([5])	([5])	7.23	([22])	206	3.5	3.5
216	do	do		do	do				SFE	do	([5])	([5])	([5])	([5])	([5])	11.60	25	206	5.6	5.6
217	do	do		do	Deming (mill), N. Mex.	22	2	5	SFE	Lead zinc ore	([5])	([5])	([5])	([5])	([5])	15.20	25	183	8.3	8.3
218	Mountainair	Carocito	41	Torrance	El Paso, Tex.	54	3	6	SFE	Flux	([5])	8.97	10.34	11.70	12.69	[23]15.57	([22])	263	4.9	([5])
	OREGON																			
219	Baker	Granite	13	Grant	Tacoma, Wash.	62	3	6	UP	Gold ore or conc.	([5])	([5])	([5])	11.38	[8]13.34	16.27	20	482	2.7	3.4
220	do	do		do	do				UP	do	([5])	6.00	([5])	8.65	[8]10.27	[23]11.61	50	482	2.1	2.4

	OREGON--Continued																			
221	Grants Pass	Walso	(64)	Josephine	Tacoma, Wash.	63	3	6	SP	Copper ore	[3]10.34	(5)	10.98	11.65	12.54	15.29	30	440	2.9	3.5
222	do			do	do				SP	do	[3]8.19	(5)	8.68	9.17	(5)	9.46	30	440	2.2	2.2
223	do			do	do				SP	Gold ore	[3]10.29	(5)	11.63	11.63	(5)	15.29	30	440	2.7	3.5
224	do			do	do				SP	do	[3]8.10	(5)	9.10	9.10	(5)	9.39	30	440	2.1	2.1
	UTAH																			
225	Milford	Rocky, San Francisco, Star, North Star	101	Beaver	Hayden, Ariz.	1	3	6	UP	Copper ore or conc.	16.30	20.72	23.52	26.34	(5)	(5)	30	848	(5)	(5)
226	do	do		do	do				UP	do	(5)	(5)	(5)	(5)	(5)	28.60	25	848	2.1	2.1
227	do	do		do	Miami, Ariz.	3	3	6	UP	do	[3]26.65	28.41	31.85	35.29	(5)	(5)	30	1,110	(5)	(5)
228	do	do		do	do				UP	do	(5)	(5)	(5)	(5)	(5)	34.40	25	1,110	3.1	3.1
229	do	do		do	Superior, Ariz.	5	3	6	UP	do	16.30	20.72	23.52	26.34	(5)	(5)	30	824	(5)	(5)
230	do	do		do	do				UP	do	(5)	(5)	(5)	(5)	(5)	28.20	25	824	3.4	3.4
231	do	do		do	El Paso, Tex.	54, 55	3	6		Copper, lead ore or conc.	(5)	25.62	29.04	32.41	(5)	(5)	30	1,244	(5)	(5)
232	do	do		do	do				UP	do	(5)	(5)	(5)	(5)	(5)	35.40	25	1,244	2.9	3.0
233	do	do		do	Salt Lake Valley, Utah[15]	58	3	6	UP UP	Lead-zinc ore or conc.	3.18	4.21	4.30	(5)	4.34	6.03	20	203	2.5	3.6
234	do	do		do	do				UP	do	2.59	3.56	3.89	(5)	[8]5.83	(5)	40	203	2.9	(5)
235	do	do		do	McGill, Nev.	37	3	6	UP	Copper ore or conc.	19.40	19.40	19.40	19.40	19.40	19.40	25	477	4.1	4.1
236	do	do		do	Selby, Calif.	11	3	6	UP	Lead ore or conc.	[3]18.62	20.64	22.88	25.08	27.33	(5)	40	963	2.8	(5)
237	do	do		do	do				UP	do	(5)	(5)	(5)	(5)	(5)	28.60	25	963	3.0	3.0
238	Eureka	Tintic	102	Juab	Tooele, Utah	58	3	6	UP or D&RGW	Lead ore or conc.	1.56	1.94	2.27	2.59	2.92	4.54	30	64	4.6	7.1
239	do	do		do	do				UP or D&RGW	Lead ore	0.93	(5)	(5)	(5)	(5)	(5)	(5)	64	(5)	(5)
240	do	do		do	Bauer, Utah	28	2	5	UP or D&RGW	do	(5)	2.01	2.27	2.59	2.92	4.54	30	59	4.9	7.7
241	Marysvale	Gold Mountain, Mount Baldy, and Ohio	103	Piute	Tooele, Utah	58	3	6	UP or D&RGW	Gold-silver fluxing ore	2.40	2.79	3.30	3.69	4.08	5.25	(5)	185	(5)	(5)
242	Bingham or Lark	West Mountain	104	Salt Lake	Midvale, Utah	30	2	5	D&RGW	Lead-zinc ore	[3]0.85	[6]1.54	(5)	(5)	2.03	2.60	20	20	10.2	13.0
243	do	do		do	do				D&RGW	do	0.78	[6]1.40	(5)	(5)	1.87	2.40	30	20	9.4	12.0
244	do	do		do	Bauer, Utah	28	2	5	D&RGW	do	1.14	[6]1.71	(5)	(5)	2.01	2.40	30	71	2.8	3.4
245	do	do		do	do				D&RGW	do	(5)	[6]1.40	(5)	(5)	(5)	(5)	40	71	(5)	(5)
246	do	do		do	Tooele, Utah				D&RGW	Lead ore or conc.	1.14	[6]1.71	(5)	(5)	2.01	2.40	30	69	2.9	3.5
247	Park City	Uintah, Blue Ledge and Snake Creek	105, 109	Summit, Wasatch	do				UP	do	7.02	7.32	7.79	7.94	(5)	8.01	30	142	5.6	5.6
248	do	do		do	Midvale, Utah	30	2	5	UP	Lead-zinc ore	6.93	6.93	6.93	6.93	6.93	6.93	25	115	6.0	6.0
249	do	do		do	Bauer, Utah	28	3	6	UP	do	7.02	7.32	7.79	7.84	(5)	8.01	30	143	5.6	5.6
250	St. John	Ophir	108	Tooele	Tooele, Utah	58	3	6	UP	Lead ore or conc.	1.56	1.94	2.27	2.59	2.92	4.54	20	14	20.9	32.4
251	do	do		do	do				UP	do	(5)	0.63	0.78	1.09	1.40	2.79	40	14	10.0	19.9
252	do	do		do	Midvale, Utah	30	2	5	UP	Lead zinc ore	1.56	1.94	2.27	2.59	2.92	4.54	20	59	5.0	7.7
253	do	do		do	do				UP	do	(5)	0.93	1.02	1.17	1.40	2.79	40	59	2.4	4.7
254	do	do		do	Bauer, Utah	28	2	5	UP	do	1.56	0.94	2.27	2.59	2.92	4.54	20	9	32.4	50.4
255	do	do		do	do				UP	do	(5)	0.63	0.78	1.09	1.40	2.79	40	9	15.6	31.0
256	Cedar City	Harrisburg, Tutsagubet		Washington	Salt Lake Valley, Utah[15]	58	3	6	UP	Zinc-lead, copper ore or conc.	3.95	5.25	6.16	6.80	7.58	8.49	20	280	2.7	3.0
257	do	do		do	do				UP	do	[3]3.95	(5)	5.51	6.16	6.80	[10]8.10	40	280	2.4	(5)
258	do	do		do	do				UP	do	3.24	3.89	4.54	5.18	5.83	[8]6.48	50	280	2.1	(5)

See footnotes at end of table.

Item	From: Railroad loading point	From: Mining districts served	From: Map reference symbol (fig. 1)	From: County	To: Location of smelter or mill: City and State	To: Map reference: Symbol	To: Map reference: Figure	To: Map reference: Table	Railroad[1]	Class of material shipped	Condensed schedule of carload rates in dollars per short ton for ore of a valuation[2] per short ton not over: $10	$20	$30	$40	$50	$100	Minimum carload short tons	Rail miles	Calculated carload rates in cents per ton mile for ore valuation: $50	$100
	WASHINGTON																			
259	Northport	Northport	18	Stevens	East Helena, Mont.	30	3	6	GN	Lead ore or conc.	([5])	12.54	([5])	([8])	13.93	15.57	30	750	1.9	2.1
260	Omah	Conconully		Okanogan	Tacoma, Wash.	62	3	6	GN	Copper ore	([5])	([5])	6.80	7.27	7.72	10.01	30	291	2.5	3.4
261	Metalline Falls	Metalline	17	Pend Oreille	Kellogg, Idaho	13, 14	3	6	MLW	Lead-zinc ore or conc.	( )	( )	6.06	6.53	7.04	[10]8.00	50	210	3.4	3.9

[1] Railroad symbols designate originating carriers as follows:

Symbol	Railroad
SFE	Atchison, Topeka and Santa Fe
C&S	Colorado and Southern
D&RGW	Denver and Rio Grande Western
GN	Great Northern
MILW	Milwaukee
NP	Northern Pacific
SP	Southern Pacific
TRONA	Trona
UP	Union Pacific
WP	Western Pacific
RGMW	Rio Grande Motor Way
NN	Nevada Northern

[2] Freight value per short ton is calculated on smelter or mill settlements with copper valued at 14 cents per pound, lead at 7 cents per pound, and zinc at 8 cents per pound. For simplicity, tables are condensed. Many published freight tariffs list ore valuations in $5 steps and in excess of $100; use of the rate for the valuation nearest the specific ore under consideration is suitable for estimating purposes.

[3] Rate applies to ore valuation not exceeding $15.00 per ton.

[4] Special rate applying to minimum carload of 40 tons of copper ore.

[5] No rate quoted.

[6] Rate applies to ore valuation not exceeding $25.00 per ton.

[7] Rate applies to ore valuation not exceeding $35.00 per ton.

[8] Rate applies to ore valuation not exceeding $60.00 per ton.

[9] Mining district classification not used in California.

[10] Rate applies to ore valuation not exceeding $70.00 per ton.

[11] Rate applies to ore valuation not exceeding $150.00 per ton.

[12] Ton-mile rate for ore valuation not exceeding $20.00 per ton.

[13] Rate applies to ore valuation not exceeding $80.00 per ton.

[14] No rate quoted from Texas Creek to Amarillo; Salida-Amarillo rate is given for estimating purposes.

[15] Salt Lake Valley plants include smelter at Tooele, Utah, and mills at Bauer and Midvale, Utah.

[16] Rate applies to ore valuation not exceeding $12.00 per ton.

[17] Rate applies to ore valuation not exceeding $45.00 per ton.

[18] Rate applies to ore valuation not exceeding $55.00 per ton.

[19] Minimum weight is 90 percent of marked capacity of car.

[20] Minimum weight is 80 percent of marked capacity of car.

[21] Rio Grande Motor Way is a subsidiary of the Denver and Rio Grande Western Railroad and rates quoted are for a combined truck-rail haul.

[22] Minimum weight is marked capacity of car.

[23] Rate applies to ore valuation not exceeding $90.00 per ton.

[24] Not shown on figure 1.

APPENDIX N. - REPRESENTATIVE TRUCK FREIGHT RATES ON ORE AND CONCENTRATES IN THE WEST

From	To	Approximate distance in miles	Class of material shipped	Minimum shipment in short tons	Freight rate in dollars per short ton	Calculated rate in cents per short ton-mile	Type of road	Remarks
ARIZONA								
Cripple Crew mine north of Wenden, Yuma County.	RR loading point, Wenden, Ariz.	701	Copper ore.	6	$1.00	20.0	Mainly unsurfaced desert roads.	Arizona rates apply to intrastate operations of one common carrier. Distance commodity rates apply only to hauls for which specific commodity rates have not been published. Source: Arizona Motor Tariff Bureau.
Rawhide mine near Signal, Mohave County.	RR loading point, Yucca, Ariz.	45	Lead and copper ore.	6	5.22	11.6	do	
Do	RR loading point, Wenden, Ariz.	68	Lead ore.	6	4.22	6.2	do	
Silver Star mine southeast of Hope, Yuma County.	RR loading point McVay, Ariz.	20	Copper ore.	6	1.72	8.6	do	
CALIFORNIA								
Placerville, El Dorado County.	Selby, Calif.	105	Gold-silver ore.	13	4.77	4.6	Mainly hard-surfaced highways.	California rates are calculated from hourly rates applying to heavy construction equipment and cover loading without need for auxiliary equipment. Power loading incurs an additional charge. No rates on point-to-point or ton-mile basis are available. Source: Public Utilities Commission of California.
Lone Pine-Olancha, Inyo County.	do	466	Lead ore and concentrates.	13	19.04	4.1	do	
Colfax, Placer County.	do	113	Gold and silver ore.	13	5.22	4.6	do	
Trona, San Bernardino County.	do	436	Lead ore and concentrates.	13	17.82	-	do	
Campo, San Diego County.	do	594	Gold and silver ore.	13	24.25	4.1	do	
Hazel Creek, Shasta County.	do	235	Lead ore and concentrates.		10.93	4.7	do	
COLORADO								
Boulder County mining districts (within 20 miles of Boulder, Colo.)	Leadville, Colo.	160	Gold ore or concentrates.	10	10.00	6.3	Up to 20 miles of natural gravel or dirt roads and balance hard-surfaced highway all in mountainous terrain.	
Front Range mill west of Idaho Springs, Colo.	do	76	Gold-silver-copper concentrates.	10	6.50	8.6	All surfaced highway in mountainous terrain.	Freight rate set by negotiation with local trucker.
White Pine, Gunnison County.	Salida, Colo.	44	Lead or zinc concentrates.	5	6.00	13.6	do	Do.
Do	Leadville, Colo.	96	do	5	7.00	7.3	do	Do.
Keystone mill near Crested Butte, Gunnison County.	Salida, Colo.	98	do	20	5.30	5.4	Mainly hard-surfaced highway in mountainous terrain.	
Keystone mill near Crested Butte, Gunnison County.	Leadville, Colo.	150	Lead concentrates.	20	7.94	5.3	do	
Ouray, Ouray County.	do	210	do	10	12.00	5.7	do	
Camp Bird mine, near Ouray, Ouray, County.	Leadville, Colo.	215	do	10	14.00	6.5	Five miles of steep gravel-surfaced road and balance hard-surfaced highway in mountainous terrain.	Published rates. Source: Colorado Motor Carriers Association.
Do	RR loading point, Ridgway, Colo.	15	Lead or zinc concentrates.	5	3.25	21.6	do	Do.

From	To	Approximate distance in miles	Class of material shipped	Minimum shipment in short tons	Freight rate in dollars per short ton	Calculated rate in cents per short ton-mile	Type of road	Remarks
COLORADO--Continued:								
Mines within 5 miles of Alma or Fairplay, Park County.	RR loading point, Salida, Colo.	45	Zinc concentrates.	5	3.20- 4.49	7.1-10.0	Up to 5 miles of steep gravel- or dirt-surfaced road and balance hard-surfaced highway in mountainous terrain.	Published rates. Source: Colorado Motor Carriers Association.
Do	Leadville, Colo.	78	Lead concentrates.	5	5.25- 7.05	7.1- 9.0	do	Do.
Bonanza district, Saguache County.	RR loading point, Villa Grove, Colo. (abandoned)	16	Lead-zinc ore.	5	1.69	10.5	Graded dirt or graveled roads in mountainous terrain.	Do.
Silverton, San Juan County.	RR loading point, Ridgway, Colo.	33	Lead or zinc	6	4.00	12.1	Hard-surfaced highway in mountainous terrain.	
Do	RR loading point, Montrose, Colo.	59	do	6	4.85	8.2	do	Do.
Do	Leadville, Colo.	232	Lead concentrates.	6	13.35	5.8	do	Do.
Gladstone district, San Juan County.	Shenandoah-Dives mill, Silverton, Colo.	12-15	Lead-zinc ore	6	3.00- 4.50	20.0-37.5	Steep dirt roads and up to 5 miles of hard-surfaced road.	Do.
Animas Forks, district, San Juan County.	do	8-10	do	6	2.00- 3.00	20.0-37.5	do	Do.
Mineral Point district, San Juan County.	do	12-15	do	6	3.50- 4.50	23.3-37.5	do	Do.
Cunningham Gulch district, San Juan County.	do	4- 6	do	6	1.00- 2.50	25.0-41.7	do	Do.
Chattanooga district, San Juan County.	do	12-15	do	6	2.50- 3.50	16.6-29.0	Short, steep access roads and up to 10 miles of hard-surfaced highway.	Do.
Pandora mill, Telluride, San Miguel County.	RR loading point, Montrose, Colo.	67	Lead or zinc concentrates.	20	3.25	4.9	Hard-surfaced highway in mountainous terrain.	
Mines within 5 miles of Breckenridge, Summit County.	Leadville, Colo.	45-55	Lead-zinc ore or concentrates.	5	3.00	5.4- 6.7	Short, steep access roads and balance maintained gravel roads or hard-surfaced highway.	Do.
Mines from 6 to 10 miles from Breckenridge, Summit County.	do	50-60	do	5	3.50	5.8- 7.0	do	Do.
Mines within 1 mile of Kokomo, Summit County.	do	18	do	5	1.50	8.3	do	

730-683 O-64—10

IDAHO and MONTANA	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	Not specified.	
Private hauling operation.	RR loading point	16	do	5	2.54	16.0	do	2,700 tons shipped in 1958. Trucks operated by shipper.
Do	do	2	do	8	.87	44.0	do	5,200 tons shipped in 1958. Trucks operated by shipper.
Do	do	71	do	15	2.10	3.0	do	29,000 tons shipped in 1958. Trucks operated by shipper.
Do	Smelter	400	Copper ore or concentrates.	20	11.40	3.0	do	Contract rate.
Do	do	110	Lead-zinc ore.	15	4.80	4.4	do	Do.
Do	do	100	do	18	6.50	6.5	do	Do.
NEVADA								
Yellow Pine district, Henderson, Clark County.	Tooele, Utah	538	Lead ore	20	26.90	5.0	Mainly hard-surfaced highway.	
Maggie Creek district, Carlin, Elko County.	Hayden, Ariz.	1,017	Copper ore	20	50.85	5.0	do	
Do	Anaconda, Mont.	555	do	20	27.75	5.0	do	Estimated freight costs based on a flat 5 cents per ton-mile. Estimated freight rates based on a cost of $1.00 per running mile for a 20-ton truck or 5 cents per ton-mile, quoted by a Nevada contract carrier who stated that point-to-point rates would have to be set after analysis of each individual case. No distance-commodity or point-to-point rates are available in Nevada. The Public Service Commission, State of Nevada, states that it does not require contract carriers to file rates, and common carriers have not established rates for ores and ore products.
Contact district, Elko County.	Hayden, Ariz.	997	do	20	49.85	5.0	do	
Do	Anaconda, Mont.	435	do	20	21.70	5.0	do	
Merrimac district, Elko, Elko County.	Tooele, Utah	213	Lead ore	20	10.65	5.0	do	
Delano district, Montello, Elk County.	do	156	do	20	7.80	5.0	do	
Railroad district, Palisade, Eureka County.	do	243	do	20	12.15	5.0	do	
Bullion district, Battle Mountain, Lander County.	Hayden, Ariz.	1,066	Copper ore	20	53.30	5.0	do	
Do	Anaconda, Mont.	604	do	20	30.20	5.0	do	
Pioche district, Pioche Lincoln, County.	Hayden, Ariz.	701	Copper ore	20	35.05	5.0	do	
Do	Anaconda, Mont.	731	do	20	36.55	5.0	do	
Yerington district, Wabuska, Lyon County.	Hayden, Ariz.	878	do	20	43.90	5.0	do	
Do	Anaconda, Mont	841	do	20	42.05	5.0	do	
Candelaria district, Mina, Mineral County.	Hayden, Ariz.	785	do	20	39.25	5.0	do	
Do	Anaconda, Mont.	861	do	20	43.05	5.0	do	
White Pine and East Ely districts, White Pine County.	Tooele, Utah	224	Lead ore	20	11.20	5.0	do	

From	To	Approx-imate distance in miles	Class of material shipped	Minimum shipment in short tons	Freight rate in dollars per short ton	Calculated rate in cents per short ton-mile	Type of road	Remarks
NEW MEXICO								
Central, Swartz, and Pinos Altos districts, Silver City, Grant County.	Deming, N. Mex.	53	Lead and zinc ore.	30	7.80	14.7	Short dirt access roads and balance hard-surfaced highways.	Freight rates from New Mexico points herein listed are derived largely from distance class rates published by the New Mexico Motor Carriers Association, Inc. Few point-to-point commodity rates on ores and concentrates have been established by common or contract carriers in New Mexico.
Do	El Paso, Tex.	153	Lead ore.	5	12.60	8.2	do	
Eureka district, Hachita, Grant County	Deming, N. Mex.	51	Copper, lead-zinc ore or concentrates.	30	7.80	15.3	do	
Do	El Paso, Tex.	155	Lead, copper ore.	30	11.00	7.1	do	
Do	Amarillo, Tex.	562	Zinc concentrates.	30	31.60	5.6	do	
Lordsburg district, Lordsburg, Hidalgo County	El Paso, Tex.	162	Copper ore.	25	13.00	8.0	do	
Cuba district, Cuba, Sandoval County.	RR loading point, Bernalillo, N. Mex.	66	do	25	8.40	12.7	do	
Do	El Paso, Tex.	355	do	25	26.40	7.4	do	
Cerrillos, Cooper, San Pedro, Old Placer, and New Placers districts, Santa Fe County.	do	326	Copper ore and concentrates. Lead ore and concentrates.	25	20.60	6.3	do	
Socorro, Socorro County.	do	197	Lead ore	30	15.40	7.8	do	
Do	Deming, N. Mex.	163	Lead-zinc ore	30	11.40	7.0	do	
Magdalena district, Socorro County.	El Paso, Tex.	224	Lead ore.	30	16.40	7.3	do	
Do	Deming, N. Mex.	189	Lead-zinc ore	30	13.60	7.2	do	
Hansonberg district Socorro County.	RR loading point, San Antonio, N. Mex.	30	do	30	.29	19.3	do	
WASHINGTON								
Loomis, Okanogan County.	RR loading point, Nighthawk, Wash.	-	Not specified	7.5	.98	-	Not specified.	
Palmer siding, Colville, Stevens County.	Tacoma, Wash.	-	do	20	10.97	-	do	
Grandview mill, Pend Oreille County.	Metaline Falls, Wash.	-	do	5	.65	-	do	
Leadhill mine, Pend Oreille County.	Grandview mill.	-	do	5	1.25	-	do	
Do.	Metaline Falls, Wash.	-	do	5	1.25	-	do	

APPENDIX O. - REPRESENTATIVE DISTANCE-COMMODITY OR CLASS RATES APPLYING TO TRUCK TRANSPORTATION OF ORES AND CONCENTRATES IN THE WEST[1] [2]

Example	State	Type of road or equipment	Minimum load in short tons	Rates in cents per ton-mile for distances in miles not over:																				
				[3]1	[3]5	[3]10	[3]15	20	25	30	35	40	50	60	75	80	90	100	150	200	300	400	500	600
1	Arizona[4]	Off-road	5	100.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Dirt and/mountain roads not maintained.	5	15.0	15.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Non-surfaced but maintained roads.	5			10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		Surfaced roads.	5			6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
2	Colorado[5]	All roads, mountain, and plain areas.	5	270.0	54.0	28.0	20.0	18.0	16.0	14.7	12.9	12.7	11.6	10.5	9.6	9.4	9.2	9.0	8.8	8.8	8.8	8.8	8.8	8.8
		do	15	220.0	44.0	23.0	18.0	15.0	14.0	12.7	11.7	11.0	10.0	9.7	8.6	8.5	7.8	7.2	6.3	6.1	5.5	5.5	5.5	5.5
3	Colorado[6]	All roads, mountainous areas.	10	13.0	13.0	13.0	13.0	13.0	13.0	10.0	10.0	10.0	7.0	1.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
4	New Mexico[7]	All roads, largely plains area.	[8]25-30	455.0	91.0	49.0	35.7	28.4	24.1	22.1	19.2	18.2	15.5	14.6	12.5	12.4	12.2	11.3	8.5	7.7	6.3	5.4	4.9	4.7
		do	[9]LTL	816.0	163.0	90.0	63.2	51.0	43.2	38.8	34.0	32.1	28.3	25.8	23.2	22.4	21.3	20.3	16.0	13.8	11.1	9.7	8.8	8.3
		do	[8]25-30	406.0	81.2	44.8	32.0	25.6	21.6	19.9	17.2	16.4	13.2	13.2	11.2	11.2	10.9	10.2	9.4	6.9	5.7	4.8	4.4	4.2
		do	[9]LTL	744.0	744.0	80.4	57.6	45.6	38.9	34.8	30.6	28.8	25.4	23.2	21.0	20.1	18.6	18.4	14.3	12.4	10.0	8.7	8.0	7.4
5	New Mexico[10]	All roads, largely plains area.																						
		2-axle truck or 3-axle tandem unit.	8	10.0	10.0	8.0	8.0	8.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
		4-axle or 5-axle combination unit.	8	7.0	7.0	6.0	6.0	6.0	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
6	New Mexico[11]	All roads, mountain and plain areas.	8	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.0	7.0	7.0	7.0	7.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
7	Idaho[12] (Coeur d'Alene district)	All roads, mountainous areas.	10 15	15.0	13.0	12.0	12.0	11.0	11.0	10.0	10.0	10.0	9.0	9.0	8.0	8.0	8.0	6.0	5.0	5.0	5.0	5.0	5.0	5.0
8	Washington[13]	State-wide minimums.	5	19.2	12.7	10.1	8.9	8.2	7.6	7.3	7.0	6.7	4.6	-	-	-	-	-	-	-	-	-	-	-
		do	7.5															3.0	-	-	-	-	-	-
		do	10																	1.9	-	-	-	-
9	Northwestern United States[14]	Not specified	10	17.0	17.0	16.0	16.0	15.0	15.0	13.0	13.0	11.0	10.0	10.0	9.0	9.0	9.0	8.0	8.0	7.0	7.0	7.0	7.0	7.0

See footnotes on following page.

[1] Tables are presented for illustration and should be used for estimating purposes only. The rates listed apply only to truck hauls for which no specific point-to-point commodity rates have been established.

[2] The actual published tariffs on which the rates in this table are based are set up in several ways: (1) rates per ton-mile applying to specific distance ranges; (2) rates per ton or hundredweight for distance increments of 5 miles, 10 miles, or other interval. For convenience of comparison all rates have been converted to a ton-mile basis. Where ton-mile rates apply over a distance range, this fact is indicated by an arrow. Where arrows are not used, the quoted ton-mile rates apply only to the distance specified in the column headings. Ton-mile rates for intermediate distances can be estimated.

[3] Although distance commodity tables may cover the distance range under 15 miles, freight rates for hauls under 15 miles computed from such tables are not always realistic. Truck hauls for short distances are normally made by local contract haulers at unpublished rates set for each individual operation.

[4] Intrastate rates applying to a specific Arizona contract and common carrier. Published by the Arizona Motor Tariff Bureau. Applies to ores, concentrates, and products of mines. Rates are not based on valuation.

[5] Intrastate and interstate rates in Colorado and Four Corners area of Arizona, Colorado, New Mexico, and Utah. Rates apply to operations of a specific contract and common carrier hauling ore and concentrates. Rates as published by Colorado Motor Carriers Association are on a basis of hundredweight units and have been converted to a ton basis. Rates are not based on valuation.

[6] Intrastate rates applying to operation of local carrier between mines in Clear Creek, Gilpin, Grand, and Jefferson Counties and destinations in Colorado.

[7] Data are derived from class rate table (class 100) published by New Mexico Carriers' Association, Inc. The rates in the published table have been converted from hundredweight to ton units and adjusted to cover ore shipments on the following basis: For truckload (TL) lots, 35 percent of class 100 rate applies; for less than truckload (LTL) lots, 60 percent of class 100 rate applies on ore having a valuation of $100 or less. Ore having a valuation of more than $100 per ton is subject to higher rates.

[8] Intrastate rate.

[9] Interstate rate; LTL denotes "less than truckload".

[10] Intrastate distance commodity rates applying to a specific contract carrier operating in New Mexico. Published by New Mexico Motor Carriers' Association, Inc. Rates are not based on valuation.

[11] Intrastate distance commodity rates applying to ores quoted by an individual contract carrier. Rates are not based on valuation; ore in sacks.

[12] Average rates for ore-trucking in 1958 quoted by a contract carrier. Rates are not based on valuation.

[13] Intrastate distance commodity rates applying to ores and concentrates set by the Public Service Commission of the State of Washington. Rates are minimums, that is, carriers may not charge less than quoted rates. Rates apply to products having an actual value not exceeding $50 per ton. For ore of higher valuation add 5 percent to the rate for each $10 per ton ore valuation over $50 per ton.

[14] Interstate distance commodity rates applying to truck shipment of ores and concentrates in Washington, Oregon, Idaho, and Montana if tariffs have not been established by State public utilities commissions. Published by Pacific Inland Tariff Bureau, Inc. Rates are not based on valuation.

APPENDIX P. - FREIGHT RATES APPLYING TO SHORT TRUCK HAULS

From			To	Length of haul in miles	Class of material	Freight rate in dollars per short ton	Minimum truck load, short tons	Short ton-mile rate in cents	Type of haul
Mine	District	County and State							
Ajax mine......	Cripple Creek.	Teller County, Colo.	Carlton mill, Cripple Creek, Colo.	2.3	Gold ore	$0.65	12	28.2	Graveled maintained road, 2 to 4 percent grade with the load.
Cresson mine...	do	do	do	1.0	do	.45	12	45.0	Graveled maintained road, up to 8 percent grade with the load.
Grace Greenwood mine.	do	do	do	7.0	do	.75	12	10.7	Three miles of graveled road (abandoned railroad grade) up to 4 percent grade with the load and 4 miles of hard-surfaced highway with a slight grade against the load.
Mary McKinney dump.	do	do	do	2.0	do	.50	12	25.0	Hard-surfaced highway with a slight grade against the load.
Elkton dump....	do	do	do	0.5	do	.20	12	40.0	Short access road, grade with the load.
Bald Eagle mine.	Virginia Canyon.	Clear Creek County, Colo.	Front Range mill west of Idaho Springs, Colo.	6.0	Gold-silver-copper ore	1.25	6	20.8	Two miles of graded road, up to 10 percent grade with the load, and 4 miles of surfaced highway with slight grade against the load.

APPENDIX Q. - TRI-STATE ORE BUYERS' REPRESENTATIVE

Ore Buyer and Address:	Representing
J. H. McCoglin 212 Courthouse Building Joplin, Missouri	American Steel & Wire Co.
Dan Stewart, District Manager American Zinc, Lead & Smelting Co. 206 Courthouse Building Joplin, Missouri	American Zinc Co. of Illinois
Mrs. Jack Ferneau 116-1/2 West 4th Street Joplin, Missouri	M & H Zinc Co.
Clyde Ingram Picher, Oklahoma	American Metal Climax Co., Inc.
O. A. Rockwell, Manager The Eagle-Picher Co. Cardin, Oklahoma	
H. W. Robertson 915 Virginia Avenue Joplin, Missouri	National Zinc Co., Inc.

APPENDIX R. - BUYERS OF COPPER, LEAD, ZINC, GOLD, AND SILVER ORES SERVING THE WEST

American Smelting & Refining Company

(1) Southwestern Ore Purchasing Department
810 Valley National Bank Bldg., Tucson, Ariz.
Ores and concentrates of copper, lead, gold, and silver; zinc concentrates; lead-zinc-copper milling ores; for treatment in appropriate southwestern plants.

(2) P. O. Box 1605, Tacoma, Wash.
Gold, silver, and copper ores and concentrates for treatment at the Tacoma smelter.

(3) 405 Montgomery St., San Francisco, Calif.
Gold, silver, lead, and lead-copper ores and concentrates for treatment at the Selby, Calif. smelter.

(4) East Helena, Mont.
Gold, silver, and lead ores and concentrates for treatment at the East Helena smelter.

American Zinc, Lead & Smelting Company
Ore Buying Department
1600 Paul Brown Bldg., St. Louis 1, Mo.
High-grade lead and zinc concentrates.

The Anaconda Company
Anaconda Reduction Works
Anaconda, Mont.
Gold, silver, and copper ores and concentrates.

The Bunker Hill Company
Ore Purchasing Department
P.O. Box 29, Kellogg, Idaho
Lead ore and concentrates; zinc concentrates.

The Consolidated Mining & Smelting Company of Canada, Ltd.
Trail, British Columbia
Siliceous gold ore (this plant formerly treated lead-zinc ores from the United States, but not under current tariffs governing entry of lead and zinc products into the United States).

Inspiration Consolidated Copper Company
Smelting Department, Inspiration, Ariz.
Copper, gold, and silver concentrates.

International Smelting & Refining Company
Ore Purchasing Department
815 Kearns Bldg., Salt Lake City, Utah
Lead or zinc ores and lead concentrates (lead-zinc milling ores accepted for treatment at Midvale, Utah, milling plant of the United States Smelting Refining & Mining Company).

Kennecott Copper Corporation
Nevada Mines Division
McGill, Nev.
Gold, silver, copper ores and fluxes (by prior arrangement as needed by the smelter).

Magma Copper Company
Superior, Ariz.
Copper, gold and silver ores.

National Zinc Company, Inc.,
Ore Purchasing Department
11 Broadway, New York 4, N. Y.
Zinc concentrates.

Phelps Dodge Corporation
Douglas, Ariz.
Copper ores.

United States Smelting Refining & Mining Company
Ore Purchasing Department
911 Newhouse Bldg., P. O. Box 1980, Salt Lake City 10, Utah
Lead-zinc milling ores.

U.S. GOVERNMENT PRINTING OFFICE 1964 O—730-683