Metallurgical Bulletin

THE GENERAL ENGINEERING COMPANY

SALT LAKE CITY

NEW YORK CITY

U. S. A.

Office and Laboratory

159 Pierpont Avenue
Salt Lake City, Utah

METALLURGICAL BULLETIN

The General Engineering Company

(Incorporated)

Consulting Engineers

OFFICERS

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KARL BERNSON	Director
JAS. W. NEILL	Director
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U. S. A.

ACKNOWLEDGMENTS

In a publication of this nature, use is made of data from a variety of sources, and it is our desire that full credit be given. Some material is obviously of a public nature and it is quite impossible to give credit to the originator, but where the information has been taken bodily or adapted from published tables credit is given with our table.

Use has been made of matter published in the bulletins of the American Insitute of Mining and Metallurgical Engineers, the Institute of Mining and Metallurgy, the U. S. Bureau of Mines, the U. S. Geological Survey, and other governmental bureaus; the Engineering & Mining Journal, the Mining and Scientific Press, Richard's Ore Dressing, Allen's Handbook of Ore-Dressing, various engineers-handbooks, manufacturers catalogs, etc.

Much of the data has been accumulated by the General Engineering Company in the course of its many years service, and much has been worked up for this bulletin.

Use has been made of some of the illustrations in Agricola's De Re Metallica made available by the translation and publication of Herbert Clark Hoover and Lou Henry Hoover.

no 1

METALLURGICAL BULLETIN

Successful mining depends upon profitable marketing of the products of the operations.

The very nature of ores, with the great variation in minerals, economic metals, refractory elements, grain sizes, physical properties, etc. makes its beneficiation more than a simple process.

All ores require treatment in a metallurgical plant before the products can be profitably marketed.

Successful metallurgical plants are predicated upon forehand knowledge of the behavior of the ore and its constituents under various treatments and conditions, worked out into a comprehensive plan or flow-sheet, and embodied in a design which utilizes the best of modern machinery and appliances to obtain the desired products with the minimum of operation difficulties and at minimum cost.

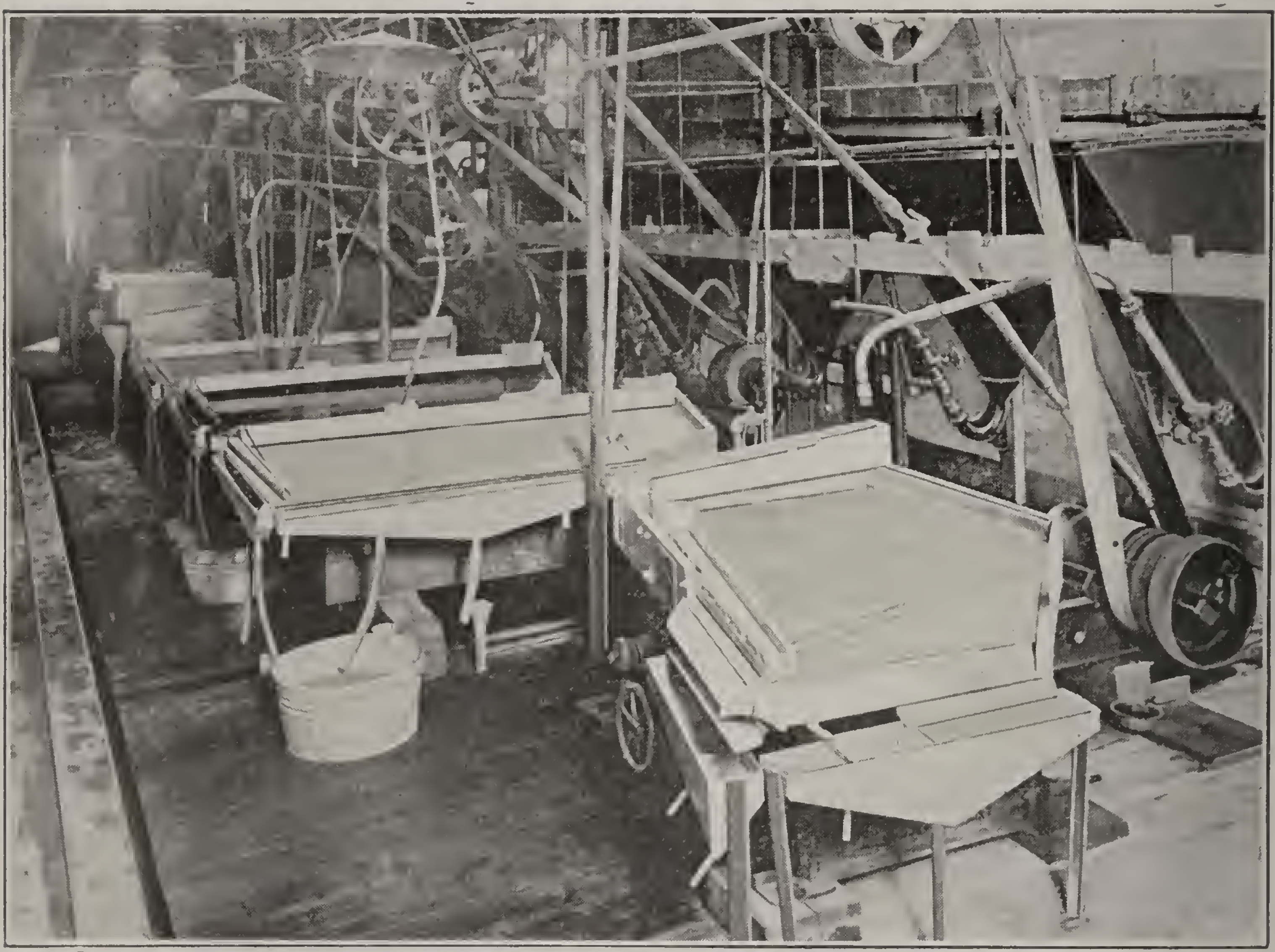
The business of the General Engineering Company is the work of putting mines upon an economical producing basis:— the examination of mines to determine those factors affecting production; sampling the mine for ore treatment; analysis and testing of ores, planning for economical recovery of the values; design of metallurgical plants based upon the results of metallurgical tests; purchase of equipment; erection and operation of plants; sampling and sale of metallurgical products; and solution of such engineering, metallurgical and economic problems as naturally arise in these connections. In addition, the plant and staff have served and will continue to be available for the solution of similar problems in industrial work.

The General Engineering Company was organized in 1905 with a strong engineering staff and a laboratory for testing ores. The original organization is practically intact, with such additions as naturally come to a business whose continued success demands the broadening and strengthening of its lines and the extension of its facilities. While the offices and testing plant are still in their original location, both have been more than doubled in floor space in the last few years.

John M. Callow, as president, has had the direct management of the company since its inception. The mining public is well aware of his international reputation as an expert in ore-treatment problems, and in the design of metallurgical plants and equipment. He has developed Pneumatic Flotation, and it is largely to his efforts that the great success of this process is due. The Callow Tank and Callow Traveling Belt Screen are also successful machines of his invention.

Mr. Callow divides his time between the Salt Lake and the New York offices of the company.

The other officials of the company are well-known men of technical training and years of practical experience.

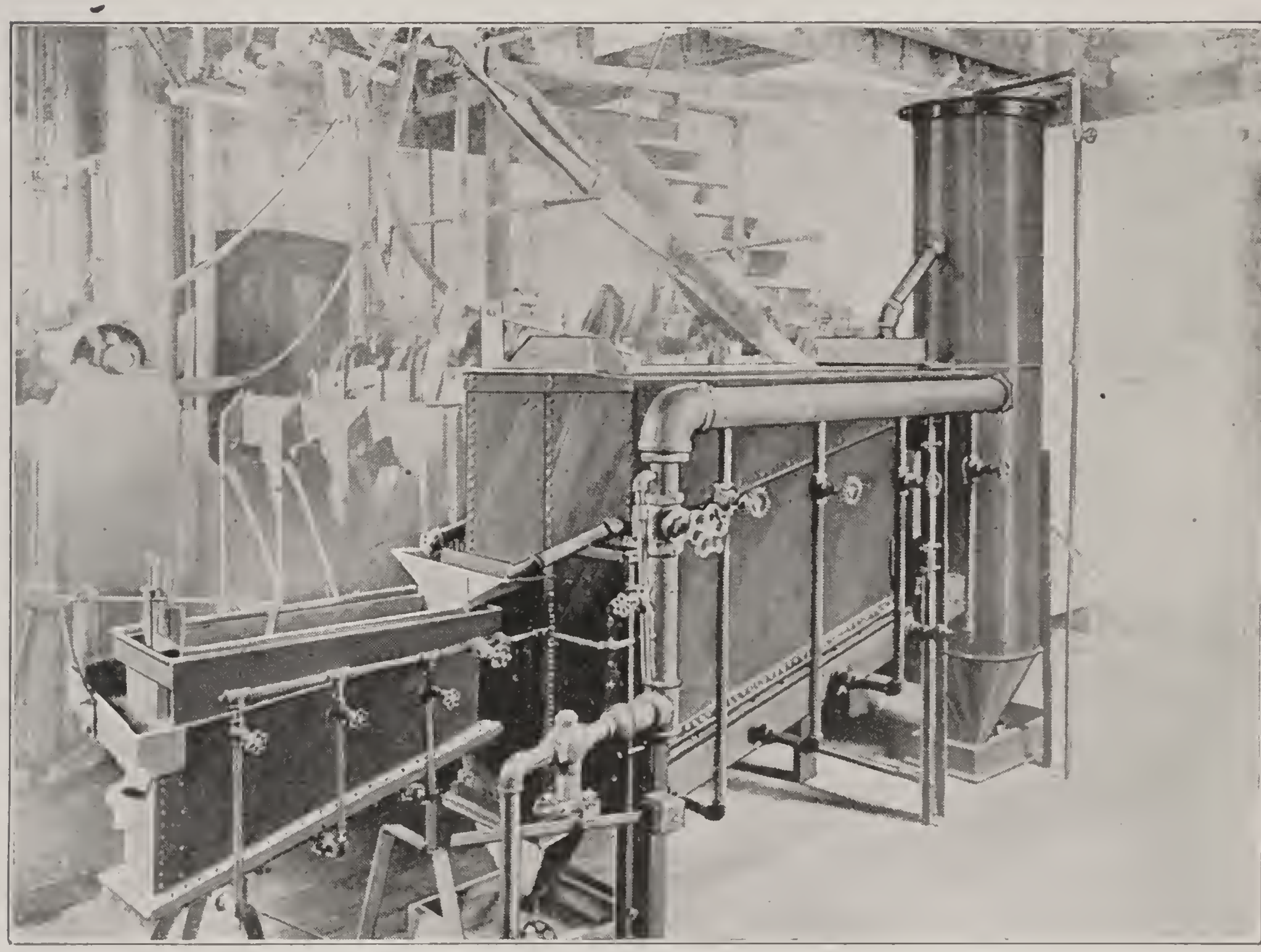


Testing Plant

Concentrating Tables, Callow Tanks

Recognition of a world demand for the services of the General Engineering Company, as well as from engineers and operators of the eastern United States, led to the establishment of an office in New York City. The coordination of our two offices is quite thorough; Mr. J. M. Callow spending a part of his time at each office, and by a system of exchange of correspondence and data, full information regarding progress of all work and new developments are made available at both offices.

In these times of rapid advance in the science and art of ore treatment and allied subjects, it is necessary to keep closely in touch, not only with new processes, but with new types of machinery. The General Engineering Company aims to be progressive; it has always been willing to spend the necessary time and money to investigate thoroughly such processes and equipment as in its judgement might be of value to its clientele, that it may be able to advise them of their merits.



Testing Plant

Tonnage Pneumatic Flotation Equipment
Jigs in background.

Modern plants make use of the pebble, ball, and rod mills for the finer crushing operations. The development of the pebble mill as a granular crusher for concentration was started in the testing laboratories of the General Engineering Company; it was among the first to adopt the ball mill for wet crushing. Rod mills and other improvements are being carefully investigated for the benefit of its clients.

Flotation, the most important metallurgical process of recent years, has made tremendous strides since the General Engineering Company built the first Pneumatic Flotation plant in 1914. Particular attention has been given to the perfection and commercializing of special and new flotation reagents, and its laboratory is equipped to deal with flotation problems of any nature.

Some of the leaching processes have great commercial possibilities on ores and concentrated products. Leaching with acids and alkalies, sulphatizing roasting with leaching, etc. show promising results, both in the laboratories of the General Engineering Company and in several commercial plants.

Investigation of new processes and new types of machinery is a specialty, for which the General Engineering Company's laboratories are particularly well equipped. A number of well known successful machines, devices and processes have been developed in these laboratories, under its supervision, or with its advice as consultants.

The sale of ore-shipments with the attendant supervision of sampling is done for clients unable to attend to such matters themselves. Familiarity with local samplers and smelters, ore schedules, etc, qualify the General Engineering Company peculiarly to safeguard their interests.

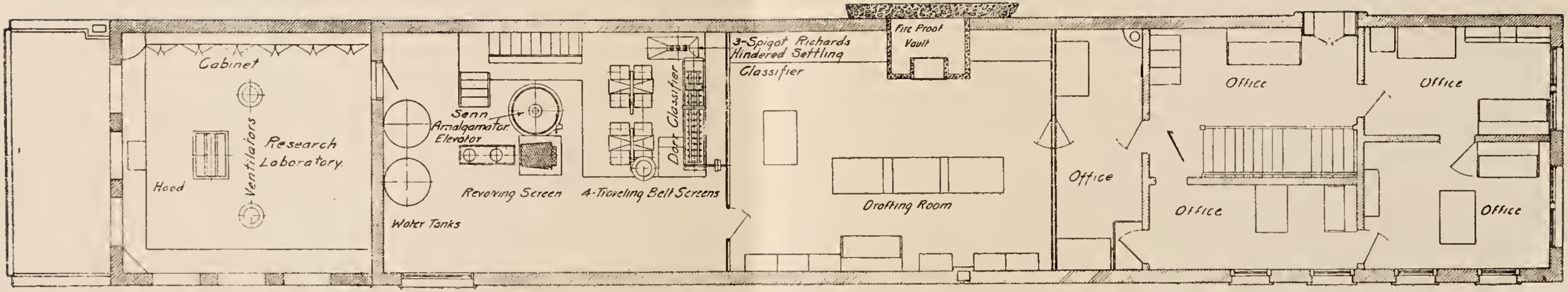
MINE EXAMINATION WORK

Before a mine can be valued or put into production, the economic method of treatment of its ore must be known. Likewise, before a treatment process can be worked out, the mine itself must be studied, for character of ore bodies, tonnage of ore available, determination of shipping ore, milling ore, and waste; all these have an economic bearing upon the property.

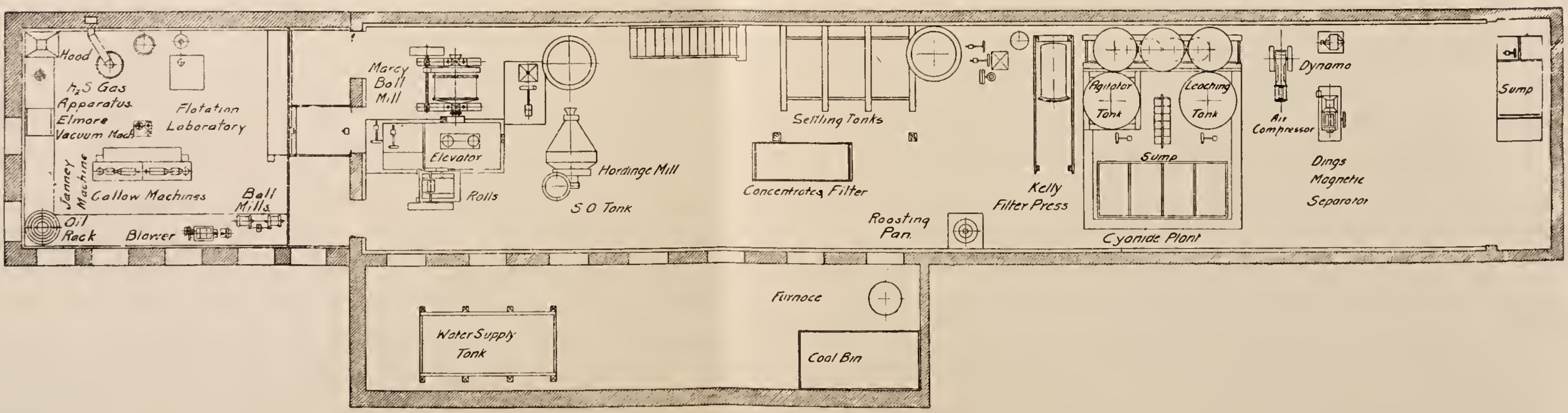
It follows logically that the examination and valuation of mines and the treatment of the ores are so closely related, that best results are obtained by the use of one organization for this work.

The General Engineering Company is affiliated with experienced mining engineers, and is prepared to undertake mine examinations and reports, in connection with proposed treatment plants, or for other purposes, as desired.

DEVELOPMENT OF PROSPECTS AND SMALL MINES.—The supervision of the development of smaller mining properties, aiming at the opening of such ore-bodies as may be made commercial by shipment or milling will be undertaken.

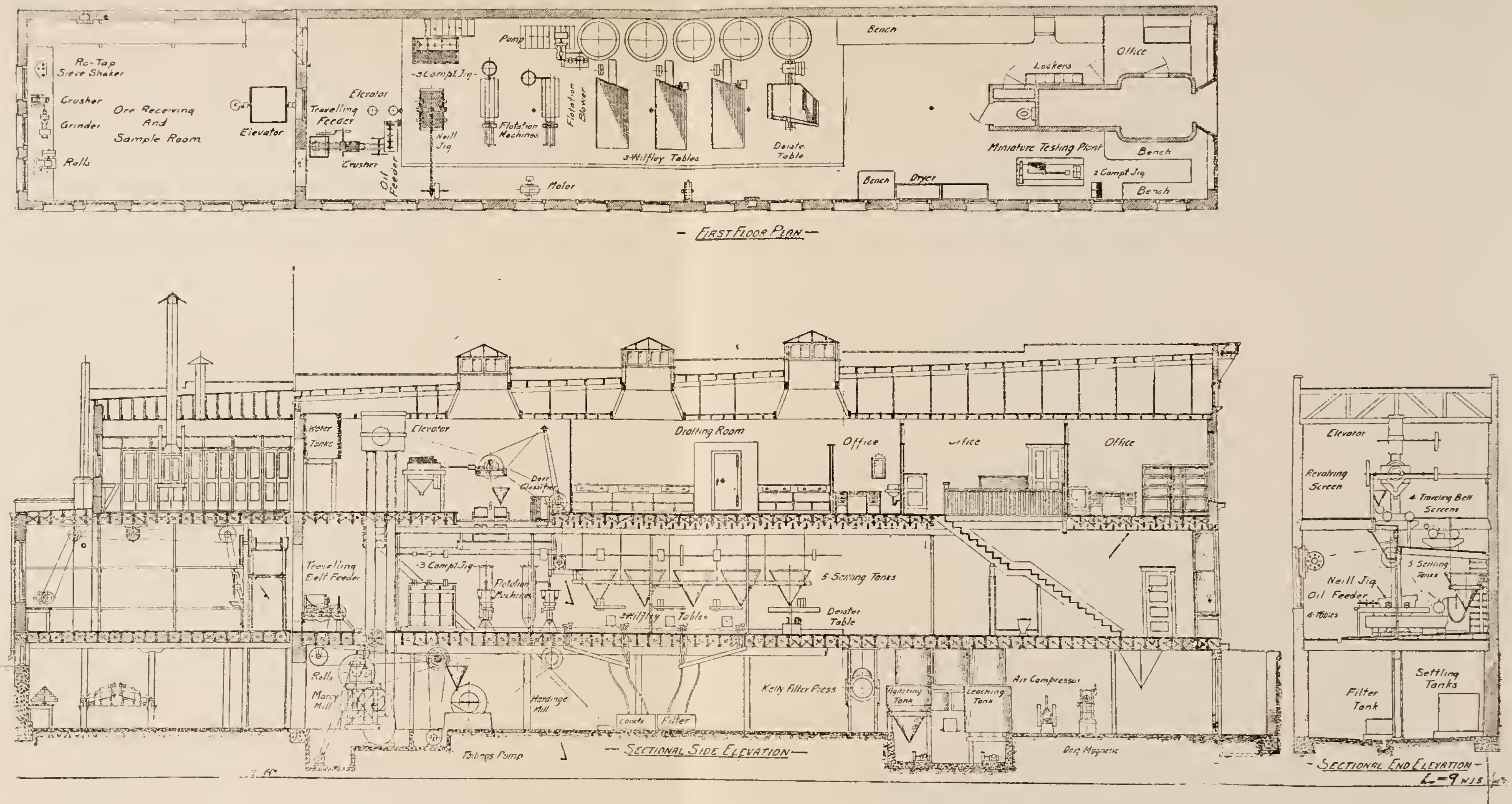


SECOND FLOOR PLAN



BASEMENT PLAN

Testing Plant The General Engineering Co., Salt Lake City, Utah



Testing Plant The General Engineering Co., Salt Lake City, Utah

ORE TESTING

Mill operations can be expected to be successful only when the design of the plant is suitable to the ore to be treated. Accurate and complete data for the design of treatment plants for ores can only be obtained in a suitably equipped testing plant. The Ore Testing Plant of the General Engineering Company is generally recognized as the best equipped and the most practical in the entire world; on the results of its testing, a large number of successful plants have been built.

DESIGN OF TESTING LABORATORY

The Ore Testing Laboratory of the General Engineering Company is unique and differs from other plants of similar nature in that actual mill conditions are here duplicated, the process of whatever character being continuous and not intermittent. This plant is so arranged that all possible ore dressing combinations can be made at will, the ore starting at the feeder and progressing through, from machine to machine, in exactly the same manner as if it had been especially built for the particular ore.

The laboratory covers two floors, each 20x120 feet, and part of an upper floor, 20x30 feet. The arrangement, variety and character of equipment, and the exceptional facilities will be better comprehended from an examination of the line drawings inserted here. As new machines are perfected and new processes commercialized, the General Engineering Company aims to include in its laboratory such new machines and such necessary equipment for new processes wherever possible; it is only by keeping up-to-date that the best service can be given.

METALLURGICAL TESTS

These divide naturally into three classes:

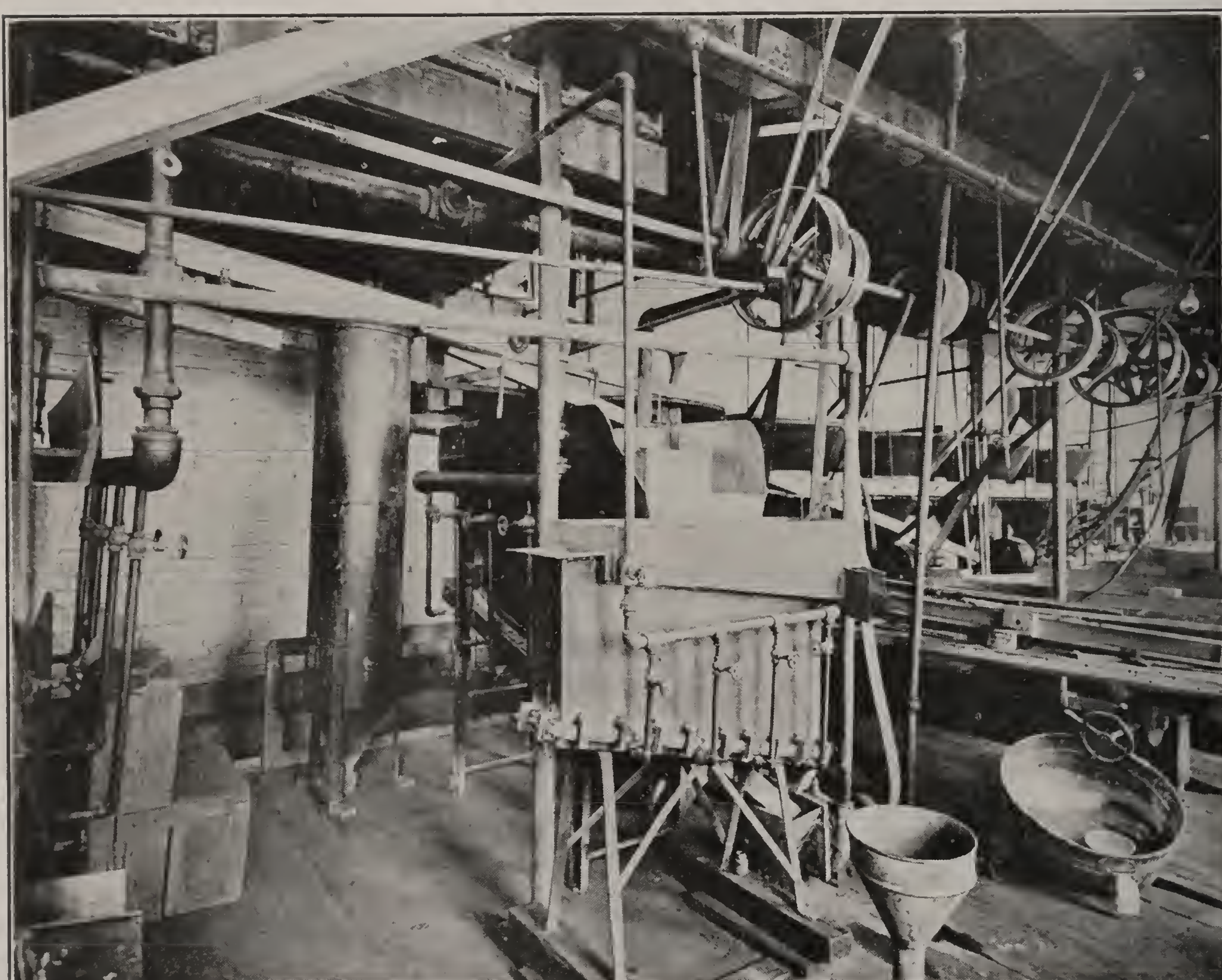
Preliminary Investigation Tests

Complete Metallurgical Tests

Tonnage Check Tests

In addition, Operating Tests may be desirable, either in a leased commercial plant, or in a new Pilot Plant.

It was formerly the custom to divide this metallurgical testing into three classes: Short Cut Tests, Preliminary Tests, Tonnage Tests; to some extent we follow this practice in special cases. Long experience has brought increased confidence in the ability to attain in the smaller quantity tests the results obtained in the tonnage tests; as check results between the two show. The new system of tests offers the client in the Complete Metallurgical Test nearly all the information which was formerly obtained only by the Tonnage test.



Testing Plant

Flotation and Gravity Concentration Equipment.

PRELIMINARY INVESTIGATION TESTS are made upon small samples, of from 50 to 100 pounds, to determine in a general way what process of milling is likely to be most applicable to the ore in question. Detail is not gone into and the report gives only an outline of the methods employed and the results obtained.

COMPLETE METALLURGICAL TESTS are what the term implies, and, except where the client specifies the method or flow-sheet, the sample is subjected to any or all of the established processes that could be considered applicable. The General Engineering Company's reports are very complete and detailed, generally accompanied by a flow-sheet, diagramatically illustrating the method of treatment employed to obtain the results shown in the reports; each sample and product from the test is given an individuality and identity of its own, and its importance or insignificance becomes at once apparent.

TONNAGE CHECK TESTS are made to establish the physical behaviour of the ore under conditions more nearly approaching practice. When satisfactory results are obtained with the smaller Complete Metallurgical Test, the Tonnage Check Test becomes unnecessary in many cases; however for such cases as appear to require the Tonnage Check Test, the necessary equipment is maintained in these laboratories.

OPERATING TESTS.—In addition to the laboratory tests outlined, it may be desirable, in certain cases, to make use of an operating mill and to treat several thousand tons of ore, following out the flow-sheet determined in the testing plant..

The General Engineering Company will take charge of such operations, recording all the information obtained, and furnishing a comprehensive report.

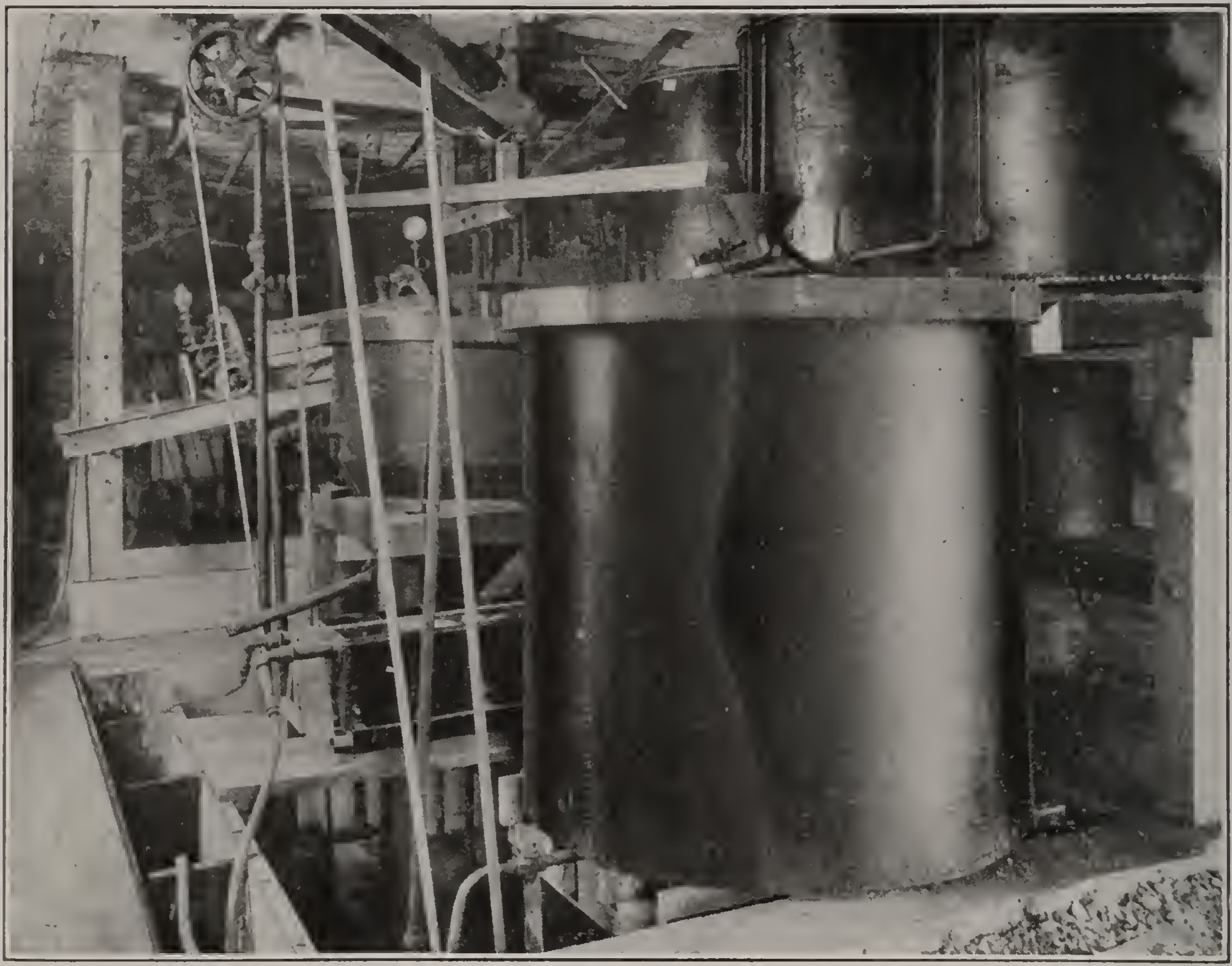
PILOT PLANT.—These are experimental operating plants built at the property, and are justified only when the ultimate erection of a reasonably large plant is contemplated, say of a daily capacity of 500 tons or more. Its capacity will depend upon local conditions at the property, but it should be large enough so that operating conditions and costs will be comparable to those of a full size commercial plant. With a capacity of 50 tons per day of 24 hours, the pilot plant should contribute materially to its support; and much of the machinery can be used afterwards in the commercial plant.

The General Engineering Company is prepared to design, erect and operate such pilot mills or experimental plants.

Information Required

In order to show the full commercial significance of the results obtained in the tests, the final deductions are usually reported in their money return per ton of crude ore treated, after subtracting all expenses and costs of milling, hauling, railroad freights and smelting. To do this correctly, it is necessary that there be furnished information as to:

Cost of hauling from mill to nearest R. R. station,
Freight Schedules,
Ore Schedule under which the mill products would be sold.



Testing Plant

Cyanide Equipment, consisting of
Leaching Tank, Agitating Tank, Solution Tank, Filter Press, Zinc Boxes, and Sumps.

As local conditions often have a direct bearing upon the best treatment for an ore, information should also be furnished as to:

Cost of labor, wages, etc.
Cost of power, fuel, etc.
Water Supply.

Such information is naturally considered of a private nature.

If a smelter schedule has not previously been obtained, the General Engineering Company will obtain an analysis of the products to be sold and will assist in obtaining the most favorable terms from the ore buyers.

QUANTITY OF ORES REQUIRED FOR TESTS

For Preliminary Investigation, 50 to 100 pounds.

For Complete Metallurgical Tests, 350 to 500 pounds.

For Tonnage Check Tests, from 3 to 5 tons, depending upon the flow-sheet as determined by previous investigation.

SHIPMENTS

All shipments should be consigned prepaid to the General Engineering Company, 159 Pierpont Avenue, Salt Lake City, Utah, mailing us bill-of-lading or express receipt.

In case of tonnage shipments that are to be sampled by the public sampler, notify us before shipment, and mark the bill-of-lading "To be sampled in transit."

ASSAYING

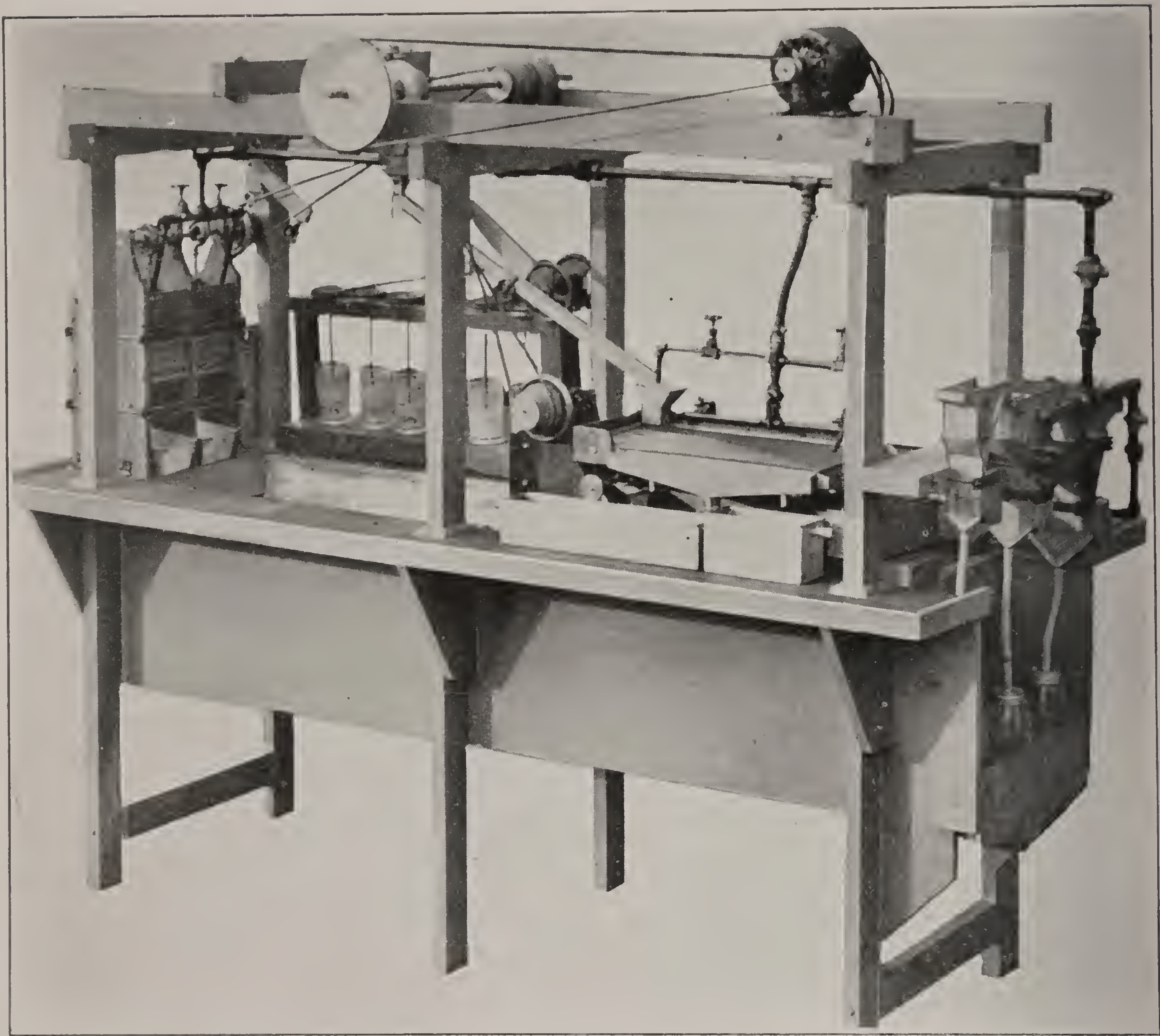
The General Engineering Company do no assaying themselves; all work and reports are based upon the assays and chemical analyses of public and independent assayers. Before starting upon test work, the client is requested to designate such assayers in Salt Lake City as they may prefer, only the actual cost of the assaying being charged.

CHARGES FOR TEST WORK

The exact cost of a test cannot be stated in advance, as it depends upon how much work has to be done to reach definite conclusions and to make final recommendations. Charges range from $150 to $250 for preliminary investigation, from $350 to $750 for complete metallurgical test, and up to $1000 for tonnage check tests

Conditions governing the operating tests vary to such a degree that it is impossible to give any estimated figures that would apply in specific cases. The charges in all cases are made as low as is consistent with good and thorough work. Anyone at all familiar with this class of work will realize that much time and care must be expended upon it, and that the remuneration should be commensurate.

Clients, when applying for terms, should roughly outline the character of the ore, the class of test, and give all information available with regard to the ore as affecting the test work; an approximate cost for the work can then be submitted by the General Engineering Company .



Miniature Ore Testing Plant

This is a complete, self-contained Ore Testing Plant consisting of: 2 compartment 4"x6" jig; 12"x24" concentrating table; 3 spigot hydraulic classifier; automatic feeder; ¼ H. P. motor; piping, belting, etc.

We have supplied many of these minature ore testing plants to universities and mining companies all over the world. If interested write for special bulletin.

Consulting and Special Work

As stated in the introduction, the General Engineering Company is concerned principally with the work of putting mines upon an economical producing basis.

As Consulting Engineers, the General Engineering Company advise upon the many special problems that come up in connection with mining and the industries associated with it; problems requiring inspection, investigation, research, special designing, etc.

While the General Engineering Company has exceptional facilities for research, wide experience and a competent staff, it does not hesitate to go outside its own organization when thereby the interests of its clients are better served. It has close association with engineers, operators, and metallurgists, well-known and thoroughly experienced in those allied lines of industry and practice which lie outside the regular field of the General Engineering Company.

Similarly, special work has recently been done by this organization in such fields as: sugar refining (both beet and cane), phosphate and potash production, sewage disposal, thickening and filtration of difficult materials, roasting-and-leaching, new processes, etc.

FLOW SHEETS OF MILLS

The purpose of ore-testing work is two-fold: (a) to determine whether the ore may be treated at a profit, and (b) to find the process whereby the most profit may be obtained.

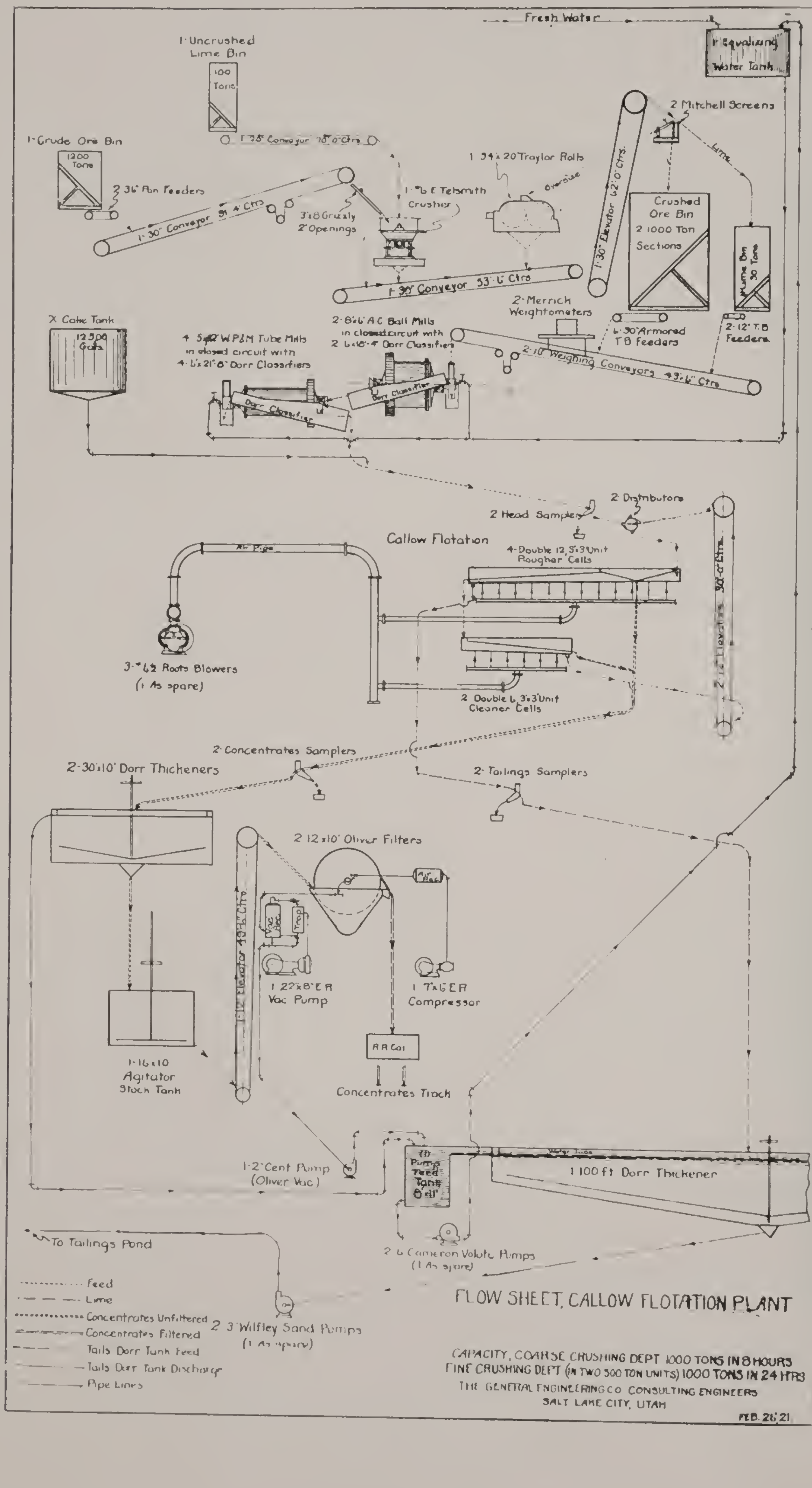
An ore-treatment process is best explained and comprehended by means of a Flow-Sheet and where considered necessary a flow-sheet accompanies the ore testing report.

The flow-sheet is the basis upon which new plants are designed, and aims to show the movement of the various constituents of the ore stream from the time it enters until it leaves the mill; quite frequently there is added information in the way of quantities and assays of the various constituents or products, and the flow-sheet may include a water chart.

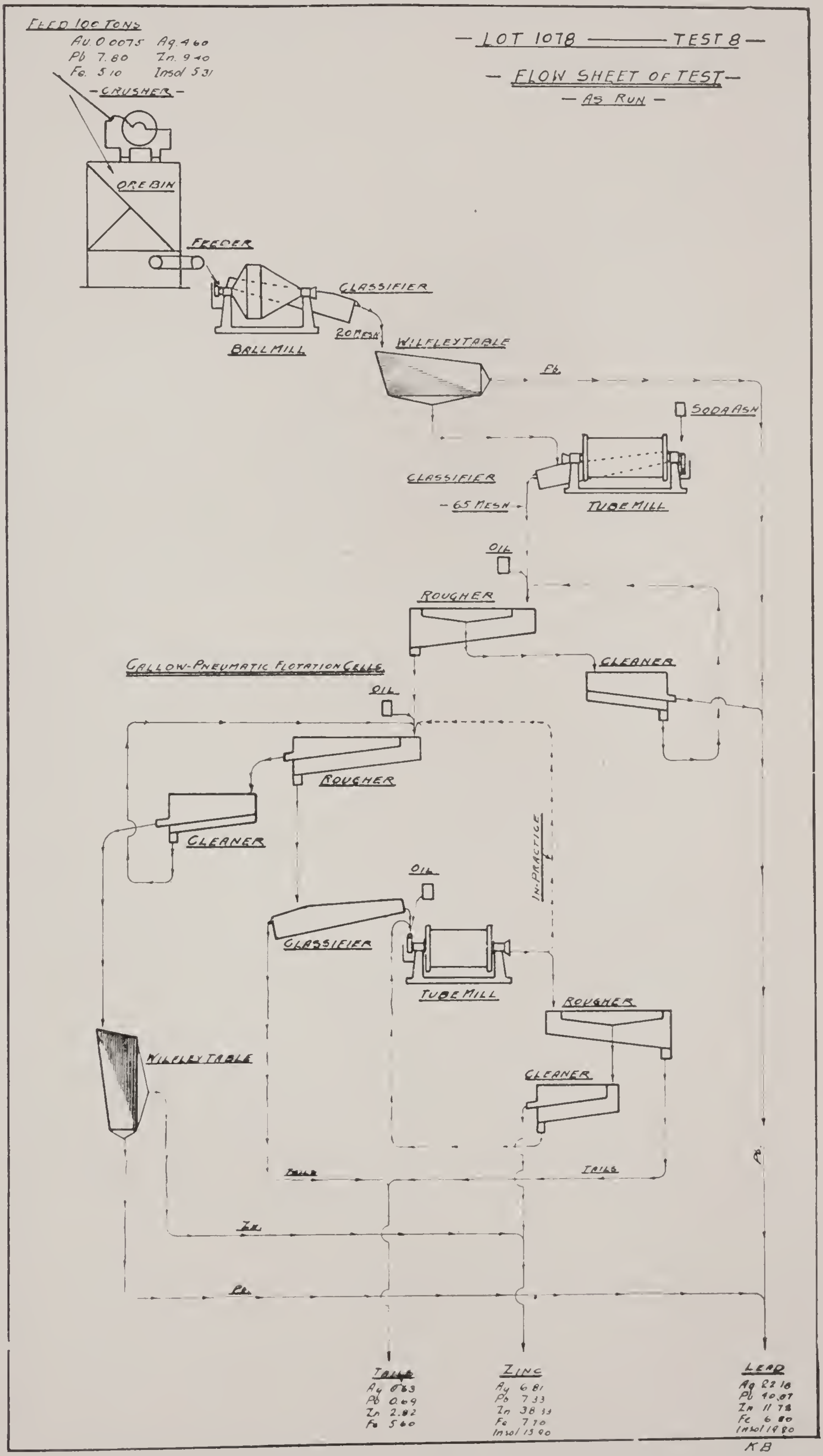
The varied characters of ores and their required treatment methods can be shown in no better manner than in the variation in the flow-sheets illustrated on the pages following. In the hundreds of flow-sheets in the test-report files of the General Engineering Company, very few are alike, indicating that requirements and conditions vary from mine to mine, and emphasizing the necessity for testing all ores, rather than depending upon the flow-sheet of an adjoining or similar property for the design of contemplated plants.

Various types of mills are illustrated by the flow-sheets on the pages which follow.

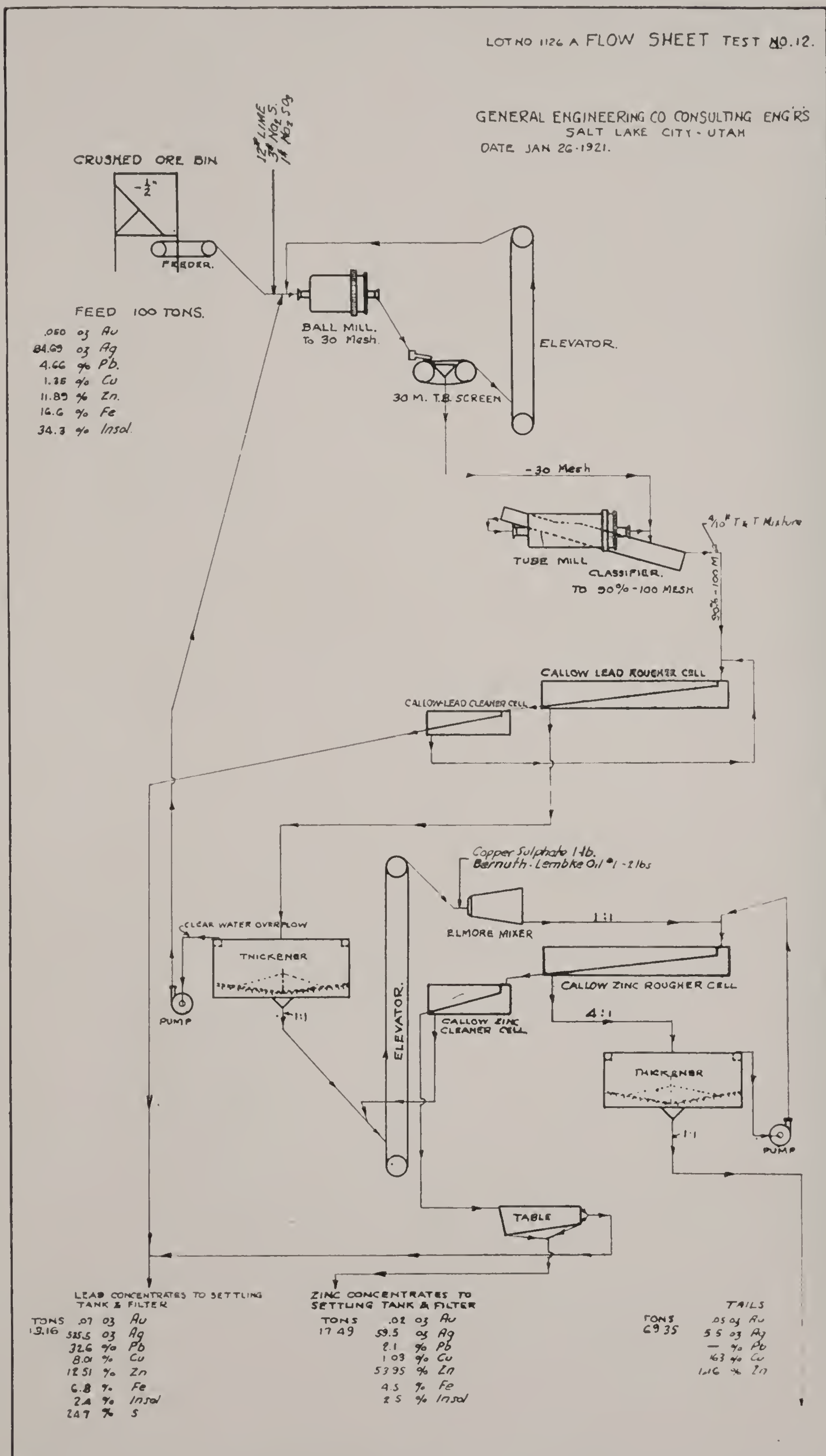
Copper Ore, all Flotation



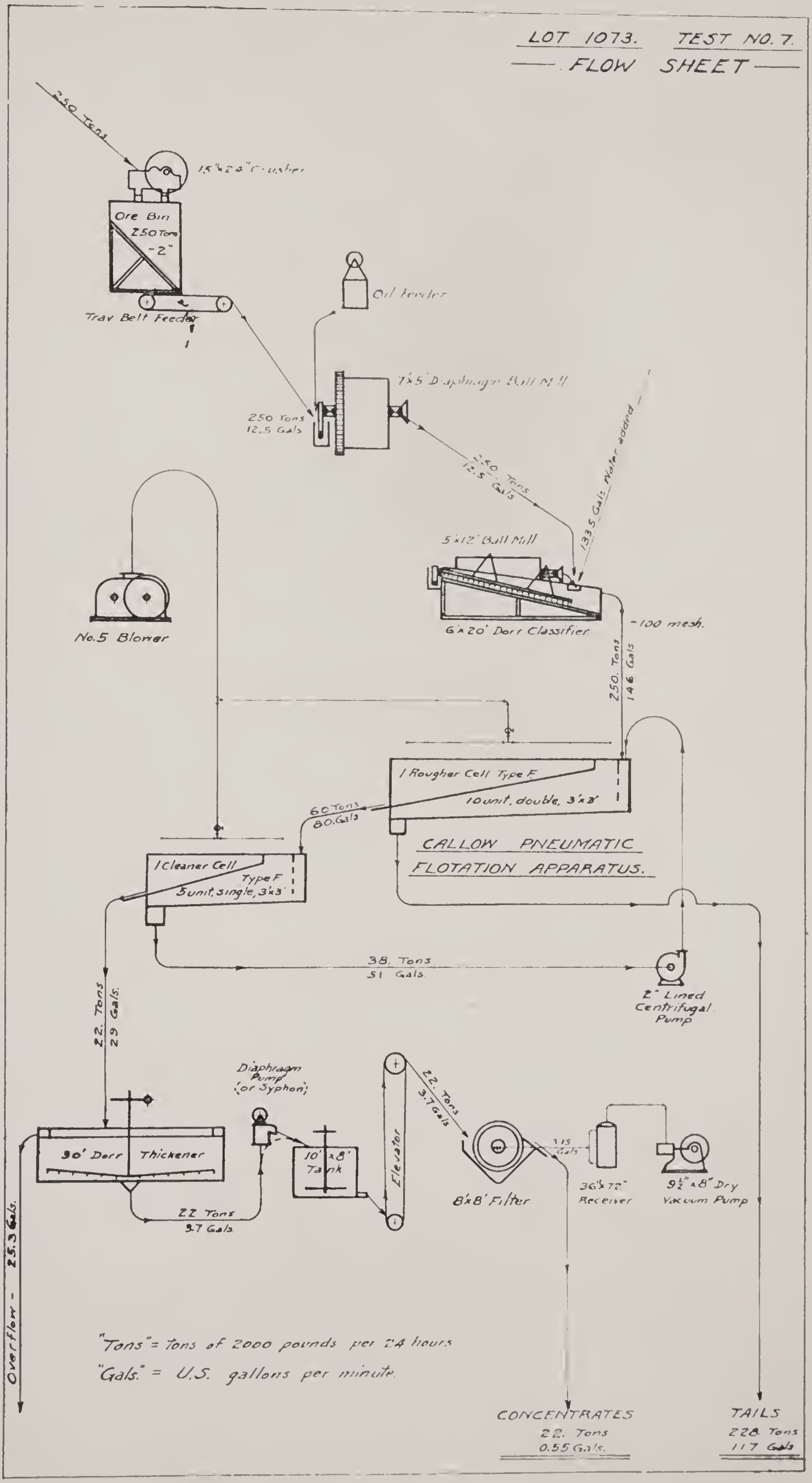
Gravity Concentration and Flotation



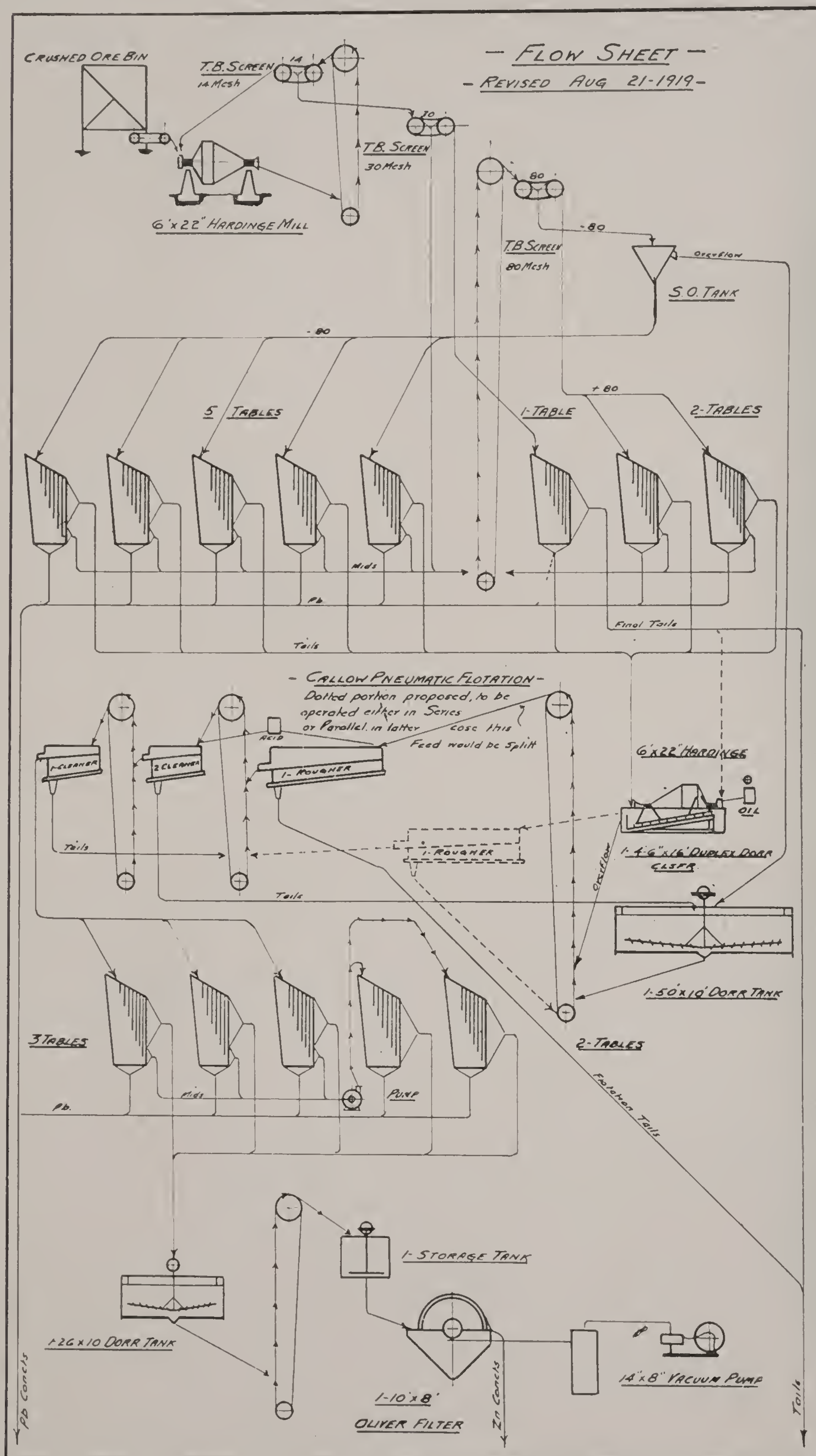
Complex Ore, All Flotation



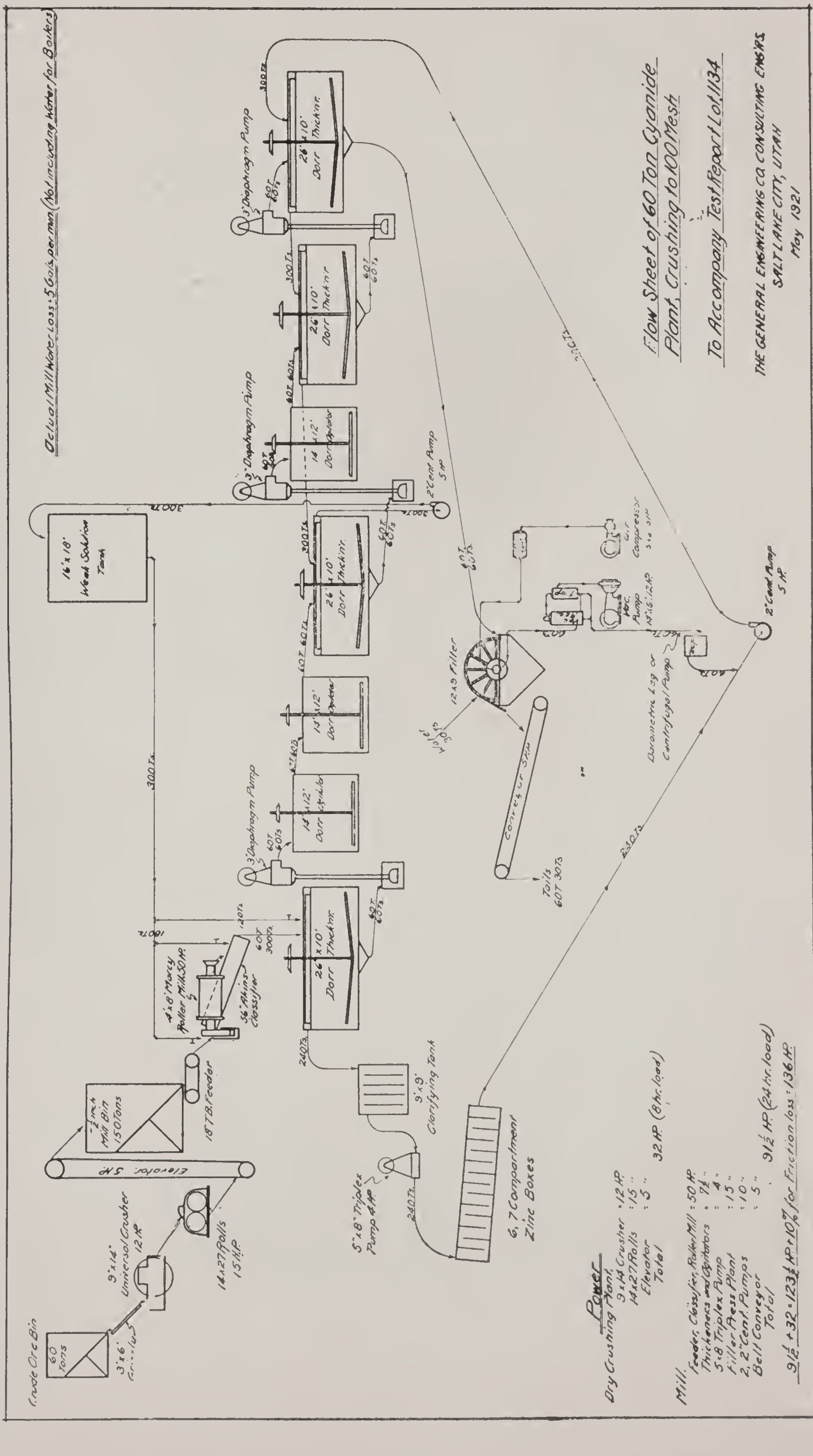
Lead or Copper, All Flotation

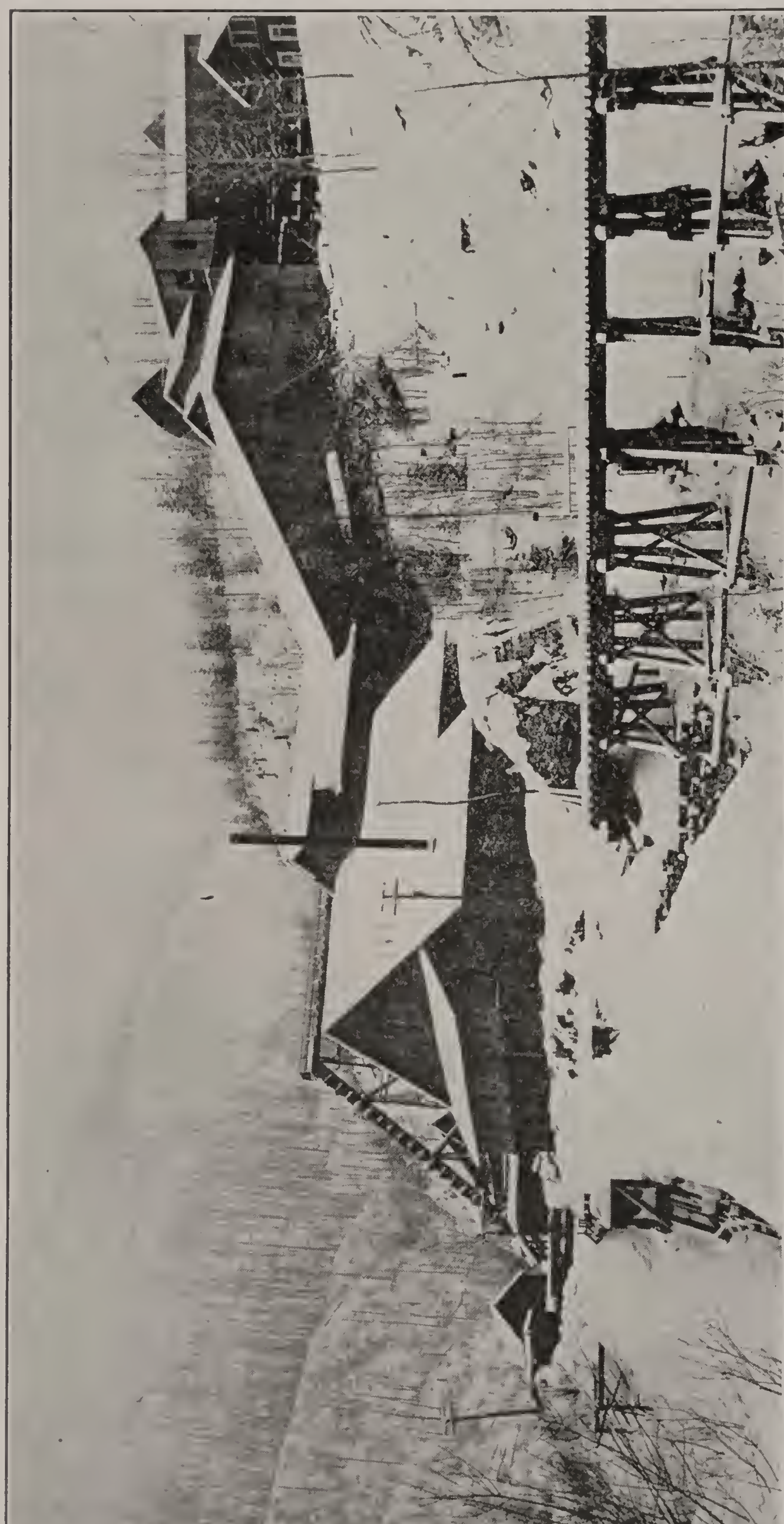


Lead-Zinc Ore, Gravity Concentration and Flotation



Cyanide, Counter-Current Decantation





Concentrator—Gravity and Flotation

C. C. Cunningham, Sandon, British Columbia.

Designed and built by the General Engineering Company.

Design, Erection, Operation

The results of the testing work and other investigations indicating that the ore may be mined, treated and disposed of at a reasonable profit, the obvious thing is to design and erect a plant suitable for the ore, so that operations may be begun at an early date.

First Pneumatic Flotation Plant in the World

National Copper Company, Mullan, Idaho.
Designed and built by the General Engineering Company

The General Engineering Company maintain a staff particularly well fitted by both technical training and experience to deal with the problems of design. With the test results before them, and such necessary data and decisions as to capacity, water supply, source of power, available sites, etc., the engineers make preliminary studies, designs and estimates for plants to give the desired metallurgical results. After staff consultation, such modifiations as are deemed advisable are made, and the results embodied in a report; a conference is held with the clients and decisions arrived at as to the design and other details.

A complete set of working drawings is prepared, specifications for machinery and building material are gotten out, the the equipment is ordered, and preparations are made to erect the plant.

The General Engineering Company supply a Superintendent of Construction who remains at the property during the construc-

Concentrator

Utah-Apex Mining Company, Bingham, Utah.
Redesigned and rebuilt by the General Engineering Company

tion period; he, together with staff engineers, in collaboration with the management and engineers of the mining company, all working together, make up an organization which is efficient from the start; the work progresses smoothly to completion.

Once the enterprise is financed and the decision made to build the plant, good business demands that the plant be operating as soon as possible. Here the interests of the client and the General Engineering Company are identical, for its reputation for exceptional service is one of its greatest assets

This exceptional service covers: economical design, the spending of no more money than is necessary for low operating costs and for the saving of only such values as can be saved at a profit; rapidity of construction, by proper planning and specifying, so that material is gotten on the ground when needed and the work of erection is expedited; efficient and competent supervision, insuring readiness-to-run with a minimum of changes.

The charges made by the General Engineering Company are based upon the cost of the work involved, and will be found reas-

Gravity Concentration and Flotation
Magma Copper Company, Superior, Arizona
Designed and built by The General Engineering Company

onable for the services rendered. Local conditions and expenses incident to work in different localities vary so widely that no definite figures can apply to all cases. In general, the fee to cover the design and superintendence of erection of metallurgical plants will be in the neighborhood of 10% of the cost of the work.

The fee for the operation of metallurgical plants is usually upon a per diem or monthly basis, and depends upon the character of the work involved.

Representative Mills

Designed and Constructed by

The General Engineering Company

Hecla Mining Company	Wallace, Ida.	Ore Sorting Plant
Imlay Mining Company	Imlay, Nev.	Amalgamation—Cyanide
Jennie Gold Mining Co.	Good Springs, Nev.	
Pulaski Minerals Co.	Ketchum, Ida.	Amalgamation— Gravity Concentration
Tomahawk Mines Co.	Durango, Colo.	Amalgamation—Gravity Concentration— Cyanide
Bingham & New Haven G. & C. Co.	Bingham, Utah.	
Yukon District G. M. Co.	Alaska	
Conrad Cons, Mines Co.	Alaska	
Iron Mountain Tunnel Co.	Iron Mtn., Mont.	
Phoenix Mining Co.	Bingham, Utah.	Gravity Concentration
Rico-Wellington Mines Co.	Rico, Colo.	
Utah Apex Mining Co.	Bingham, Utah.	
Watters Tunnel & Mining Co.	Sheridan, Mont.	
National Copper & Pyrite Co.	Pyriton, Ala.	
Glasgow & Western Expl. Co.	Cherry Creek, Nev.	Gravity Concentration—Cyanide
Winnemucca Mountain Mining Co.	Winnemucca, Nev.	Cyanide
Dominion Molybdenum Co.	Quyon, Quebec	
American Graphite Co.	Ticonderoga, N. Y.	
Steel Alloys Co.	Canada (molybdenum)	
Vermont Copper Co.	S. Statford, Vt.	
Molybdenum Products Co.	Wilberforce, Ont.	
Bingham & New Haven G. & C. Co.	Bingham, Utah	Flotation
Caldo Mining Co.	Frisco, Utah	
National Copper Co.	Mullan, Ida.	
Carbon Mountain Graphite Co.	Lineville, Ala.	
Utah Cons. Mining Co.	Tooele, Utah	
Armstead Mines Inc.	Talache, Ida.	Flotation—Gravity Concentration
Cons. Copper Mines Co.	Kimberley, Nev.	
Cia. Huanchaca de Bolivia	Pulcayo, Bolivia	

Amalgamated M. & S. Corp.	Pioche, Nev.	
Magna Copper Company	Superior, Ariz. (copper)	Gravity Concentration—Flotation
Magna Copper Company	Superior, Ariz. (zinc)	
C. C. Cunningham	Sandon, B. C.	
Noble Five Mine	Sandon, B. C.	
El Rayo M. & D. Co.	Parral, Mex.	Flotation—Cyanide
Knight-Christensen Metal Co.	Silver City, Utah	Roasting—Acid Leaching
Tomboy Gold Mines Co.	Telluride, Colo.	Roasting—Magnetic Separation.

Pneumatic Flotation Plant

Consolidated Copper Mines Co., Kimberley, Nev.
Redesigned and rebuilt by the General Engineering Company

METAL STATISTICS

The data contained in this section has been obtained from a variety of sources considered reliable.

"Round Numbers" are used and slight liberties have been taken with some of the statistics; it is believed that in the form here presented they will be found most serviceable.

Where possible, "foreign ores smelted in the U. S." have been omitted from U. S. production.

Aproximate Averages

For 20 years up to 1920.

Metal	World Production Per Year	United States Production Per Year	% of World	Prices f. o. b. New York
Gold	19,000,000 oz.	4,400,000 oz.	23	$20.67 per oz.
Silver	188,000,000 oz.	61,000,000 oz.	31	0.61 per oz.
Copper	1,910,000,000 lbs.	1,120,000,000 lbs.	59	$0.18\frac{1}{4}$ per lb.
Lead	*2,200,000,000 lbs.	*838,000,000 lbs.	*38.1	0.053 per lb.
Zinc	*1,790,000,000 lbs.	* 692,000,000 lbs.	*38.6	0.074 per lb.

* For 17 years 1904 to 1920.

Gold and Silver

Production—United States and World

GOLD $20.67 per oz.				SILVER			
United States Millions Dollars	United States % World	World Millions Dollars	Year	United States Millions Ounces	United States % World	World Millions Ounces	Ave. Price per Ounce
79.2	31.1	254.6	1900	57.6	33.1	173.6	$0.62
78.7	30.2	261.0	1901	55.2	31.9	173.0	.60
80.0	27.0	296.7	1902	55.5	34.1	162.8	.53
73.6	22.5	327.7	1903	54.3	32.4	167.7	.54
80.5	23.2	347.4	1904	57.6	35.1	164.2	.58
88.2	23.4	380.3	1905	56.1	32.5	172.3	.61
94.4	23.4	402.5	1906	57.5	34.2	165.1	.68
90.4	21.9	413.0	1907	56.5	30.3	186.2	.66
94.6	21.3	442.5	1908	52.4	25.8	203.1	.53
99.7	21.9	454.1	1909	54.7	25.8	212.1	.52
96.3	21.1	455.2	1910	57.1	25.8	221.7	.54
96.9	21.2	461.9	1911	60.4	26.7	226.2	.53
93.5	20.1	466.1	1912	63.8	28.4	224.3	.615
88.9	19.3	460.5	1913	66.8	29.7	225.4	.604
94.5	21.5	439.0	1914	72.5	43.0	168.5	.553
101.0	21.6	468.7	1915	75.0	40.7	184.2	.507
92.6	20.4	454.2	1916	74.4	44.1	168.8	.658
83.8	20.0	419.4	1917	71.7	41.1	174.2	.824
68.6	18.0	380.9	1918	67.8	34.3	197.4	.98
60.3	16.5	365.1	1919	56.7	32.7	174.5	1.12
49.5	....	....	1920	56.6	....	....	1.015

Copper

Smelter Production—United States and World

Year	World Production Millions of lbs.	UNITED STATES Ores of Co'per Millions of Tons	Yield %	From Dom's'c Ores Millions of lbs.	% of World's	Ap'arent Con-sump'on Millions of lbs.	Prices Per lb. Cents
1900	1,091	*	*	606	55.6	357	16.6
1901	1,160	*	*	602	51.9	383	16.7
1902	1,228	*	*	660	53.6	552	12.2
1903	1,313	*	*	698	53.2	526	13.7
1904	1,454	*	*	813	55.9	482	12.8
1905	1,570	*	*	889	56.6	581	15.6
1906	1,589	18	2.53	918	57.7	686	19.3
1907	1,596	20	2.15	869	54.4	488	20.0
1908	1,651	22	2.12	943	57.1	480	13.2
1909	1,832	28	1.95	1,093	59.7	689	13.0
1910	1,901	28	1.89	1,080	56.8	732	12.7
1911	1,968	30	1.82	1,097	55.8	682	12.5
1912	2,209	36	1.75	1,243	56.3	776	16.5
1913	2,133	36	1.67	1,224	57.4	812	15.5
1914	2,023	35	1.60	1,150	56.8	702	13.3
1915	2,326	43	1.66	1,388	59.7	1,137	17.5
1916	2,994	58	1.70	1,928	64.4	1,479	24.6
1917	3,147	59	1.60	1,886	60.0	1,395	27.3
1918	3,076	62	1.51	1,909	62.0	1,662	24.7
1919	*	*	*	1,311	*	877	18.6
1920	*	*	*	1,209	*	1,054	18.4

* Not Available.

High Price (1864), 55 cents (47 cent ave.); Low Price (1894), 9.00 cents (9.43 cents ave.)

Production in U. S.—By State Groups

Millions of Pounds

	1913	1914	1915	1916	1917	1918	1919	1920
Alaska	23	25	71	114	85	67	57	66
Arizona, New Mexico	454	447	495	775	827	866	597	605
California	32	30	38	43	45	44	24	12
Colorado, Wyoming	9	7	8	9	8	7	4	2
Idaho, Oregon, Washington	10	7	8	12	10	11	9	6
Michigan	156	158	239	270	269	231	178	153
Montana	286	237	268	352	276	326	176	178
Nevada, Utah	233	221	243	333	343	328	204	163
Tennessee	19	19	18	15	16	15	16	17
All Others	1	1	1	2	1	1	*17	1

*Including 15,500,000 lbs. undistributed.

Copper

Balance Sheet Refined Copper in U. S.

Millions of Pounds

Year	On Hand Jan. 1.	Refined in U. S.		Exported	Consumed	Exp-For Domestic %
		Domestic Origin	Foreign Origin			
1913	105	1,237	378	817	812	35.6
1914	91	1,210	323	748	702	39.3
1915	174	1,388	246	589	1,137	24.0
1916	82	1,889	371	735	1,479	19.3
1917	128	1,874	555	1,048	1,395	26.3
1918	114	1,883	550	705	1,662	*8.2
1919	180	1,442	326	440	877	*7.9
1920	631	1,182	453	553	1,054	*8.5
1921	659	900 Est.		1175 Est.		
1922	384 Est.					

*Additional exports of old copper, sheets, plates, etc., for the years 1918, 1919, 1920 increased exports and % to the following figures, respectively; 748, 10.8%; 517, 13.2%; 624, 14.4%.

Note.—The last column, gives in percent the ratio of the difference between the copper exported and that imported as foreign ores for smelting and refining, to the copper refined from domestic ores only. This is the actual percentage of copper produced from U. S. ores which is exported, without further manufacture. During the world war a great part of the copper produced was exported in manufactured form for which statistics are not available.

Lead and Zinc

Production United States and World

LEAD				Year	ZINC			
United States Millions of lbs.	United States % of World	World Millions of lbs.	Prices Cents per lb.		United States Millions of lbs.	United States % of World	World Millions of lbs.	Prices Cents per lb.
*645	x	x	4.4	1900	*248	x	x	4.4
*650	x	x	4.3	1901	*282	x	x	4.1
*645	x	x	4.1	1902	*315	x	x	4.8
*647	x	x	4.2	1903	*318	x	x	5.4
614	29.5	2087	4.3	1904	*373	27.0	1385	5.1
604	29.0	2084	4.7	1905	*407	28.0	1455	5.9
700	33.2	2107	5.7	1906	*450	29.0	1550	6.1
730	33.3	2190	5.3	1907	*500	30.7	1630	5.9
623	27.1	2300	4.2	1908	*420	26.3	1595	4.7
706	30.3	2340	4.3	1909	*512	30.0	1710	5.4
751	31.0	2420	4.4	1910	*538	28.6	1885	5.4
784	31.8	2455	4.5	1911	543	27.5	1970	5.7
785	30.6	2565	4.5	1912	648	30.3	2140	6.9
824	32.4	2540	4.4	1913	675	30.2	2230	5.6
1025	56.0	1828	3.9	1914	687			5.1
1014	44.2	2290	4.7	1915	916	49.8	1840	12.4
1102	53.3	2062	6.9	1916	1129	50.3	2240	13.4
1097	53.9	2035	8.6	1917	1169	53.9	2170	10.2
1080	48.2	2243	7.1	1918	985	51.3	1920	9.1
849	41.2	2060	5.3	1919	905	65.1	1390	7.3
954	53.0	1800 Est.	8.0	1920	900	60.0	1500 Est.	8.1

*Including foreign ores smelted in U. S.

x Figures not available.

COSTS

Milling Costs

The costs given in the following tables have been gathered from a variety of sources, such as published company reports, technical articles, handbooks, manufacturers catalogs, and private information. Usually the methods of arriving at the costs of the various operations and the distribution of overheads, etc., differ considerably, so that unless all details are known and comparable, considerable judgement must be used in applying such figures.

The only safe method of arriving at milling costs for proposed plants or processes is to furnish to competent engineers all the facts available, and let them estimate such costs.

In plants of the same type, the large factor producing the wide variation in costs per ton is obviously the capacity of the plant, greater economies being possible in a large plant than a small one.

Recent figures show increased costs because of the effects of the world war; it is believed that costs for the period 1912-1916 will be of as much value as for the period 1917-1920, and that actual costs will be found midway between these two sets of figures, for the years following the publication of this bulletin.

Tables of partial costs are given together with tables made up of the results of operations of individual plants. Total costs may be made up by totaling the partial costs, using the tables of total costs for the purpose of checking, and for estimating the effect of various variables, such as freight and transportation, power, labor, climate, etc.

The value extracted from the ore is believed to have some bearing upon the amount that may be expended to treat the ore, and for that reason the production has been calculated in dollars extracted rather than in assays of the mill feed. In some cases this figure has been roughly approximated, and it is intended to be used only for its bearing upon the cost, however variable that may be.

In the cases of Gold and Silver mills, a study of costs indicated that more consistent costs were obtained by a division as affected largely by climatic conditions:

DESERT CONDITIONS indicate high costs for power, water and transportation, with unfavorable labor, living and climatic conditions, or most of these.

AVERAGE CONDITIONS indicate that there are not more than two of the unfavorable factors under Desert Conditions, the balance being normal or favorable.

Costs of Mill Operations

Flotation Concentration Mills

Copper, Iron, Zinc

Tons 24-Hrs.	Location	Value Extr per ton	xtrn %	Treatment Details	Cost Per Ton	% -200	Date	Remarks
125	New York	......	.....	Cr. Ball. Flot	$1.31	....	1919	
200	Arizona	$19.00	93	Cr. Ball. Tab. Flot.	0.87	45	1916	
400	Utah	......	.....	Cr. Rolls Ball. Jig. Tab. Flot	......	....	.....	Lead
1100	Montana	19.00	.....	Cr. Rolls. Peb. Tab. Flot.	2.75	....	1919	Zinc
4000	Arizona	......	78	Cr. Rolls. Ball. Tab. Flot.	......	62	1919	Copper
5000	Arizona	9.00	78	Cr. Rolls. Ball. Tab Flot.	0.73	60	1918	Copper
5000	Arizona	5.80	.....	Cr. Rolls. Ball. Tab. Flot.	1.01	....	1919	Copper
10000	New Mexico	7.00	.....	Cr. Rolls. Ball. Tab. Flot.	1.37	....	1918	Copper
12000	Nevada	6.40	68	Cr. Rolls. Ball. Tab. Flot.	0.93	....	1918	Copper
12000	Utah	5.00	.....	Cr. Rolls. Ball. Tab. Flot.	0.93	....	1918	Copper
15000	Arizona	5.66	75	Cr. Dis. Ball. Flot.	0.53	60	1916	Copper

Gravity Concentration Mills

Lead, Copper, Zinc

Tons 24-Hrs.	Location	Value Extr per ton	xtrn %	Treatment Details	Cost Per Ton	% -200	Date	Remarks
125	Utah	......	.....	....	$1.44	....	1912	
150	Utah	......	.....	....	1.09	....	1917	
200	Utah	......	.....	Sort. Cr. Roll. Conc.	0.58	....	1912	
300-400	Missouri	......	.....	Cr. Roll. Jigs.	0.41	....	1913	Zinc
400	Colorado	$6.50	.....	Cr. St. Peb. Conc.	2.08	....	.....	Cyaniding Concentrates
500	Missouri	......	.....	Cr. Roll. Jig. Tab.	0.97	....	1912	
500	Idaho	......	.....	....	0.57	....	1919	
1000	Idaho	11.00	91	Cr. Roll. Jig. Tab.	0.37	....	1908	Lead-Silver
1000	Idaho	17.00	.....	Cr. Roll. Jig. Tab.	0.72	....	1918	Lead-Silver
1250	Idaho	......	.....	Cr. Roll. Jig. Tab.	0.36	....	1911	Lead-Silver
1250	Missouri	......	.....	Cr. Roll. Jig. Tab.	0.33	...	1912	Lead
2500	Missouri	......	.....	Cr. Roll. Jig. Tab.	0 26 0.34	....	1913	Lead
3300	Arizona	4.80	70	Cr. Roll. Ch. Tab. Van.	0.57	...	1912	Copper-Disseminated
4500	New Mexico	3.40	70	Cr. Roll. Tab. Van.	0.50	....	1912	Copper-Dissemintaed
6500	Arizona	3.15	67	Cr. Rolls. Tab. Van.	0.43	....	1913	Copper-Disseminated
8000	Nevada	......	.....	Cr. Rolls. Tab. Van.	0.49	....	1912	Copper-Dissemintaed
21000	Utah	2.30	66	Cr. Rolls. Tab. Van.	0.31	....	1913	Copper-Disseminated
1000	Michigan	2to4	70-80	Cr. S St. Jig. Tab.	.27-30	....	1908	Copper-Amydaloid
2000	Michigan	2-4½	70-80	Cr. S St. Jig. Tab.	.24-30	....	1908	Copper-Amygdaloid
4000	Michigan	1¾3½	70-80	Cr. S St. Jig. Tab.	.17-40	....	1908	Copper,Amyg.&Conglom. Conglom Costs Highest.

Abbreviations used in column of "Treatment Details" in all tables of Cost of Mill Operations:—

CR—Crushers
ST—Stamps
BALL—Ball mills
PEB—Pebble or Tube Mills
DISC—Disc Crushers
CH—Chilean mills
PAN—Grinding Pans
TAB—Concentrating tables
VAN—Vanners
JIG—Hartz Jigs
FLOT—Flotation
CONC—Gravity Concentration
CY—Cyanide
AMAL—Amalgamation

Cost of Mill Operations

Silver Mills—All Slime Cyaniding

Average Conditions

Tons 24-Hrs.	Location	Value Extr per ton	xtrn %	Treatment Details	Cost Per Ton	% -200	Date	Remarks
180	Canada	$30.00	90	Milling	$2-$3	....	1913	Costs Roughly Approx.
250	Canada	......	92	Cr. St. Peb. Cy.	2.95	28	1913	
350	Canada	10.25	95	Cr. St. Peb. Cy.	2.10	....	1913	
450	Mexco	......	.....	Cr. St. Conc. Peb. Cy.	2.64	....	1918	
500	Canada	......	.....	Cr. Ball. Peb. Cy.	2.64	....	1919	

Silver—Desert Conditions

Tons 24-Hrs	Location	Value Extr per ton	xtrn %	Treatment Details	Cost Per Ton	% -200	Date	Remarks
100	Nevada	$15.30	90	Cr. St. Peb. Conc. Cy.	$3.29	90	1913	
110	Nevada	13.00	94	Cr. St. Peb. Conc. Cy.	3.54	....	1913	
130	Nevada	19.00	92	Cr. St. Peb. Conc. Cy.	2.62	....	1913	
135	Nevada	16.00	93	Cr. St. Ch. Peb. Cy.	2.75	69	1914	
175	Nevada	......	.....	Milling	3.80	....	1912	
250	Mexico	11.00	93	Cr. St. Peb. Conc. Cy.	3.86	....	1913	
400	Nevada	......	.....	Milling	2.90	....	1912	
500	Nevada	16.30	90	Cr. St. Peb. Conc. Cy.	2.67	....	1913	
500	Nevada	16.00	.....	Cr. St. Peb. Conc. Cy.	2.57	....	1914	
500	Nevada	21.00	94	Cr. St. Peb. Conc. Cy.	2.05	80	1914	1913. Cost $2.50

Gold Mills—Roasting Cyanide

Tons 24-Hrs.	Location	Value Extr per ton	xtrn %	Treatment Details	Cost Per Ton	% -200	Date	Remarks
100	Washington	$8.00	91	Cr. Rols. Roast. Peb. Cy.	$2.00	....	1913	
550	Utah	......	.....	Cr. Rolls. Roast. Peb. Cy.	1.10	....	11-12	33% Roasted
600	W. Australia	5.00	.....	Cr. Rolls. Roast. Peb. Cy.	2.29	....	1913	
700	W. Australia	9.50	85-%	Cr. St. Pan. Con. Roast. Cy.	2.08	....	1912	Conc. only Roasted.

Gold Mills—Amalgamation—Concentration

Tons 24-Hrs.	Location	Value Extr per ton	xtrn %	Treatment Details	Cost Per Ton	% -200	Date	Remarks
30	California	$3.00	.....	Cr. St. Amal.	+1.92	....	1912	Followed by Cyanide
50	California	13.50	90	Cr. St. Amal. Conc.	1.07	....	1913	
200	Korea	......	.....	Cr. St. Conc. Amal.	+0.67	....	1914	Followed by Cyanide.
300	California	......	.....	Cr. St. Amal.	+0.22	....	1913	Followed by Cyanide.
1000	Alaska	......	.....	Cr. St. Conc. Amal.	0.24	....	1912	
1300	Transvaal	......	.....	Cr. St. Amal.	+0.27	...	1913	Followed by Cyanide.
2500	Alaska	2.50	92	Cr. St. Amal. Conc.	0.185	....	1912	
4000	So. Dakota	......	.....	Cr. St. Amal.	+0.28	....	1914	Followed by Cyanide.
7000	Alaska	1.05	82	Cr. Rolls. Peb. Conc.	0.24	35	1917	No Amalgamation

+ These are partial costs, as extraction is completed in Cyanide operation following.

Cost of Mill Operations

Gold Mills—All Slime Cyaniding

Average Conditions

Tons 24-Hrs.	Location	Value Extr per ton	xtrn %	Treatment Details	Cost Per Ton	% -200	Date	Remarks
85	California	$14.00	95	Cr St. Peb. Cy.	$1.73	....	1912	
115	Montana	11.55	.....	Cr. Peb. Cy.	2.00	....	1918	Sand Leaching.
150	Colorado	......	.....	Milling	1.90	....	1912	
200	Korea	6.50	92	Cr. St. Peb. Cy.	1.01	....	1914	
200	Cent. Am.	7.00	.....	Milling	1.50	....	1910	
250	Colorado	26.00	94	Cr. St. Peb. Conc. Cy.	1.80	....	1908	
250	New Zealand	......	.....	Cr. St. Peb. Conc. Cy.	1.52	....	1915	
300	California	......	.....	Cr. St. Ama. Peb. Conc. Cy.	0.79	....	1913	
300	California	11.00	97	Cr. St. Conc. Peb. Cy.	0.98	....	1912	
350	Canada	20.50	95	Cr. St. Peb. Conc. Cy.	1.49	....	1913	
400	Colorado	2.25	75	Cr. Roll. Peb. Conc. Cy.	1.31	....	1913	
400	California	9.35	.....	Cr. St. Amal. Peb. Conc. Cy.	1.07	....	1917	
500	Colorado	6.50	93	Cr. St. Amal. Peb. Conc. Cy.	1.38	74	1913	
500	Transvaal	6.25	.....	Cr. St. Peb. Cy.	0.96	60	1913	
500	Transvaal	11.25	.....	Cr. St. Peb. Cy.	1.09	60	1913	
600	Canada	13.00	.....	Cr. St. Peb. Cy.	1.24	....	1914	
700	India	17.00	85	Cr. St. Peb. Cy.	0.86	..	1907	
875	Transvaal	4.70	.....	Cr. St. Peb. Cy.	0.87	60	1913	
1000	Transvaal	4.50	...	Cr. St. Peb. Cy.	0.91	60	1913	
1100	Transvaal	......	93	Cr. St. Peb. Cy.	0.82	62	1913	Sands Treated Separately.
1350	Transvaal	6.20	.....	Cr. St. Peb. Cy.	0.85	60	1913	
1400	Transvaal	10.00	.....	Cr. St. Amal. Peb. Cy.	0.84	....	1918	
1500	Transvaal	......	93	Cr. St. Peb. Cy.	0.69	60	1913	
2000	Transvaal	4.00	.....	Cr. St. Peb. Cy.	0.85	60	1913	
2000	Transvaal	9.70	.....	Cr. St. Peb. Cy.	1.22	....	1919	Same
2500	Transvaal	8.70	.....	Cr. St. Peb. Cy.	1.02	....	1917	Plant
4000	So. Da ota	3–4	.....	Cr. St. Amal. Peb. Cy.	0 79	30	1914	Sands Treated Separately.

Desert Conditions

Tons 24-Hrs.	Location	Value Extr per ton	xtrn %	Treatment Details	Cost Per Ton	% -200	Date	Remarks
70	California	$5.70	95	Cr. St. Am. Cy.	$4.02	....	1912	30 tons stamped. bal. tailings
100	So. Africa	11.00	.93	Cr. St. Ch. Pan. Cy.	2.05	....	12–13	
150	Arizona	20.00	95	Cr. St. Peb. Cy.	2.50	70	1913	Same
200	Arizona	7.60		Cr. St. Peb. Cy.	2.04	....	1917	Property
250	Arizona	22.00	96	Cr. Ball. Peb. Cy.	1.79	82	17–18	
270	Nevada	6.50	80	Cr. Roll. Ball. Peb. Cy.	1.59	70	1914	
400	Mexico	7.25	.....	Cr. St. Peb. Cy.	1.61	....	1912	
500	Nevada	5.00	.....	Cr. St. Peb. Cy.	1.12	....	1912	
1000	Mexico	5.75	85	Cr. St. Peb. Cy.	1.11	....	1912	
1000	Nevada	13.70	92	Cr. St. Ch. Peb. Conc. Cy.	1.97	75	1913	$2.20 cost in 1908 on
900	Nevada	12.50	92	Cr. St. Ch. Peb. Conc. Cy.	1.61	75	1914	$10 Xtrn

Partial Milling Costs

CRUSHING

This general term applies to all milling processes which aim to reduce the sizes of the pieces of ore. For cost purposes it has been found practical to make four rough divisions of crushing;

BREAKING (preliminary crushing, coarse crushing) is the first operation and is done in Gyratory or Jaw Breakers or Crushers. Costs depend upon the character of the ore, the cost of power, and the load factor of the crushing unit, more than upon the relative capacity of the plant, according to most reported costs. Size of product: all through 1½" to 3".

Cost of Breaking, per ton of mill feed..............$0.07 to 0.13

SECONDARY CRUSHING (intermediate crushing, fine crushing, stamping) follows breaking, and aims to give a product about all of which passes 4-mesh; it is performed with rolls, disc crushers, and stamps.

Cost of Secondary Crushing, per ton of mill feed....$0.10 to 0.20

GRINDING (comminuting, pulverizing, primary grinding) gives a product of which 15% to 50% passes through a 200-mesh screen; BALL MILLS, Chileans, and pans are the commonly used machines.

Cost of Grinding, per ton of mill feed...............$0.10 to 0.20

SLIMING (regrinding, fine grinding, secondary grinding, tube-milling) reduces a feed, all of which passes a 10-mesh to 20-mesh screen, and gives a product of which 50% to 90% passes through a 200-mesh screen. This is generally done in tube mills using pebbles or small balls; it is also partially done in ball and rod mills.

Cost of Sliming, per ton of mill feed................$0.15 to 0.50

COST OF ALL CRUSHING TO SLIME, for each percent-minus-200-mesh, per ton of run-of-mine ore, ... ¾ to 1½ cents

Stamps, Chileans and Ball Mills are occasionally used for the combined operations of Secondary Crushing and Grinding, with a cost about equal to the sum of the two partial costs given above.

CONCENTRATING

By Vanners and Tables in Gold Stamp Mills, following Amalgamation,

Cost per ton of mill feed.......................$ 0.04 to 0.15

By Jigs, Tables and Vanners on Lead and Copper Ores,

Cost per ton of mill feed....................... 0.20 to 0.40

By Tables after Flotation,

Cost per ton of mill feed....................... 0.05 to 0.10

By Flotation,

Cost per ton of mill feed....................... 0.06 to 0.30

CYANIDING (not including crushing)

	per ton milled
SAND LEACHING, previous to 1912 (now obsolete)	0.15 to 1.25
ALL SLIMING, Silver	1.00 to 2.00
ALL SLIMING, Gold	0.50 to 1.00
ALL SLIMING, Gold, South Africa only	0.30 to 0.60
Partial Costs: (Excluding South African figures)	
Chemicals, Gold	0.25 to 0.60
Chemicals, Silver	0.75 to 1.25
Classifying	0.02 to 0.05
Agitation	0.05 to 0.10
Filtering, both cyanide and flotation slimes,	0.05 to 0.15
Clarifying, Precipitating and Refining	0.15 to 0.50
(higher costs are for silver ores)	
	per ton so treated
Roasting ores and concentrates	0.65 to 1.25

COPPER LEACHING

	per ton milled
Tailings, with Sulphuric acid, precipitated on scrap, 1914 2,000 tons daily capacity est.	0.70
Oxidized Ores, with Sulphuric Acid, 1918, 1,200 tons daily est.	1.06

DREDGING

River bottom carrying an average of 8.66 cents per yard, 1919, 5,000 yards per day, cost per yard 6.41 cents

MISCELLANEOUS

	per ton milled
Water	0.01 to 0.25
General Expense, including Superintendence, Assaying, etc.	
Small plant	about 0.75
Large plant, several thousand tons	about 0.10

Cost of Power

STEAM POWER

	Costs per H. P. per 24 hrs.
Non-Condensing Engines, coal at $7.00	$ 0.20 to 0.22
Condensing Engines	0.17 to 0.19
Compound Condensing Engines	0.14 to 0.17

For each variation of $1.00 per ton in cost of coal, costs per H. P. should be varied: 1½ cents for Non-Condensing Engines, 1¼ cents for Condensing Engines, 1 cent for Compound Condensing Engines.

A rough general figure for power costs in mining camps is $0.30 per H. P. per 24 hours.

See also "Steam Plants" (page 45) giving fuel consumption for different operating conditions, from which costs may be calculated.

ELECTRIC POWER

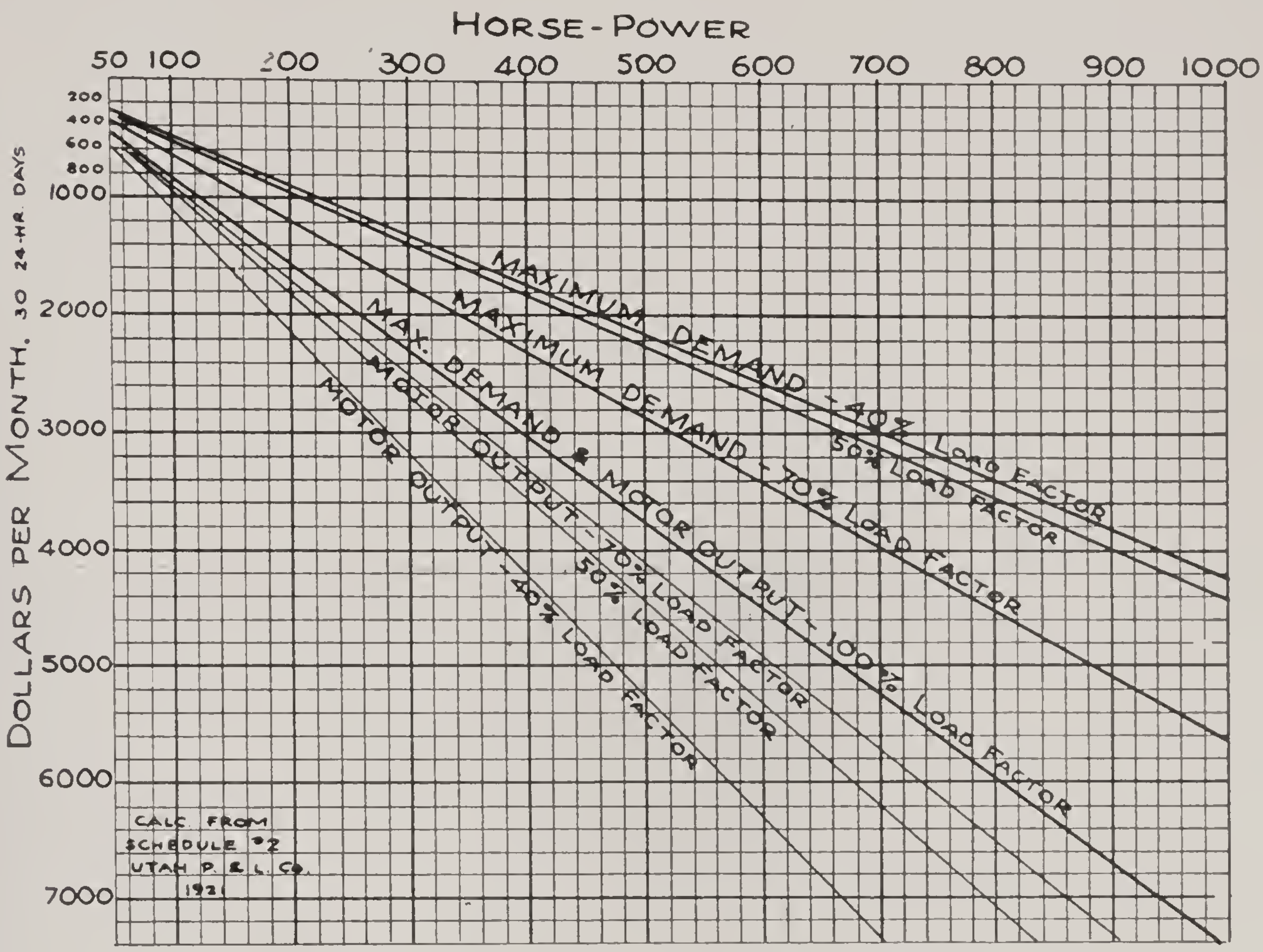
Charges for electric power are usually based upon a variety of factors, in which the total power consumed and maximum demand have most influence in determining the rate.

The following rate comparison is based upon reported costs of power in milling plants:

Per H.P. year	Per H.P. month	Per K.W. hour	Conditions		
$150.00	$12.50	2.0 cents	Desert	and	unfavorable
120.00	10.00	1.6 "	"	"	"
90.00	7.50	1.2 "	"	"	"
75.00	6.25	1.0 "	Average		
60.00	5.00	0.8 "	"		
45.00	3.75	0.6 "	Favorable		
30.00	2.50	0.4 "	"		

Above figues are for 360 24-hour days per year, and an average motor efficiency of 85 to 88 per cent.

The diagram following gives monthly power costs for various powers, for various "load factors;" the load factor being the ratio of average load to maximum demand. In this schedule a discount of 10% is allowed when load factor is maintained at 50% or higher. Load factors based upon maximum demand vary from 50% to 95%, with an average around 70%; based upon connected load (ratio average power to total motor H.P.) this factor would vary between 40% and 65%.



COST OF ELECTRIC POWER

3-PHASE SERVICE 2300 15000 VOLTS (11000 NORMAL)

ACTUAL POWER BASED UPON: 3% TRANSFORMER LOSS 4% LINE LOSS, AND 86% MOTOR EFFICIENCY ONE MOTOR H.P. MONTH REQUIRES 670 K.W. HRS

MAXIMUM DEMAND: THE HIGHEST AVERAGE 5-MIN LOAD AS METERED

LOAD FACTOR · RATIO OF AVERAGE LOAD TO MAX DEMAND

Drafting Room

The General Engineering Company
Salt Lake City, Utah

Pneumatic Flotation Plant
Utah Consolidated Mining Company, Tooele, Utah.
Designed and built by the General Engineering Company

Cost of Erection

MILLING PLANTS

	Cost per ton capacity per 24 hrs.
Coarse Concentration, no Flotation	$ 300 to $ 450
Gravity Concentration and Flotation	800 to 1,200
All Flotation	600 to 800
Cyanide, All-Slime, Stamps or Ball Mills, Pebble Mills, Filtering or Counter-Current,	1,000 to 1,400
Stamps, with Vanners	475 to 550

An empirical figure for the erection and installation of ore mills and similar reduction plants is: $1.25 to $1.50 for each $1.00 cost of machinery, f. o. b. factory.

Under ordinary conditions, as found in mining camps, the cost of Mill Buildings may be arrived at as follows:

Wooden Buildings------3 to 6 cents per cubic foot of volume

Steel Buildings--------7 to 10 cents per cubic foot of volume

Erecting Mill and Smelter Buildings,

Wood, $30.00 to $40.00 per 1,000 feet B. M.

Steel, 0.75 to 1.5 cents per pound of steel.

Erection of Sectionalized machinery, two to three times that for standard equipment.

POWER

HORSE-POWER for DIFFERENT TYPES of MILLS

	H.P. per ton milled in 24 hours.
Crushing only, product to contain 60-80% minus-200 - mesh	0.80 to 2.50
Coarse Gravity Concentration, 10-20 mesh	0.50 to 0.80
Stamp Mills with Vanners, 20-40 mesh	0.75 to 1.00
Gravity Concentration, Tables and Vanners, 30-100 mesh	1.50 to 1.75
Concentration, all Flotation	1.25 to 4.00
Cyanide Mills, dry rolls, to 20 mesh	0.50 to 0.80
Cyanide Mills, wet stamping to 80 mesh	2.00 to 3.50
Magnetic Separator Mills	0.25 to 0.50
Combination Stamp Mills, 16-30 mesh	1.50 to 1.75

COSTS OF POWER, see under Costs

POWER UNITS AND RELATIONS

One HORSE-POWER equals:

550 foot-pounds per second
33,000 foot-pounds per minute
1,980,000 foot-pounds per hour
2,545 B. T. U. (British Thermal Units) per hour
746 Watts, or 0.746 Kilowatts
4,562 Kilogram-Meters per minute
0.986 Metric Horse-Power

One Foot-Pound is the work required to raise one pound one foot, or overcome the resistance of one pound for one foot.

One B. T. U. (equal to 778 foot-pounds) is the heat required to raise one pound of water one degree F. (from 62° to 63°).

ELECTRICITY

VOLT is the unit of electrical pressure, electromotive force, or difference of potential. Symbol-E.

OHM is the unit of electrical resistance. Symbol-R.

AMPERE is the unit of electrical current, or rate of flow of electricity. Symbol-I.

Ohm's Law expresses the relations between the above:

$$I = \frac{E}{R} \; ; \; R = \frac{E}{I} \; ; \; E = IR$$

WATT is the unit of electrical power, that delivered by one ampere at one volt pressure. 746 watts equal one horsepower. One thousand watts equal one Kilowatt.

With Direct Current, and single phase alternating at 100% power factor.

Watts, $W = EI = I^2R$

With Alternating Current, power factor (PF) and phases affect power.

POWER FACTOR (symbol PF) is the ratio of actual watts to the product of current and voltage from switchboard readings.

Watts, Single phase, W = EI times PF.
Watts, Three phase, W = 1.732 times above.
Current, single phase, I = W divided by product of E and PF.
Current, three phase, I = 0.578 times above.
Three phase Generator Current = 0.578 W divided by product of E and PF.

Three phase Motor Current = 0.578 HP times 746 divided by product of E and PF.

KILOWATT-HOURS-per-TON equals 21 times total Horse-power divided by tons-per-24-hours, when motor efficiency is about 85%.

Electrical Power Transmission

Copper Wire Table

Dimensions, Weights, Resistances, Carrying Capacities

No.	Diam. Inches	Area Circ. Mils	Weight Lbs. Per 1000 Ft.	Resistance Ohms Per 1000 Ft.	Carrying Amperes Rubber Insulation	Capacity Amperes Other Insualtion
0000	.460	211 600	639	.049	225	325
000	.410	167 800	507	.062	175	275
00	.365	133 080	402	.078	150	225
0	.325	105 540	319	.098	125	200
1	.289	83 690	253	.124	100	150
2	.258	66 370	201	.156	90	125
3	.229	52 630	159	.197	80	100
4	.204	41 740	126	.249	70	90
5	.182	33 100	100	.314	55	80
6	.162	26 250	79.3	.395	50	70
8	.128	16 510	49.9	.629	35	50
10	.102	10 380	31.4	1.00	25	30
12	.081	6 530	19.7	1.59	20	25
14	.064	4 110	12.4	2.53	15	20
16	.051	2 580	7.8	4.02	6	10
18	.040	1 620	4.9	6.39	3	5

Carrying Capacity, according to National Board of Fire Underwriters, is independent of Voltage Drop.

To determine size of conductor:

$$\text{Circ. Mils} = \frac{21.6\ DI}{E},$$

Where

D = Length of Transmission (one way)

I = Current in Amperes.

E = Total Volt Drop in wires

The above applies only to a Direct Current, or Single Phase Alternating with 100% Power Factor. Circular mills vary inversely as power factor.

Volt Drop in wires vary from 2% to 10% of the initial line voltage, and is a direct proportional loss of power.

For THREE PHASE Current, (given equal voltage, drop, and power), and at about 86% power factor, the total copper required is 75% of that required for direct current; in other words there will be three wires each of one-half the area of those required for the equal power direct current transmission. When value of current is obtained from motor manufacturer (or on name plate) it may be applied in the above formula without further allowance.

(For Induction Motor Current, see page 46).

Steam Plants

Coal and Water Consumption and Boiler Capacities for Various Types and Sizes of Steam Engines

ENGINES	Size	WATER			FOR DELIVERED H. P. OF RATING					
					Boiler H. P. Includ Aux il	COAL—TONS Per 24 Hours At Full Load—125-150 lbs. Press. 10.000 BTU Per Lb. Coal As Used For Following Boiler Efficiencies				
TYPE	H. P.	Gals. Per Min. Full Load Deliv.	Pounds Per I. H. P. Full Load	Pounds Per I. H. P. Half Load		40 (Horiz. Tubular)	50 (Horiz. Tubular / Scotch Marine)	60 (Scotch Marine / Water Tube)	70 (Water Tube)	80 (Water Tube)
Throttling	50	5	39	41	80	8.2	6.3	....	....	....
Plain Slide Valve	100	9	36	39	145	15.1	11.7	....	....	....
Non-Condensing	150	12	34	37	205	21.4	16.5	....	....	....
Automatic	100	7	29	30½	115	13.3	10.4	....	....	....
Pl. Slide or Piston V.	200	12	27½	29	220	25.0	19.5	16.4	....	....
Non-Condensing	300	17½	26½	28	305	35.0	29.9	22.9	....	....
Automatic	150	8½	23	28	140	15.7	12.2	10.4	....	....
Tandem-Compound	300	15	22	26½	255	28.7	22.5	19.0	16.5	....
Non-Condensing	450	21½	21½	26	370	....	32.9	27.9	24.3	21.3
Corliss	200	10	22	25	175	....	15.6	13.1	11.4	....
Simple	400	19	21½	24½	330	....	29.1	24.9	21.5	18.9
Non-Condensing	600	27	21	24	485	....	42.5	36.3	31.5	27.6
Corliss	300	13	19½	26½	225	....	....	16.9	14.6	12.9
Compound	600	25	19	26	435	....	....	32.8	28.5	25.0
Non-Condensing	900	37	18½	25½	610	....	....	46.0	40.0	35.0
Corliss	500	17	14½	16	280	....	....	20.9	18.3	15.9
Compound	1000	31	13¾	15¼	505	....	....	38.0	33.0	29.0
Condensing	1500	44	13¼	15	730	....	....	55.0	48.0	42.0

Auxiliaries and steam losses are included in boiler H. P. and coal consumption on following basis: Up to 200 H. P., 20%; 300-600 H. P., 15%; 900 to 1,500 H. P., 10%.

Mechanical efficiency of all engines figured at 91%.

10000 BTU for coal as used is a lower value to cover coals with high ash; for other values, coal will vary inversely. 12,000 BTU is perhaps nearer normal.

Boiler H. P. calculated for feed water at 60 degrees F., 30# steam per hour per H. P. If feed is heated by exhaust, reduce rating and coal consumption 1% for every 12 degrees feed temperature is higher than 60 degrees F.

Induction Motors

FULL LOAD CURRENT—RUNNING

Approximate Amperes per Terminal. For determining size of wires, capacity of fuse, and setting of circuit breakers.

For single phase motors, multiply the current per terminal for a two phase motor by two.

H. P.	110 Volts		220 Volts		440 Volts		550 V.	1100 V.	2200 V.
Motor	2 Ph.	3 Ph.	2 Ph.	3 Ph.	2 Ph.	3 Ph.	3 Ph.	3 Ph.	3 Ph.
.5	3.3	3.7	1.7	1.8	.9	1.0			
1	6	6.5	3.	3.2	1.5	1.6			
2	10.5	12	5.	6.	2.6	3.	2.5		
3	15	17	7.5	9.	3.8	4.5	3.5		
5	27	30	13.	15.	6.5	7.5	6.		
7.5			20.	22.	10.	11.	9.		
10			25.	29.	12.5	14.	11.		
15			35.	41.	18.	20.	16.		
20			48.	55.	24.	27.	22.		
25			54.	62.	27.	31.	25.		
30			70.	81.	35.	40.	32.	16	8
40			95.	109.	47.	54.	44.	21	11
50			110.	127.	55.	64.	52.	27	18
75			165.	192.	83.	96.	77.	39	20
100			215.	248.	108.	124.	100.	50	25
150			320.	366.	160.	183.	147.	80	40
200			410.	475.	205.	237.	192.	98	49
250			510.	590.	250.	295.	237.	125	62
300			600.	700.	300.	350.	285.	150	74

From catalog, Westinghouse E. & M. Co.

Water and Pulp

Liquid or Fluid Measure

4 gills = 1 pint, pt.
2 pints = 1 quart, qt.
4 quarts = 1 gallon, gal.

31½ gals. is frequently given as the equivalent of a barrel, but there is no standard barrel in the U. S., the capacity varying between this value and something over 50 gals.

1 cubic foot of water = 62.425 pounds = 28.3153 kilograms (kilos) = 7.48 gals.

1 cubic inch of water = 0.036125 pounds = 252.88 grains = 16.386 grams.

1 ton of water = 32.038 cubic feet = 239.665 gallons.

1 pound of water = 0.016019 cubic foot = 0.47933 quart = 27.681 cubic inches = 0.45359 liter.

1 U. S. gallon of water = 8.3448 pounds = 3785.3 grams.

1 cubic meter of water = 2204.6 pounds.

1 kilogram of water = 1 liter of water = 2.2046 pounds = 0.035317 cubic foot = 61.027 cubic inches = 1.0567 quarts.

1 cubic centimeter of water = 1 gram = 0.001 kilogram = 15.432 grains.

Multipliers

Cu. ft. per sec. × 449 = U. S. gals. per min.
U. S. gals. per min. × 3.85 = Cu. inches per sec.
U. S. gals. per min. × 6 = Tons of water per day.
U. S. gals. per min. × 500 = Pounds of water per hour.
Note—All the above figures are for water at specific gravity of 1.000.

Specific Gravity

Definition: The Specific Gravity of a solid or liquid is the ratio of the weight (mass) of the body to the weight (mass) of an equal volume of water under standard conditions. Density, which is frequently used for specific gravity is the mass (weight) per unit volume, and is the same if grams-per-cubic-centimeter is calculated, but of course different if pounds-per-cubic-foot is used.

Pure water at a temperature of 4° C or 39° F is at its maximum density and has a specific gravity of 1.000.

Sea water averages 1.028 specific gravity; it contains about 3.44% solids, of which about 2.5% of the total is sodium chloride.

The waters of Great Salt Lake and of the Dead Sea have a specific gravity of 1.17 and contain about 22.4% solids.

Water Requirements of Mills

	tons water per ton ore	Gals. p. m. per 24 hr-ton
Coarse Gravity Concentration, Crushers, rolls, jigs, tables	15 to 20	2.5 to 3.5
Gravity Concentration, Crushers, ball and pebble mills, tables, vanners	7 to 10	1.2 to 1.7
Stamp Mills, with vanners	4 to 6	0.7 to 1.0
Gravity and Flotation Concentration, Crushers, ball and pebble mills, tables and flotation	5 to 7	0.8 to 1.2
All Flotation Concentration, Crushers, ball and pebble mills, and flotation	3 to 6	0.5 to 1.0
Cyanide Mills, shoveling tailing and filter-pressing	0.2 to 0.35	0.03 to 0.06
Cyanide Mills, sluicing tailing	1.3 to 1.9	0.2 to 0.35

Above quantities do not include water for boilers nor return circuit water. With settling tanks or ponds, from 50% to 60% of the original water (except in case of mills shoveling tailing) is available for use on return to the mill circuit With automatic discharge tanks for sand and decantation tanks for slime, from 75% to 80% of the original water may be recovered and used again in the mill circuit.

For water requirements in individual machines, see particular machine under Mill Machinery.

Pulp Calculations

Let W = weight of a given volume of water (1 gram = 1 c.c.)
Ws = weight of an equal volume of dry solids.
Wp = weight of an equal volume of pulp, or by wetting solids to make water level equal.

$$Gs = \text{specific gravity of solids} = \frac{Ws}{W - (Wp - Ws)}$$

$$Gp = \text{specific gravity of pulp} = \frac{Wp}{W}$$

$$Ws = \frac{Gp - 1}{Gs - 1} \, GsW$$

$$S = \text{percent of solids in pulp} = 100 \, \frac{Gp - 1}{Gs - 1} \times \frac{Gs}{Gp}$$

$$\text{Weight per cubic foot} = \frac{Gp}{32.038} \text{ tons} = 62.425 \, Gp \text{ pounds.}$$

$$\text{Cubic Feet per ton} = \frac{32.038}{Gp}$$

$$\text{Cubic Feet pulp per ton dry solids} = \frac{32.038\,(Gs - 1)}{(Gp - 1)\,Gs}$$

$$\text{Percent water in pulp} = 100 - S = 100 \, \frac{Gs - Gp}{(Gs - 1)\,Gp}$$

Tons of dry solids per foot depth for round tanks of diameter

$$D \text{ (in feet)} = \frac{D^2\,(Gp - 1)\,Gs}{40.8\,(Gs - 1)}$$

See also Table of "Pulp and Sludge Density Relations."

Water Piping in Mills

$$\text{Nominal Diameter of Pipe, } D = \sqrt[2]{\frac{\text{U. S. gals. p. Min.} \times 0.41}{\text{velocity in ft. p. sec}}}$$

GALLONS per Minute

Pipe diam. D	½	¾	1	1–¼	1–½	2	2–½	3	4	5
at 6 ft. p. s. maximum	3–½	8.2	14.6	23	33	58	91	130	233	365
at 4 ft. p. s. normal	2–½	5.5	9.8	15	22	39	61	87	156	245

Pulp and Sludge Density Relations*

Per Cent Solids.	Ratio of Solids to Solution.	Specific Gravity of Pulp and Volume of One Ton in Cubic Feet, for Slimes Containing Solids of Different Specific Gravities.									
		2.50		2.70		2.90		3.10		3.30	
		S. G.	Vol.	S. G.	Vol.	S. G.	Vol.	S. G.	Vol.	S. G.	Vol.
5	1:19.000	1.031	31.03	1.032	30.99	1.034	30.95	1.035	30.92	1.036	30.89
6	1:15.667	1.037	30.85	1.039	30.79	1.041	30.74	1.042	30.70	1.043	30.66
7	1:13.286	1.044	30.66	1.046	30.59	1.048	30.53	1.049	30.48	1.051	30.43
8	1:11.500	1.050	30.46	1.053	30.39	1.055	30.32	1.057	30.27	1.059	30.21
9	1:10.111	1.057	30.27	1.060	30.19	1.063	30.11	1.065	30.05	1.067	29.99
10	1: 9.000	1.064	30.08	1.067	29.99	1.070	29.90	1.072	29.83	1.075	29.77
11	1: 8.091	1.071	29.88	1.074	29.79	1.078	29.69	1.080	29.61	1.083	29.54
12	1: 7.333	1.078	29.70	1.082	29.59	1.085	29.48	1.088	29.40	1.091	29.32
13	1: 6.692	1.085	29.50	1.039	29.39	1.093	29.27	1.096	29.18	1.099	29.10
14	1: 6.144	1.092	29.31	1.097	29.19	1.101	29.06	1.105	28.96	1.108	28.88
15	1: 5.667	1.099	29.18	1.104	28.99	1.109	28.85	1.113	28.74	1.117	28.66
16	1: 5.250	1.105	28.93	1.112	28.78	1.117	28.65	1.122	28.53	1.125	28.43
17	1: 4.882	1.114	28.74	1.119	28.58	1.125	28.44	1.130	28.31	1.134	28.21
18	1: 4.556	1.121	28.54	1.128	28.38	1.134	28.23	1.139	28.10	1.143	27.99
19	1: 4.263	1.129	28.35	1.136	28.18	1.142	28.02	1.148	27.88	1.153	27.76
20	1: 4.000	1.136	28.17	1.144	27.98	1.151	27.81	1.157	27.66	1.162	27.54
21	1: 3.762	1.144	27.97	1.152	27.77	1.159	27.60	1.166	27.44	1.171	27.32
22	1: 3.545	1.152	27.78	1.161	27.57	1.168	27.39	1.175	27.23	1.181	27.09
23	1: 3.348	1.160	27.58	1.169	27.37	1.177	27.18	1.184	27.01	1.191	26.87
24	1: 3.167	1.168	27.39	1.178	27.17	1.186	26.97	1.194	26.79	1.201	26.65
25	1: 3.000	1.176	27.21	1.187	26.97	1.195	26.76	1.204	26.58	1.211	26.42
26	1: 2.846	1.185	27.01	1.195	26.77	1.205	26.55	1.214	26.37	1.222	26.20
27	1: 2.704	1.193	26.82	1.205	26.56	1.215	26.34	1.224	26.15	1.232	25.98
28	1: 2.571	1.202	26.62	1.214	26.36	1.224	26.13	1.234	25.93	1.242	25.75
29	1: 2.448	1.211	26.43	1.223	26.16	1.234	25.92	1.244	25.71	1.253	25.53
30	1: 2.333	1.220	26.24	1.233	25.95	1.244	25.71	1.255	25.50	1.264	25.31
31	1: 2.226	1.229	26.05	1.242	25.75	1.255	25.50	1.266	25.28	1.275	25.08
32	1: 2.125	1.238	25.86	1.252	25.55	1.265	25.29	1.277	25.06	1.287	24.86
33	1: 2.030	1.247	25.66	1.262	25.35	1.276	25.08	1.288	24.85	1.299	24.64
34	1: 1.940	1.256	25.47	1.272	25.15	1.287	24.87	1.299	24.63	1.311	24.41
35	1: 1.857	1.266	25.28	1.283	24.95	1.298	24.66	1.310	24.41	1.323	24.19
36	1: 1.778	1.276	25.09	1.293	24.75	1.309	24.45	1.322	24.19	1.335	23.97
37	1: 1.703	1.285	24.90	1.304	24.55	1.320	24.24	1.334	23.98	1.347	23.75
38	1: 1.632	1.295	24.70	1.314	24.35	1.332	24.03	1.346	23.76	1.360	23.52
39	1: 1.564	1.305	24.51	1.326	24.14	1.343	23.82	1.358	23.55	1.373	23.30
40	1: 1.500	1.316	24.32	1.336	23.95	1.355	23.61	1.371	23.33	1.387	23.08
41	1: 1.439	1.326	24.13	1.348	23.74	1.367	23.40	1.384	23.11	1.400	22.85
42	1: 1.381	1.337	23.94	1.359	23.55	1.380	23.19	1.396	22.89	1.414	22.63
43	1: 1.326	1.348	23.74	1.371	23.34	1.392	22.99	1.411	22.68	1.428	22.41
44	1: 1.273	1.359	23.55	1.383	23.15	1.405	22.78	1.425	22.46	1.442	22.18
45	1: 1.222	1.370	23.36	1.395	22.94	1.418	22.57	1.438	22.24	1.456	21.96
46	1: 1.174	1.381	23.17	1.408	22.73	1.432	22.36	1.452	22.02	1.471	21.74
47	1: 1.128	1.393	22.98	1.420	22.54	1.445	22.15	1.467	21.81	1.487	21.51
48	1: 1.083	1.404	22.78	1.433	22.33	1.458	21.94	1.483	21.60	1.503	21.29
49	1: 1.041	1.416	22.59	1.446	22.13	1.473	21.73	1.497	21.38	1.519	21.07
50	1: 1.000	1.429	22.39	1.460	21.92	1.487	21.52	1.512	21.16	1.535	20.85
51	1: 0.961	1.441	22.21	1.473	21.72	1.502	21.31	1.528	20.94	1.551	20.62
52	1: 0.923	1.453	22.02	1.487	21.52	1.517	21.10	1.544	20.73	1.568	20.40
53	1: 0.887	1.466	21.82	1.501	21.32	1.532	20.89	1.560	20.51	1.585	20.18
54	1: 0.852	1.479	21.63	1.515	21.12	1.548	20.68	1.577	20.29	1.603	19.96
55	1: 0.809	1.493	21.44	1.530	20.92	1.564	20.47	1.594	20.08	1.621	19.73
56	1: 0.786	1.506	21.25	1.545	20.72	1.580	20.26	1.611	19.87	1.640	19.51
57	1: 0.754	1.520	21.06	1.560	20.51	1.596	20.05	1.628	19.65	1.659	19.29
58	1: 0.724	1.534	20.86	1.574	20.31	1.613	19.84	1.646	19.43	1.678	19.06
59	1: 0.695	1.548	20.67	1.591	20.11	1.629	19.63	1.665	19.21	1.697	18.84
60	1: 0.667	1.563	20.48	1.607	19.91	1.645	19.42	1.684	19.00	1.718	18.62
61	1: 0.639	1.577	20.29	1.623	19.71	1.664	19.21	1.704	18.78	1.739	18.39
62	1: 0.613	1.592	20.10	1.641	19.51	1.683	19.00	1.724	18.56	1.761	18.17
63	1: 0.587	1.603	19.90	1.657	19.30	1.703	18.79	1.745	18.34	1.783	17.95
64	1: 0.563	1.623	19.71	1.675	19.10	1.723	18.58	1.765	18.12	1.805	17.72
65	1: 0.538	1.639	19.52	1.69[illegible]	18.90	1.742	18.37	1.786	17.91	1.828	17.50
66	1: 0.515	1.6[illegible]6	19.32	1.711	18.70	1.762	18.16	1.808	17.69	1.852	17.28
67	1: 0.493	1.672	19.14	1.730	18.50	1.783	19.95	1.831	17.47	1.876	17.06
68	1: 0.471	1.689	18.94	1.749	18.30	1.803	17.74	1.854	17.26	1.901	16.83
69	1: 0.449	1.706	18.75	1.768	18.10	1.825	17.53	1.878	17.04	1.927	16.61
70	1: 0.429	1.724	18.56	1.786	17.90	1.847	17.32	1.902	16.83	1.953	16.39

*H. B. Lowden, *Metallurgical and Chemical Engineering*,

Circulating Feed

To find total tonnage in a crushing element of a mill, when part of the load is returned from classifier or sizing screen, back to the beginning:

$$Q = \frac{100T}{100 - P}$$

Where

T = Initial Tonnage per day, feed and discharge from element.
P = % of oversize returned.
Q = Total Tonnage per day through the element.

Example:

$$T = 100 \text{ tons}, \quad P = 75\% \quad Q = \frac{100 \times 100}{100 - 75} = 400$$

tons.

Ratio

Recovery and [redacted] of Concentration

Knowing the assay value of the Heads, Tails and Concentrates,

$$R = \frac{C - T}{H - T}, \quad E = \frac{100\,C}{H\,R}, \quad E = \frac{100\,C \times (H - T)}{H \times (C - T)}$$

Where

H = heads assay, T = tailing assay, C = Concentrates assay,
R = ratio of concentration (tons into one,) E = recovery in %.

Example:

Heads, 2.4% Pb; Tails, 0.95% Pb;
Concentrates, 11.95% Pb.

$$R = \frac{11.9 - 0.95}{2.4 - 0.95} = \frac{10.95}{1.45} = 7.56, \text{ Ratio of Concentration.}$$

$$E = \frac{11.9 \times 100}{2.4 \times 7.56} = \frac{11.90}{18.15} = 65.6\%, \text{ Recovery.}$$

Equivalents of Weights and Measures*

LENGTH

1 mile = 5,280 feet = 1609.31 meters.
1 foot = 12 inches = 0.30479 meter.
1 inch = 25.3995 millimeters.
1 kilometer = 1,000 meters = 0.62138 mile = 3281 feet.
1 meter = 100 centimeters = 3.280899 feet = 39.370791 inches.
1 centimeter = 10 millimeters = 0.393708 inch.
1 millimeter = 0.039371

SURFACE

1 square yard = 9 square feet = 0.83610 square meter.
1 square foot = 144 square inches = 9.2900 square decimeters = 929.00 square centimeters.
1 square inch = 6.4514 square centimeters.
1 square meter = 100 square decimeters = 10764 square feet.
1 square decimeter = 100 square centimeters = 0.10764 square foot = 15.501 square inches.
1 square centimeter = 100 square millimeters = 0.15501 square inch.
1 square millimeter = 0.00155 square inch.

VOLUME

1 cubic yard = 27 cubic feet = 0.76451 cubic meter = 201.97 gallons.
1 cubic foot = 1728 cubic inches = 0.28315 cubic meter = 7.4805 gallons = 28.3153 liters = 29.922 quarts.
1 cubic inch = 0.017316 quart = 16.386 cubic centimeters.
1 gallon = 4 quarts = 0.13368 cubic foot = 231.0000 cubic inches = 3.7852 liters.
1 quart = 2 pints = 57.75 cubic inches = 0.94630 liters = 0946.30 cubic centimeters.
1 cubic meter = 1,000 liters = 1.3080 cubic yards = 35.317 cubic feet = 264.19 gallons.
1 liter, or 1 cubic decimeter = 1,000 cubic centimeters = 0.035317 cubic foot = 61.027 cubic inches = 0.26419 gallons = 1.0567 quarts.
1 cubic centimeter = 0.061027 cubic inch.

*Taken from C. Herring. Table of Equivalents of Units of Measurement.

WEIGHT

1 ton = 2,000 pounds avoirdupois = 907.18 kilos. This is the ton used throughout this book unless otherwise specified.
1 long ton = 2,240 pounds avoirdupois = 1016.05 kilos.
1 metric ton = 1,000 kilos = 2204.62 pounds avoirdupois = 1.1023 tons = 0.98421 long ton.
1 pound avoirdupois = 16 ounces avoirdupois = 0.45359 kilo = 7,000 grains = 1.2153 pounds troy.
1 pound troy = 5760 grains = 0.82286 pound avoirdupois = 12 ounces troy = 0.37324 kilo.
1 ounce avoirdupois = 437.50 grains = 28.3495 grams = 0.91146 ounce troy.
1 ounce troy = 480 grains = 20 pennyweights = 31.1035 grams = 1.0971 ounces avoirdupois. The troy ounce and pound are used only for gold and silver and other precious metals.
1 grain = 64.799 milligrrams.
1 kilo or kilogram = 1000 grams = 2.2046 pounds avoirdupois.
1 gram = 0.035274 ounce avoirdupois = 0.032151 ounce troy = 15.43235 grains = 1,000 milligrams.
1 milligram = 0. 015432 grains.

MISCELLANEOUS MULTIPLIERS

Avoirdupois oz. per min. × 0.0450 = Tons per day.
Troy oz. per min. × 0.04937 = Tons per day.
Grams per min. × 0.00159 = Tons per day.
Tons per day × 630. = Grams per min.
Tons per day × 1.39 = Pounds Av. per min.
Troy oz. per ton × 0.00343 = % per ton.
% per ton × 292. = Troy oz. per ton.
Avoirdupois ounces × 0.9114 = Troy oz.
Troy ounces × 1.0971 = Avoirdupois oz.
Grams × 0.0321 = Troy oz.
Grams × 0.0353 = Avoirdupois oz.
Millimeters × 0.04 = inches.
Inches × 25. = millimeters.
1 Gram per Metric ton = 62c in gold.
1 Gram per Metric ton = 1.55 cents in silver (at 50c).
1 Dwt. of gold = $1.00.
1 Pound Avoirdupois = 453.60 grams.

PRESSURE

1 atmosphere at mean sea level = 760 millimeters or 29.922 inches of mercury column, = 10.333 meters or 33.001 feet of water column, = 14.696 pounds per square inch, = 1.0333 kilos per square centimeter.

1 pound per square inch = 0.070310 kilo per square centimeter = 2.041 inches of mercury = 2.31 ft. head of water.

1 kilo per square centimeter = 14.223 pound per square inch.

ALTITUDE EFFECTS

Altitude Above Sea Level	Barometric Pressure				Approx. Boiling Point-F	Relative Volumetric Efficiency
	Mercury Col. MM.	Mercury Col. Inches	Water Col. Feet	Pounds Per Sq. In.		
0	762	30.00	34.0	14.72	212	1.000
1000	733	28.85	32.7	14.17	210	0.965
2000	707	27.82	31.5	13.64	208	0.93
3000	681	26.82	30.3	13.13	206	0.895
4000	657	25.85	29.2	12.64	204	0.86
5000	631	24.92	28.1	12.17	202	0.83
6000	610	24.00	27.0	11.71	201	0.80
7000	587	23.1	26.0	11.27	199	0.77
8000	562	22.17	25.0	10.85	197	0.74
9000	540	21.3	24.1	10.45	195	0.71
10000	517	20.34	23.2	10.06	193	0.68
11000	503	19.8	22.4	9.69	191	0.66
12000	485	19.1	21.6	9.33	190	0.635
13000	464	18.3	20.8	8.98	188	0.61
14000	447	17.6	20.0	8.64	186	0.59
15000	432	17.0	19.3	8.32	184	0.57

FALLING BODIES

$$v = gt = 32.16\,t = \sqrt{2gh} = 8.02\,\sqrt{h} = \frac{2h}{t}$$

where

v = velocity at the end of t seconds
g = force (acceleration) of gravity, = 32.16 ft. p. sec. p. sec.
h = height or space passed in t seconds.

The following table gives the falls and maximum velocities (in feet per minute) for different periods of time from beginning of fall. Any other values within these limits may be found per interpolation, or by plotting three or four values nearest to that desired.

Time Sec.	Fall Ft.	Fall In.	Velocity Max. Ft. P. M.
0.05	....	½	97
0.10	....	2	193
0.15	....	4¼	290
0.20	....	7.7	386
0.25	....	12.	483
0.3	1	5.3	579
0.4	2	6.7	772
0.5	4	0.2	965
0.6	6	1.2	1158
0.7	7	11.0	1351
0.8	10	3	1544
0.9	13	0	1737
1.0	16	1	1930
1.5	36	2	2895
2.0	64	4	3860
2.5	100	6	4825
3.0	144	9	5790

CENTRIFUGAL FORCE

$F = 1.227\ W\ R\ n^2 = .000341\ W\ R\ N^2$ pounds where
F = force or pull on the radius arm in pounds
W = weight of the body in pounds
N = revolutions per minute
n = revolutions per second

Pneumatic Flotation Plant

Designed and built by the General Engineering Company

MILLING MACHINERY

Owing to the diverse character of ores, the capacities, power consumption, water requirements, etc. of the various machines used in milling operations can only be given in very general figures.

The information given in this section is for general estimating purposes, and while taken from reliable sources, it cannot be expected to supplant the experience of engineers and operators in close touch with the development of the art of ore-treatment.

Crushing Machinery

Some rocks offer as much as five times the resistance to crushing as others; this variation affects capacity, power and repairs.

There is a constant development in crushing machinery, new machines replacing older types, larger sizes being developed, etc.; at the same time many of the very oldest of machines retain their position; with possibly one or two exceptions, it is believed that the machines for which data is given represent those most in use at the time of this publication.

Blake Jaw Crushers

(BREAKERS)

Opening For Feed Inches	CAPACITY				Horse Power
	Min. Product		Max. Product		
	Size Inches	Tons Per Hr.	Size Inches	Tons Per Hr.	
7x10	¾	1½	2	5	6-9
9x15	1	6	2½	12	10-15
10x20	1½	10	3	20	15-20
12x24	2	20	4	35	20-28
18x30	2½	30	5	50	35-50
24x36	4	70	6	100	50-60

Gyratory Crushers

(BREAKERS)

Size No.	Openings For Feed Inches	CAPACITY				Horse Power
		Min. Product		Max. Product		
		Size Inches	Tons Per Hr.	Size Inches	Tons Per Hr.	
1	5x18	1	4	2	8	5-8
2	6x21	1⅛	6	2¼	12	7-12
3	7x22	1⅜	10	2½	20	10-16
4	8x30	1½	15	3	40	14-21
5	10x38	1¾	30	3½	70	22-30
6	12x44	2	50	3½	90	28-45
7½	14x52	2½	80	4	120	50-75
8	18x68	3½	130	4	150	70-110
9	21x76	4	250	5	300	100-150

Disc Crushers

Size Diam. Discs Inches	Opening For Feed Inches	CAPACITY				Horse Power To Run
		Min. Product		Max. Product		
		Size Inches	Tons Per Hr.	Size Inches	Tons Per Hr.	
18	1½	⅜	5-8	1	12-15	12-18
24	2½	½	12-15	1½	25-30	18-25
36	3½	¾	25-30	2	50-60	30-40
48	6	1	45-60	2½	100-120	50-65

Adapted from catalog, Chalmers & Williams, Inc.

Crushing Rolls

Size	Max.	At 50 R. P. M.				At 100 R. P. M.			
Diam. x Face Inches	Feed Inches	Peripheral Speed Ft. P. M.	Horse Power	Capacity Tons 24Hr ¼″ Opening	Capacity Tons 24Hr 1″ Opening	Peripheral Speed Ft. P. M.	Horse Power	Capacity Tons 24Hr ¼″ Opening	Capacity Tons 24Hr 1″ Opening
9x9	⅜	118	1¼	13	....	235	2½	26	....
12x12	½	157	2	23	....	315	4	47	....
18x10	¾	235	3½	29	....	470	7	58	....
24x12	1	315	6	47	190	630	12	95	380
30x14	1¼	390	9	68	275	780	18	137	550
36x14	1½	470	12	82	330	940	24	165	660
42x16	1¾	550	15	110	440	1100	30	220	880
48x16	2	630	25	125	500	1260	50	250	1000
54x20	2¼	705	40	175	700	1410	80	350	1400
60x24	2½	785	65	235	940	1570	130	470	1880
72x24	3	940	100	280	1120	1880	200	560	2240

Size represents commonly manufactured sizes. Power and capacity of other sizes will be proportional to both dimensions of nearest size given.

Max. Feed is the size of rock the rolls should nip when close up. (15 deg. or 30 deg. "angle of nip"). While rolls will nip larger pieces (1-24 the diameter plus opening between rolls), the strength of the roll parts is such that it is generally inadvisable to crush pieces larger than designated.

Speeds of rolls given in manufacturers tables are usually the maximum for which designed; the speeds here given cover the usual speeds; H. P. and capacity for other speeds being proportional. 700 F. P. M. for coarse rock (max. feed), and 1000 F. P. M. for fine material, are common in larger plants, and for some very large rolls speeds nearly 2000 F. P. M. are used.

Capacities are 10% of the theoretical; with proper feeding devices, capacities may be doubled and probably tripled. Capacities are proportional to opening; tabulated values are for material weighing 100# per cubic foot.

Horse powers are for the capacities given, and indicate the amount which should be available for variations in feed; with doubled capacity due to better feeding, power required will be increased about 50%.

For finished products down to as fine as 16-mesh, rolls may be used to advantage, but where further reduction is required it is usually better practice to reduce to about ¼" in the rolls, and finish in ball, pebble, or rod mills.

6 ft. Chilean Mills

R. P. M.	Feed	Capacity: Fine Product Mesh	Capacity: Fine Product Tons Per Hr.	Capacity: Coarse Product Mesh	Capacity: Coarse Product Tons Per Hr.	Horse Power
29	8 Mesh	30	3½-5	6	7½	50-90
37	2 Mesh	30	7	6	12	75-120

Water required: about 1 gal. P. M. per 24-Hr. Ton.

Stamp Mills

Weight of Stamp Pounds	DROPS		CAPACITY				Horse Power Per Stamps
	Inches	Per Minute	Fine Products		Coarse Products		
			Mesh	Tons Per 24 Hrs.	Mesh	Tons Per 24 Hrs.	
850	7-8	90-106	40	4.3	12	6	2.4
1050	6-8	94-108	30	4.6	3	10	2.6
1250	6-8	90-110	14	5.4	3½	12	3.0
1500	6½-8	96-100	10	8	3	14	3.5

Water required per Stamp: 3-10 gals. per minute; about 1 gal. P. M. per 24-Hr. Ton.

Cylindrical Ball Mills

Capacities are for medium hard quartz and in closed circuit with classifier or screen.

Size of Mill in Feet Dia. X Length	Tons per 24 hrs. 2″ to 48 Mesh	Tons per 24 hrs. 2″ to 14 Mesh	H. P. Required to Run	H. P. of Motor Recom-mended	R. P. M. of Mill	Ball Charge in Pounds
3x3	20	30	10	15	40	1,200
3x5	30	40	15	25	40	2,000
4x4	40	75	25	40	32½	3,000
5x4	60	120	40	60	28	5,000
5x5	75	150	50	75	28	6,500
6x4	120	210	60	85	24	9,000
6x5	150	260	80	100	24	11,000
6x6	190	320	100	125	24	13,500
7x5	225	375	110	125	20	18,000
7x6	275	450	135	150	20	23,000
8x5	320	500	150	175	18	25,000
8x6	385	600	180	200	18	30,000

From catalog, The Allis-Chalmers Mfg. Co.

Conical Ball Mills

Capacities given are for medium hard quartz ore and in closed circuit with classifiers or screens.

Size of Mill Dia length Ft. In.	Tons per 24 hrs. 2″ to 20 Mesh	H.P.Req'd. to Run	H. P. Motor Recomended	R. P. M. of Mill	Ball Charge in Pounds
3x8	8	5	7½	35	1,000
4½x16	40	18	25	33	4,500
5x22	60	30	40	29	7,500
6x22	150	50	60	26	12,000
7x22	200	75	100	24	20,000
7x36	250	85	125	24	27,000
8x22	300	110	150	22	30,000
8x36	400	150	200	22	34,000
8x48	550	200	250	22	42,000

From catalog, The Hardinge Co

Conical Pebble Mills

Capacities given are for medium hard quartz ore and in closed circuit with classifiers or screens.

Size of Mill Dia. length Ft. Inches	Tons per 24 h ¼″ feed to 28 Mesh	H. P. Req'd. to run	H. P. Motor Recom-mended	R. P. M. of Mill	Pebble Charge in Pounds
3x8	6	3	5	36	300
4½x16	20	8	12½	32	2,500
6x22	45	18	25	28	4,500
6x30	55	21	30	28	4,800
6x48	70	27	35	28	5,500
8x22	100	40	50	24	10,000
8x30	125	48	60	24	11,000
8x36	140	55	60	24	12,000

From catalog, The Hardinge Co.

Cylindrical Pebble Mills (Tube Mills)

Capacities are for medium hard quartz and in closed circuit with classifiers or screens.

(Intermediate Lengths furnished every 2 feet; power, capacity, and pebble charge proportional)

Size of Mill In Feet Dia x Length	Tons per 24 hrs. 8 Mesh to 95%-100M	H. P. Required to Run	H. P. Motor Recom-mended	R. P. M. of Mill	Pebble Charge in Pounds
4x8	25	15	20	32	5,000
4x12	29	23	30	32	7,500
4x16	38	30	40	32	10,000
4x20	40	38	50	32	12,500
5x8	42	22	40	28	7,800
5x12	50	33	50	28	11,800
5x16	59	44	50	28	15,700
5x22	75	61	75	28	21,500
6x8	55	34	50	24	11,300
6x12	71	52	75	24	17,000
6x16	90	70	100	24	22,600
6x22	118	97	125	24	30,200
7x10	85	63	75	20	19,200
7x16	120	100	125	20	30,800
8x10	112	83	100	18	25,100
8x16	186	134	150	18	40,200

From catalog, Allis-Chalmers Co.

Revolving Screens
(Trommels)

Diam. Inches	CAPACITY Tons Per 24 Hrs.-1-12 Slope				Length Ave Inches	Horse Power		R.P.M.	Spray Water Gals. P. Min.	
	¼″ Deep	½″ Deep	1″ Deep	2″ Deep		Min.	2′ Deep		¼″ Deep	1″ Deep
30	8	24	70	200	60	0.33	0.75	16-22	16	
36	10	30	88	240	72	0.50	1.1	16-20	20	10
42	12	35	100	280	84	0.75	1.6	15-18	24	12
48	14	40	115	320	96	1.1	2.3	14-17	28	14
60	18	52	145	400	120	2.0	4.0	13-16	36	18
72		65	180	490	144	3.3	6.0	12-15		23
96			220	620	192	5.6	9.0	10-12		28

Capacities include all undersize, and are based upon the maximum R. P. M. given. Minimum R. P. M. will reduce capacity about proportionally.

Depth of ore should be based upon hole in screen, between 2 and 10 times the diameter of the hole, depending upon the quality of screening required (undersize in oversize).

Capacity will vary as the slope: ½″ per foot will have about half the capacity of the above, 2″ per foot will have double the capacity of the above, for the same conditions, with slightly better quality of screening on the flatter slopes.

Length of screen has no appreciable effect upon capacity, but increased length should slightly improve quality.

Horse Power will increase with the length.

Present day practice turns to the use of the Vibratory type of Screen with its high ratio of capacity to floor space, and low power consumption.

Inclined Impact Screens

About 45° Inclination

Capacity per sq. ft. screening area

Mesh	6	8	10	14	20	28	35	48	65	100
Tons, 24 Hrs.	17	15	13	10	7	5	4	3	2	1

Callow Traveling Belt Screen

Capacity, 24″ Duplex

Mesh	6	8	10	14	20	28	35	48	65	100	150
Tons, 24 Hrs.	600	450	400	320	250	210	175	140	110	75	50

Feed should carry 3½-4 tons water per ton ore.

Undersize spray water: 6-10 gals. per minute.

Oversize spray water: 8-12 gals per minute.

To convert square hole screen(cloth or metal) into their equivalent in Millimeters:

Square holes in inches x 33 = round holes in M. M.

Round holes in M. M. x 0.0303 = square holes in inches.

Square holes x 1.32 = round holes.

Hydraulic Classifiers

Hydraulic water: 5 - 20 tons per ton of ore.
1 - 3.3 gals. per minute per 24-hour-ton.

Callow Settling Tanks

Capacities, on Dilute Slimes giving a **Clear** overflow and discharging a thickened pulp of 15% to 25% solids.

Butte Slimes: 25 - 30 gals. per min. of feed

Coeur D'Alene Slimes: 30 - 35 gals. per min. of feed

Bingham Slimes: 35 - 40 gals. per min. of feed

As Feed Desliming Tanks for Tables - 30 Mesh Feed in 4½ or 5 to 1 water. 50 tons solids per 24 hours, contained in 35 - 40 gals. per min.

Products: Overflow 3½% Solids; Thickened Pulp 33% (67% moisture).

Thickening Tanks

Flotation Concentrates,	5-10	Sq.	Ft.	Per	24-Hr	Ton	of	Solids
Slimes (Cyanide Plants),	3-10	"	"	"	"	"	"	"
Easy Settling Ores,	3-6	"	"	"	"	"	"	"
Difficult " "	10-40	"	"	"	"	"	"	"

Vacuum Filters—Continuous

Built in various sizes from 4' Diam. with 4 sq. ft. filtering area up to 14' Diam. with over 600 sq. ft. filtering area.

Capacity depends upon physical condition of the solids (Colloidal or Granular), screen analysis, amount of water to be removed, etc.

Feed: Flotation concentrates, 50% moisture; cake: 10 - 15% moisture, 3 to 7 sq. ft. filtering area per 24 hr-ton of solids.

Vacuum Pump Capacity:—From 0.75 to 1.00 cu. ft. displacement for each square foot of Filter area, at 20 to 22 inches (mercury) vacuum.

Concentrating Tables and Vanners

Feed	Capacity Tons Per 24 Hrs.	Minimum Ratio of Water To Ore In Feed	Wash-Water Per Machine G. P. M.
Tables			
Unclassified —2½ m.m	75-150	1.5 to 1	10-15
Unclassified —20 Mesh	15-60	2.5 to 1	8-12
Unclassified —60 Mesh	10-30	3.0 to 1	6-10
Screen or Classified+30	25-50	} 3.0 to 1	
Screen or Classified+120	10-25		5-10
Vanners			
—20 Mesh	5-10	5 to 1	3-5
—200 Mesh	3-5	4 to 1	1.5-3

Vanners are little used since the adoption of flotation.

Hartz Jigs

Feed Sizes Mesh	No. Compts 18″x36″	Water Gals. Per Min.	Capacity Tons Per 24 Hrs.	Horse Power
8-14	4	8-16	5-15	3
4-6	3	15-20	8-20	2½
2-3	2	18-30	10-30	2
MM				
15-25	1	20-30	15-50	1½
25-50	1	30-50	30-100	1½

Flotation Type Rotary Blowers

Size No.	Cu. Ft. Per Min	R. P. M.	Horse Power 5 lbs.	Horse Power 3½ lbs.	Outlet Inches
¼	100	420	4.6	3.5	5
	200	615	6.7	5.0	5
½	200	455	7.1	5.3	5
	250	530	8.3	6.2	5
1	300	305	10.6	8.0	6
	500	440	15.3	11.0	6
2	600	335	19.1	14.0	8
	800	415	23.6	17.5	8
3	900	275	27.1	20.	10
	1400	390	38.4	28.	10
4	1600	290	45.4	33.	12
	2200	380	59.4	43.	12
5	2400	290	65.0	48.	14
	3000	345	81.5	60.	14
5½	3000	245	81.0	60.	16
	3800	315	101.0	75.	16
6	4000	235	107.	80.	16
	4600	270	122.	90.	16

Adapted from catalog, P. H. & F. M. Roots Co.

Above table based upon free air at sea level. Capac'ty given is for 5 lbs. pressure, and will be increased slightly for 3½ lbs. pressure. Horse-power will be reduced slightly as altitude increases. For combustion purposes at higher altitudes, additional capacity must be provided to equal sea-level conditions; but for flotation purposes, such allowance is unnecessary.

Pneumatic Flotation

Capacity is for 1½ to 2 tons of feed per square foot of aerating surface per 24 hours.

Air required is approximately 10 cubic feet of free air per minute per square foot of aerating surface, at 3½ lbs. per square inch for flat bottom and 5 lbs, for sloping bottom cells.

Pulp for pneumatic flotation should usually carry from 20 to 25 per cent solids.

Drying Ores and Concentrates

(Condensed from Ruggles-Coles Eng. Co. Cat. No. 16)
HEAT AND COAL TO DRIVE OFF MOISTURE (Theoretical)
PER TON (2,000 lbs.) OF DRY MATERIAL

Moisture %	Water Lbs.	At 100% Efficiency Total B. T. U.	At 100% Efficiency Coal Lbs.	Moisture %	Water Lbs.	At 100% Efficiency Total B. T. U.	At 100% Efficiency Coal Lbs.
1	20	86,200	7.2	25	667	809,550	67.5
2	41	109,680	9.2	30	857	1,021,970	85
4	83	156,630	13.1	35	1,077	1,267,930	106
6	128	207,940	17.7	40	1,333	1,554,130	130
8	174	258,370	21.5	50	2,000	2,299,840	193
10	222	312,040	26.0	60	3,000	3,417,840	285
12	273	369,050	30.8	70	4,667	5,280,430	440
14	325	427,190	35.6	80	8,000	9,007,840	756
16	381	489,800	40.8	85	13,333	12,734,090	1,060
18	439	554,640	46.2	90	18,000	20,188,000	1,680
20	500	622,840	52	95	38,000	42,548,000	3,550

Total B. T. U. include 63840 B. T. U. to raise temperature of material from 60 deg. F. to 212 deg F. at which point evaporation takes place (at sea level) ; specific heat of material taken as 0.21

Coal assumed to have 12000 B. T. U. per lb. as used and is for 100% per cent efficiency as specified. Efficiencies in drying vary widely, depending upon the method of applying heat, the type of apparatus, etc., probably from 25% to 75%. Table of coal added to original data by General Engg., Co.

Belt Conveyors

Belt Width Inches	Belt Ply Ave.	Material Max. Sizes *	Material Wt. Cu. Ft.	Max. Lengths Horiz.	Max. Lengths Slopes 1-12 (5 Degrees)	Max. Lengths Slopes ⅙ (9½ Degrees)	Max. Lengths Slopes ¼ (14 Degrees)	Max. Lengths Slopes ⅓ (18½ Degrees)	Tons Per Hr. 100 F.P.M.	Horse Power 100 F. P. M.	Max. Belt Speed F. P. M.
12	3	1½–2½	50	700	520	410	340	280	11	2.2	300
			100	500	325	245	195	160	22		
16	4	2½–4	50	730	530	400	340	285	20	3.8	300
			100	520	330	240	195	160	40		
20	4	3½–5	50	610	450	325	280	245	31	4.8	400
			100	435	280	200	160	135	62		
24	5	4½–8	50	685	490	375	305	250	46	7.6	450
			100	490	310	225	175	140	92		
30	6	6–12	50	670	465	350	290	245	75	11.5	500
			100	480	290	210	165	135	150		
36	6	7½–15	50	645	450	325	260	235	105	14.5	500
			100	460	280	195	150	130	210		
42	7	9–18	50	690	465	340	275	230	140	20	600
			100	490	290	200	155	125	280		
48	8	10–20	50	715	465	335	280	235	185	25.5	600
			100	510	290	200	160	130	370		

* Smaller figure is for sized material, larger for run-of-mine.
For other plies of belt, max. length and power proportional.
For other speeds, capacity and horse power proportional.

Adapted from catalog of Dodge Sales & Engineering Co.

H. P. Required for plain Cylindrical Dryers

Diam. Length	R. P. M.	H. P.	R. P. M.	H. P.
4½'x40'	4	10.5	5	13.5
5' x50'	3	14.5	4	19.1
6' x60'	2½	27.0	3	32.2

Belt and Bucket Elevators

Spacing = twice the projection of Bucket from Belt.

Bucket	Belt Plies	Max. Lift Feet	Head Pulley Diam. Inches	R. P. M.	Tons Per Hr.	Horse Power For Max. Lift
24x8	10	95	80	29	180	34
	8	80	64	32	160	25
	5	50	40	40	125	13
20x8	8	80	64	32	130	21
	6	60	48	37	110	13
	4	40	32	45	90	7
16x8	8	75	64	32	105	16
	6	60	48	37	90	11
	4	40	32	45	75	6
14x7	8	95	64	32	77	14
	6	75	48	37	65	10
	4	50	32	45	55	5.5
12x6	8	105	64	32	58	12.2
	6	80	48	37	49	7.8
	4	50	32	45	40	4.0
10x6	6	80	48	37	41	6.6
	4	55	32	45	34	3.8
8x5	6	90	48	37	27	4.9
	4	60	32	45	22	2.7
6x4	5	90	40	40	16	2.7
	3	45	24	52	12	1.2

The tonnage and horsepower in the above table are based upon the buckets being:

25% Full of Dry Material, 100 lbs. per cu.ft., or
50% Full of Dry Materials, 50 lbs. per cu. ft, or
40% Full of water and lesser amounts of pulp.

This provides liberal allowance for feed variations.

Speeds (R. P. M.) Give centrifugal discharge for the corresponding pulley diameters.

It is usual in mining practice to use greater number of plies of belt, to allow for wear.

Adapted from catalog of Dodge Sales & Engineering Co.

Strength of Timber

Table I

Unit Stress in Pounds per Square Inch.
(Americal Railway Engineering Association, 1909)

Kind of Timber	Bending			Shearing				Compression					
	Extreme Fiber Stress		Modulus of Elastcity	Parallel to the Grain		Longitudinal Shear in Beams		Perpendicular to the Grain		Parallel to the Grain		Working Stresses for Columns	
	Average Ultimate	Working Stress	Average	Average Ultimate	Working Stress	Average Ultimate	Working Stress	Elastic Limit	Working Stress	Average Ultimate	Working Stress	Length Under 15xd	Length Over 15xd †
Douglas Fir	6,100	1,200	1,510,000	690	170	270	110	630	310	3,600	1,200	900	1,200
Longleaf Pine	6,500	1,300	1,610,000	720	180	300	120	520	260	3,800	1,300	975	1,300
Shortleaf Pine	5,600	1,100	1,480,000	710	170	330	130	340	170	3,400	1,100	825	1,100
White Pine	4,400	900	1,130,000	400	100	180	70	290	150	3,000	1.000	750	1,000
Spruce	4,800	1,000	1,310,000	600	150	170	70	370	180	3,200	1,100	825	1,100
Norway Pine	4,200	800	1,190,000	*590	130	250	100	......	150	*2,600	800	600	800
Tamarack	4,600	900	1,220000	670	170	260	100	......	220	*3,200	1,000	750	1,000
Western Hemlock	5,800	1,100	1,480,000	630	160	*270	100	440	220	3,500	1,200	900	1,200
Redwood	5,000	900	8,000	300	80	......	......	400	150	3,300	900	675	900
Bald Cypress	4,800	900	1,150,000	500	120	......	......	340	170	3,900	1,100	825	1,100
Red Cedar	4,200	800	800,000	......	......	......	......	470	230	2,800	900	675	900
White Oak	5,700	1,100	1.150.000	840	210	270	110	920	450	3,500	1,300	975	1.300

† Multiply values in last column by $(1 - \frac{L}{60\ d})$.

Above stresses are intended for railroad use. For highway bridges and trestles increase 25%. For structures protected from weather and free from impact, increase 50%. For deflection under long continued loading use 50% of the corresponding modulus of elasticity. Above stresses are for green timber and are to be used without increasing the live load stress for impact. Values noted * are for partially air dry timber. Building laws of various cities specify maximum loads slightly at variance with above figures, both higher and lower. The above figures, however, may be safely followed. In the formula for columns, l = length of column in inches, d = least side or diameter in inches.

Table III

Unit working stresses in pounds per square inch, long columns.

White Pine or Tamarack, 1,000 $(1 - \frac{z}{d60})$ pounds per sq. inch.

Effective length col. in inches / Least side or dia. in inches	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Working Stress	750	733	717	700	683	667	650	633	617	600	583	567	550	533	517	500

White Pine or Tamarack was selected because the working stress for compression perpendicular to the grain is 1000 pounds. For other woods select the corresponding values from Table I above, and increase or decrease proportionally. For rectangular columns take the safe load unit stress for the square column whose side is equal to the least side of the rectangular section, and increase proportionally. For round column, take the safe load unit stress for the square column whose side is equal to the diameter of the round column and multiply by the decimal 0.78.

(Carnegie)

Strength of Timber

Table II

Safe load in pounds, uniformly distributed, for rectangular Spruce beams. Max. bending stress, 1000 pounds per sq. inch.

Size of Timber Inches	Max Bending Moment Ft. lbs.	Limit for Shear Short Lengths	Distance between supports, in feet									
			6	8	10	12	14	16	18	20	22	24
2x4	445	746	592	444	356	296	......	......	......	......	......	......
6	1,000	1,120	......	1.000	800	666	572	500	......	......	......	......
8	1,775	1,494	......	......	1,422	1,186	1016	888	790	712	......	......
10	2,795	1,866	......	......	......	1,852	1,588	1,388	1,234	1,112	1,010	926
12	4.000	2,240	......	......	......	......	......	2,000	1,778	1,600	1,454	1,334
3x6	1,500	1,680	......	1,500	1,200	999	858	750	......	......	......	......
8	2,670	2,241	......	......	2,133	1,779	1,524	1,332	1,185	1,068	......	......
10	4,190	2,799	......	......	......	2,778	2,382	2,082	1,851	1,668	1,515	1,389
12	6,000	3,360	......	......	......	......	......	3,000	2,667	2,400	2,181	2,001
14	8,190	3,921	......	......	......	......	......	......	3,630	3,267	2,970	2 721
16	10,660	4,479	......	......	......	......	......	......	......	4266	3,879	3,555
4x6	2,000	2,240	......	2,000	1,600	1.332	1,144	1,000	......	......	......	......
8	3,555	2,988	......	......	2,844	2,372	2,032	1,776	1,580	1,424	......	......
10	5,555	3,732	......	......	......	3,704	3,176	2,776	2,478	2,224	2,020	1,852
12	8,000	4,480	......	......	......	......	......	4.000	3,556	3,200	2,908	2,668
14	10,900	5,228	......	......	......	......	......	......	4,840	4,356	3.960	3,628
16	14,200	5,972	......	......	......	......	......	......	......	5,688	5,172	4,740
18	18,000	6,720	......	......	......	......	......	......	......	......	6,544	6,000
20	22,200	7,468	......	......	......	......	......	......	......	......	......	7,408
22	26,900	8,212	......	......	......	......	......	......	......	......	......	......
24	32,000	8.960	......	......	......	......	......	......	......	......	......	......

*These figures meet the New York building requirements for oak and of Boston for white pine, spruce and oak.

Spruce was selected to list in the above table because the working stress for bending (as per table I) is 1000 pounds. For other woods, select corresponding values from Table I above and increase or decrease proportionally. For other sizes select a timber from the table of same depth and increase or decrease proportionately with width of timber. For other lengths, allowable loads may be figured from "maximum bending moments" as listed above.

For concentrated load at center, safe load is half the above.

Table IV

Safe loads in pounds on square wooden columns.
White Pine or Tamarack

Length in Feet	Side of Square, Inches								
	4	6	8	10	12	14	16	17	20
	12,000	......	......	......	......	......	......	......	......
5	12,000	......	......	......	......	......	......	......	......
6	11,200	......	......	......					......
7	10,400	27.000	......	......					......
8	9,600	26,400	......	......					......
9	8,800	25,200	48.000	......					......
10	8,000	24.000	48,000	......					......
11	......	22,800	46,400	......					......
12	......	21,600	44,800	75,000					......
14	......	19,200	41,600	72,000	108,000	......	......	......	......
16	......	......	38,400	68,000	105,600	147,000	......	......	......
18	......	......	35,200	64.000	100,800	145,600	192.000	......	......
20	......	......	32 000	60 000	96.000	140.000	192,000	243.000	300 000

Working Strain=
(1)
1000(1- —)pounds
(d60)
per sq. inch.
Loads above horizontal lines are maximum allowable safe loads.

Principal Economic Minerals

MINERAL	SPEC. GRAV.	HARD-NESS	COMPOSITION FORMULA	COMPOSITION PER CENT
ANTIMONY				
STIBNITE	4.55	2	$Sb\,S_3$	Sb-71.4, S-28.6
COPPER				
ATACAMITE -Oxychloride	3.75	3-3.5	$CuCl_2\ 3Cu(OH)_2$	Cu-59.5, Cl-16.6, OH-23.9
AZURITE -Blue Carbonate	3.78	3.5-4.5	$2\,CuCO_3\ Cu(OH)_2$	Cu-55.3, O-13.9, CO_2-25.5, H_2O-5.2
BORNITE Variegated, Peacock-	5.15	3	$Cu_5\,Fe\,S_4$, or (or $Cu_3\,Fe\,S_3$)	Cu-63.3, Fe-11.1, S-25.6
BROCHANTITE -Basic Sulphate	3.9	3.5-4	$CuSO_4\ 3Cu(OH)_2$	Cu-66.2, SO_4-25.0 OH-8.8
CHALCOCITE Glance	5.65	2.5-3	$Cu_2\,S$	Cu-79.9, S-20.1
CHALCOPYRITE Copper Pyrites	4.2	3.5-4	$Cu\,Fe\,S_2$	Cu-34.6, Fe-30.4, S-35.0
CHRYSOCOLLA -Silicate	2.1	2-4	$Cu\,SiO_3\ 2H_2O$	Cu-36.1, SiO_2-34.3, O-9.1 H_2O-20.5
COVELLITE Indigo	4.6	1.5-2	$Cu\,S$	Cu-66.5, S-33.5
CUPRITE -Red Oxide, Ruby-	6.0	3.5-4	Cu_2O	Cu-88.8, O-11.2
ENARGITE -Sulph-Arsenate	4.45	3	$Cu_3\,As\,S_4$	Cu-48.4, As-19.0, S-32.6
MALACHITE -Green Carbonate	4.0	3.5-4	$CuCO_3\ Cu(OH)_2$	Cu-57.5, O-14.5 CO_2-19.9, H_2O-8.1
MELACONITE -Black Oxide	5.95	3	$Cu\,O$	Cu-79.9, O-20.1
TETRAHEDRITE Gray Copper	4.75	3-4.5	$4\,Cu_2S\ Sb\ S_3$ (As, Fe, Pb, Zn, Ag)	Cu-52.2, Sb-24.7, S-23.1
IRON				
HEMATITE SPECULAR IRON Iron Oxide	5.1	5.5-6.5	$Fe_2\,O_3$	Fe-69.9, O-30.1
LIMONITE Brown Hematite, Bog Ore	3.6-4.0	5-5.5	$2\,Fe_2O_3\ 3H_2O$	Fe-59.8, O-25.7, H_2O-14.5
MAGNETITE Magnetic Oxide	5.17	5.5-6.5	$Fe_3\,O_4$	Fe-72.4, O-27.6
ARSENOPYRITE Mispickel	6.05	5.5-6	$Fe\,As\,S$	Fe-43.7, As-31.2, S-25.1
MARCASITE White Pyrites	4.9	6-6.5	$Fe\,S_2$	Fe-46.55, S-53.45
PYRITE Pyrites	5.1			

Principal Economic Minerals

MINERAL	SPEC. GRAV.	HARDNESS	COMPOSITION FORMULA	COMPOSITION PER CENT
IRON - CONTD.				
PYRRHOTITE Magnetic Pyrites	4.65	3.5-4.5	$Fe_{11} S_{12}$	Fe-61.5, S-38.5
SIDERITE Spathic Iron	3.85	3-4.5	$FeCO_3$ (Mn, Ca, Mg)	
LEAD				
ANGLESITE -Sulphate	6.2	2.75-3	$PbSO_4$	Pb-68.3, S-10.6, O-21.1
CERRUSSITE -Carbonate	6.55	3-3.5	$PbCO_3$	Pb-77.5, O-6.0, CO_2-16.5
GALENA -Sulphide	7.45	2.5	PbS	Pb-86.6, S-13.4
MANGANESE				
PYROLUSITE -Dioxide	4.82	2-2.5	MnO_2	Mn-63.2, O-36.8
PSILOMELANE				
RHODONITE -Silicate	3.5		$MnSiO_2$	Mn-47.7, SiO_2-52.3
RHODOCHROSITE -Carbonate	3.5		$MnCO_3$	MnO-61.7, CO_2-38.3
MANGANITE	4.3		$Mn_2O_3 H_2O$	Mn-62.5, O-27.3, H_2O-10.2
MERCURY				
CINNABAR -Sulphide	8.1	2-2.5	HgS	Hg-86.2, S-13.8
MOLYBDENUM				
MOLYBDENITE -Sulphide	4.75	1-1.5	MoS_2	Mo-59.95, S-40.05
WULFENITE Lead Molybdate	6.85	3	$PbMoO_4$	Pb-56.4, Mo-26.2, O-17.4
SILVER				
ARGENTITE -Glance	7.3	2-2.5	Ag_2S	Ag-87.1, S-12.9
CERARGYRITE Horn Silver	5.55	1.5-2	$AgCl$	Ag-75.3, Cl-24.7
PROUSTITE Light Red - Ruby Silver	5.6	2.5	Ag_3AsS_3	Ag-65.4, As-15.2, S-19.4
PYRARGYRITE Ruby Silver	5.8	2-2.5	Ag_3SbS_3	Ag-59.9, Sb-22.3, S-17.8
STEPHANITE -Sulph-Antimonite	6.2	2-2.5	Ag_5SbS_4	Ag-68.5, Sb-15.3, S-16.3
SYLVANITE Telluride	8.1		$AuAgTe_2$	

Principal Economic Minerals

MINERAL	SPEC. GRAV	HARDNESS	COMPOSITION FORMULA	COMPOSITION PER CENT
TIN				
CASSITERITE Tinstone	6.95	6-7	SnO_2	Sn-78.8, O-21.2
TUNGSTEN				
WOLFRAMITE	7.35	5-5.5	$(Fe, Mn) WO_4$	(Fe, Mn)-30.9, W-51.3 O-17.8
HÜBNERITE	7.35	4 5	$Mn WO_4$	Mn-18.1, W-60.7, O-21.1
SCHEELITE	6.0	4.5-5	$Ca WO_4$	CaO-19.5, W-63.9 O-16.7
ZINC				
CALAMINE -Hydrous Silicate	3.45	4.5-5	$2 ZnO SiO_2 + H_2O$	Zn-54.2, SiO_2-38.3 H_2O-7.5
MARMATITE Iron Blende	3.9-4.2	5	$(Zn Fe)S$	Zn ± 42.7, Fe ± 36.4 S-20.9
SMITHSONITE -Carbonate	4.35	5	$Zn CO_3$	Zn-52.1, C-9.6 O-38.3
SPHALERITE Blende, Jack	4.0	3.5-4	$Zn S$	Zn-67.1, S-32.9
WILLEMITE -Silicate	4.0	5.5	$2 ZnO, SiO_2$	Zn-58.6, SiO_2-41.4
ZINCITE -Oxide	5.5	4-4.5	ZnO	Zn-80.3, O-19.7
GRAPHITE - Black Lead	2.15		C	
GANGUE				
ANHYDRITE -Anhydrous Sulphate	2.95	3-3.5	$Ca SO_4$	CaO-41.2, SO_3-58.8
BARITE Baryta, Heavy Spar	4.5	2.5-3.5	$Ba SO_4$	BaO-65.7, SO_3-34.3
CALCITE Spar, "Lime", Limestone	2.72	3	$Ca CO_3$	CaO-56.0, CO_2-44.0
DOLOMITE Magnesium Limestone	2.85	3.5-4	$Ca Mg(CO_3)_2$	CaO-30.42, MgO-21.9 CO_2-47.7
GYPSUM -Hydrous Sulphate	2.32	1.5-2	$Ca SO_4 2H_2O$	CaO-32.6, SO_3-46.5 H_2O-20.9
MAGNESITE - Carbonate	3.1	3-4.5	$Mg CO_3$	MgO-47.8, CO_2-52.2
QUARTZ Silica	2.65	7	SiO_2	Si-46.9, O-53.1
Various Common Gangue Silicates	2.5 to 3.5			

A list of Minerals, their Description and Specific Gravity

Mineral	Formula	Description	Spec. Grav.
Aluminum	Al		2.60
Andalusite	Al_2SiO_5	Silicate of aluminum	3.16—3.20
Anglesite	$PbSO_4$	Lead sulphate	6.12—6.39
Anthracite		Hard Coal	1.32—1.70
Antimony	Sb		6.71
Apatite	$3Ca_3P_2O_8,CaF_2$	Phosphate of lime	3.17—3.23
Aragonite	$CaCO_3$	Carbonate of lime	2.94
Argentite	Ag_2S	Silver sulphide	7.20—7.36
Arsenic	As		5.78
Arsenolite	As_2O_3	White arsenic	3.70—3.72
Asphaltum			1.0 —1.80
Atacamite	$CuCl_23Cu(OH)_2$	Chloride of copper	3.75
Azurite	$Cu_3(OH)_2(CO_3)_2$	Blue carbonate of copper	3.77—3.83
Barite	$BaSO_4$	Barium sulphate	4.3 —4.6
Bauxite	$Al_2O_32H_2O$	Hydrate oxide of aluminum	2.55
Beryl	$Be_3Al_2Si_6O_{18}$	Silicate of beryllium	2.63—2.80
Biotite		Magnesia-iron mica	2.70—3.10
Bismuth	Bi		9.80
Bismuthinite	Bi_2S_3	Sulphide of bismuth	6.4 —6.50
Bituminous Coal		Soft coal	1.14—1.40
Bornite	Cu_2FeS_3	Sulphide of copper and iron	4.90—5.40
Cadmium	Cd		8.60
Calamine	$H_2Zn_2SiO_5$	Silicate of zinc	3.40—3.50
Calcite	$CaCO_3$	Carbonate of lime	2.7
Cassiterite	SnO_2	Dioxide of tin	6.8 —7.10
Cerargyrite	AgCl	Horn Silver	5.55
Cerussite	$PbCO_3$	Carbonate of lead	6.46—6.57
Chalcocite	Cu_2S	Copper glance	5.5 —5.8
Chalcopyrite	$CuFeS_2$	Copper pyrite	4.1 —4.3
Chromite	$FeCr_2O_4$	Chromic iron	4.32—4.57
Chromium	Cr		6.50
Chrysolite	$(MgFe)_2SiO_4$	Silicate of magnesia and iron	3.27—3.37
Cinnabar	HgS	Sulphide of mercury	8.0 —8.2
Cobalt			8.6
Cobaltite	CoAsS	Sulph-arsenide of cobalt	6.0 —6.30
Copper	Cu		8.8 —8.90
Corundum	Al_2O_3	Oxide of aluminum	3.95—4.10
Cryolite	Na_3AlF_6	Fluoride of aluminum & sodium	3.0
Cuprite	Cu_2O	Red copper ore	5.85—6.15
Cyanite	Al_2SiO_5	Aluminum silicate	3.56—3.67
Diamond	C		3.50
Dolomite	$(CaMg)CO_3$	Carbonate of lime and magnesia	2.80—2.90
Enargite	$CuAsS_4$		4.45
Epidote	$HCa_2(AlFe)_3Si_3O_{13}$	Silicate of iron alumina and lime	3.25—3.5

Fluorite	CaF_2	Fluor spar	3.2
Franklinite		Oxide of zinc, manganese and iron	5.07—5.22
Galena	PbS	Sulphide of lead	7.43
Garnet			3.15—4.3
Gold	Au		15.6—19.3
Graphite	C		2.09—2.23
Gypsum	$CaSO_4+2H_2O$	Sulphate of lime	2.3
Hematite	Fe_2O_3	Red oxide of iron	4.90—5.3
Ice	H_2O		0.915
Iodyrite	AgI	Iodide of Silver	5.6—5.7
Iridium	Ir		22.42
Iron	Fe		7.85
Kaolinite	$2H_2OAl_2O_32SiO_2$	Silicate of alumina	2.6
Lead	Pb		11.37
Limonite	$2Fe_2O_33H_2O$	Brown oxide of iron	3.6—4.0
Magnesite	$MgCO_3$	Carbonate of magnesia	3.0—3.12
Magnetite	FeO,Fe_2O_3	Magnetic oxide of iron	5.16—5.18
Malachite	$Cu_2(OH)_2CO_3$	Green carbonate of copper	3.9—4.0
Manganese	Mn		7.39
Manganite	$Mn_2O_3H_2O$	Hydrate manganese oxide	4.2—4.4
Monazite			4.8—5.1
Marcasite	FeS_2	White iron pyrite	4.85—4.90
Mercury	Hg		13.6
Millerite	NiS	Nickel sulphide	5.3—5.6
Mimetite	$3Pb_3As_2O_8PbCl_2$	Lead arsenate	7.0—7.25
Muscovite	$H_2KAl_3(SiO_4)_3$	Potash mica	2.76—3.0
Naphtha			0.60—0.756
Niccolite	NiAs	Nickel arsenide	7.33—7.67
Nickel	Ni		8.9
Opal	SiO_2nH_2O		1.9—2.3
Orpiment	As_2S_3	Yellow sulphide of arsenic	3.4—3.5
Orthoclase	$KAlSi_3O_8$	Potash Feldspar	2.46—2.6
Ozocerite		Mineral wax	0.85—0.90
Palladium	Pd		11.3—11.8
Platinum	Pt		14.0—19.0
Proustite	Ag_3AsS_3	Light red silver ore	5.57—5.64
Pyrargyrite	Ag_3SbS_3	Dark red silver ore	5.57—5.86
Pyrite	FeS_2	Iron sulphide	4.95—5.10
Pyrolusite	MnO_2	Dioxide of manganese	4.82
Pyromorphite	$3Pb_3P_2O_8PbCl_2$	Lead phosphate	6.5—7.1
Pyrrhotite	$Fe_{11}S_{12}$	Magnetic pyrite	4.58—4.64
Quartz	SiO_2		2.65—2.66
Realgar	AsS	Red sulphide of arsenic	3.55
Rhodochrosite	$MnCO_3$	Carbonate of manganese	3.45—3.6
Rhodonite	$MnSiO_3$	Silicate of manganese	3.40—3.68
Rutile	TiO_2	Dioxide of titanium	4.2
Serpentine	$H_4Mg_3Si_2O_9$	Silicate of magnesia	2.50—2.65
Siderite	$FeCO_3$	Carbonate of iron	3.8—3.9

Silver	Ag		10.1—11.1
Smaltite	$CoAs_2$	Arsenide of cobalt	6.4 —6.6
Smithsonite	$ZnCO_3$	Carbonate of zinc	4.30—4.45
Sphalerite	ZnS	Sulphide of zinc	3.9 —4.0
Spinel	$MgAl_2O_4$	Aluminate of magnesia	3.5 —4.1
Stephanite	Ag_5S_4Sb	Brittle silver	6.2 —6.3
Stibnite	Sb_2S_3	Sulphide of antimony	4.5 —4.6
Sulphur	S		2.08
Sylvanite	$(Au,Ag)Te_2$	Telluride of gold and silver	7.9 —8.3
Talc	$H_2Mg_3Si_4O_{12}$	Silicate of magnesia	2.7 —2.8
Tephroite	Mn_2SiO_4	Silicate of Manganese	4.0 —4.1
Tetrahedrite	$4Cu_2S,Sb_2S_3$	Gray copper	4.4 —5.1
Tin	Sn		7.29
Topaz		Fluo-silicate of alumina	3.4 —3.6
Tourmaline		Silicate of alumina, iron and magnesia	2.98—3.20
Willemite	Zn_2SiO_4	Silicate of zinc	3.9 —4.18
Wolframite	$(Fe,Mn)WO_4$	Tungstate of iron and manganese	7.2 —7.5
Wulfenite	$PbMoO_4$	Molybdate of lead	6.7 —7.0
Zinc	Zn		7.15
Zincite	ZnO	Zinc oxide	5.43—5.7
Zircon	$ZrSiO_4$	Silicate of zerconium	4.70

Areas and Circumferences of Circles

Dia.	Area	Cir.	Dia.	Area	Cir.	Dia.	Area	Cir	Dia.	Area	Cir.
⅛	0.0123	.3926	10	78.54	31.41	30	706.86	94.25	65	3318.3	204.2
¼	0.0491	.7854	½	86.59	32.99	31	754.77	97.39	66	3421.2	207.3
⅜	0.1104	1.178	11	95.03	34.55	32	804.25	100.5	67	3525.7	210.5
½	0.1963	1.570	½	103.87	36.13	33	855.30	103.6	68	3631.7	213.6
⅝	0.3067	1.963	12	113.10	37.70	34	907.92	106.8	69	3739.3	216.8
¾	0.4417	2.356	½	122.72	39.27	35	962.11	109.9	70	3848.5	219.9
⅞	0.6013	2.748	13	132.73	40.84	36	1017.9	113.1	71	3959.2	223.1
1	0.7854	3.141	½	143.14	42.41	37	1075.2	116.2	72	4071.5	226.1
⅛	0.9940	3.534	14	153.94	43.98	38	1134.1	119.4	73	4185.4	229.3
¼	1.227	3.927	½	165.13	45.55	39	1194.6	122.5	74	4300.8	232.5
⅜	1.485	4.320	15	176.71	47.12	40	1256.6	125.7	75	4417.9	235.6
½	1.767	4.712	½	188.69	48.69	41	1320.3	128.8	76	4536.5	238.7
⅝	2.074	5.105	16	201.06	50.26	42	1385.4	131.9	77	4656.6	241.9
¾	2.405	5.498	½	213.82	51.83	43	1452.2	135.1	78	4778.4	245.0
⅞	2.761	5.890	17	226.98	53.41	44	1520.5	138.2	79	4901.7	248.2
2	3.141	6.283	½	240.53	54.98	45	1590.4	141.4	80	5026.5	251.3
¼	3.976	7.069	18	254.47	56.65	46	1661.9	144.5	81	5153.0	254.5
½	4.909	7.854	½	268.80	58.12	47	1734.9	147.7	82	5281.0	257.6
¾	5.940	8.639	19	283.53	59.69	48	1809.5	150.8	83	5410.6	260.7
3	7.069	9.425	½	298.65	61.26	49	1885.7	153.9	84	5541.8	263.9
¼	8.296	10.21	20	314.16	62.83	50	1963.5	157.1	85	5674.5	267.0
½	9.621	11.00	½	330.06	64.40	51	2042.8	160.2	86	5808.8	270.2
¾	11.045	11.78	21	346.36	65.97	52	2123.7	163.4	87	5944.7	273.3
4	12.566	12.57	½	363.05	67.54	53	2206.1	166.5	88	6082.1	276.5
½	15.904	14.14	22	380.13	69.11	54	2290.2	169.6	89	6221.1	279.6
5	19.635	15.71	½	397.61	70.69	55	2375.8	172.8	90	6361.7	282.7
½	23.758	17.28	23	415.48	72.26	56	2463.0	175.9	91	6503.8	285.9
6	28.274	18.85	½	433.74	73.83	57	2551.8	179.0	92	6647.6	289.0
½	33.183	20.42	24	452.39	75.40	58	2642.0	182.2	93	6792.9	292.2
7	38.485	21.99	½	471.44	76.97	59	2734.0	185.4	94	6939.8	295.3
½	44.179	23.56	25	490.87	78.54	60	2827.4	188.5	95	7088.2	298.4
8	50.265	25.13	26	530.93	81.68	61	2922.5	191.6	96	7238.2	301.6
¼	56.745	26.70	27	572.50	84.82	62	3019.1	194.8	97	7389.8	304.7
9	63.617	28.27	28	615.75	87.96	63	3117.2	197.9	98	7543.0	307.9
½	70.882	29.84	29	660.52	91.11	64	3217.0	201.1	99	7697.7	311.0

International Atomic Weights

From Smithsonian Table—1916

Element	Symbol	Atomic Weight	Valence
Aluminum	Al	27.1	3
Antimony	Sb	120.2	3, 5
Argon	A	38.88	0
Arsenic	As	74.96	3, 5
Barium	Ba	137.37	2
Bismuth	Bi	208.0	3, 5
Boron	B	11.0	3
Bromine	Br	79.92	1
Cadmium	Cd	112.40	2
Caesium	Cs	132.81	1
Calcium	Ca	40.07	2
Carbon	C	12.00	4
Cerium	Ce	140.25	3, 4
Chlorine	Cl	35.46	1
Chromium	Cr	52.0	2, 3, 5
Cobalt	Co	58.97	2, 3
Columbium [Niobium]	Cb	93.5	3, 5
Copper	Cu	63.57	1, 2
Dysprosium	Dy	162.5	3
Erbium	Er	167.7	3
Europium	Eu	152.0	3
Fluorine	F	19.0	1
Gadolinium	Gd	157.3	3
Gallium	Ga	69.9	3
Germanium	Ge	72.5	4
Glucinium	Gl	9.1	2
Gold	Au	197.2	1, 3
Helium	He	3.99	0
Holmium	Ho	163.50	3
Hydrogen	H	1.008	1
Indium	In	114.8	3
Iodine	I	126.92	1
Iridium	Ir	193.1	4
Iron	Fe	55.84	2, 3
Krypton	Kr	82.92	0
Lanthanum	La	139.0	3
Lead	Pb	207.10	2, 4
Lithium	Li	6.94	1
Lutecium	Lu	174.0	3
Magnesium	Mg	24.32	2
Manganese	Mn	54.93	2, 3, 7
Mercury	Hg	200.6	1, 2
Molybdenum	Mo	96.0	4, 6
Neodymium	Nd	144.3	3
Neon	Ne	20.2	0

International Atomic Weights—Cont

Element	Symbol	Atomic Weight	Valence
Nickel	Ni	58.68	2, 3
Niton	Nt	222.4	....
Nitrogen	N	14.01	3, 5
Osmium	Os	190.9	6, 8
Oxygen	O	16.0	2
Palladium	Pd	106.7	2, 4
Phosphorus	P	31.04	3, 5
Platinum	Pt	195.2	2, 5
Potassium	K	39.10	1
Praseodymium	Pr	140.6	3
Radium	Ra	226.4	2
Rhodium	Rh	102.9	3
Rubidium	Rb	85.45	1
Ruthenium	Ru	101.7	6, 8
Samarium	Sa	150.4	3
Scandium	Sc	44.1	3
Selenium	Se	79.2	2, 4, 6
Silicon	Si	28.3	4
Silver	Ag	107.88	1
Sodium	Na	23.00	1
Strontium	Sr	87.63	2
Sulphur	S	32.07	2, 4, 6
Tantalum	Ta	181.5	5
Tellurium	Te	127.5	2, 4, 6
Terbium	Tb	159.2	3
Thallium	Tl	204.0	1, 3
Thorium	Th	232.4	4
Thulium	Tm	168.5	3
Tin	Sn	119.0	2, 4
Titanium	Ti	48.1	4
Tungsten	W	184.0	6
Uranium	U	238.5	4, 6
Vanadium	V	51.0	3, 5
Xenon	Xe	130.2	0
Ytterbium	Yb	173.0	3
Yttrium	Yt	89.0	3
Zinc	Zn	65.37	2
Zirconium	Zr	90.6	4

Foreign Coins

VALUES IN UNITED STATES CURRENCY

(Authorized by the Secretary of the Treasury of the U. S., Oct. 1, 1920)

All money in gold unless marked: (s), silver standard, or (gs) gold and silver standard.

Country	Coin Standard Monetary Unit	Value U. S. Gold Dollars 1920
North America		
Canada	Dollar	$1.0000
Cuba	Peso	1.0000
Haiti	Gourde	0.2500
Santa Domingo	Dollar	1.0000
New Foundland	Dollar	1.0000
Mexico	Peso	0.4985
Central America		
Costa Rica	Colon	0.4653
Guatemala	Peso [s]	0.6864
Honduras	Peso [s]	0.6864
British Honduras	Dollar	1.0000
Nicaragua	Cordoba	1.0000
Salvador	Colon [s]	0.5000
Panama	Balboa	1.0000
South America		
Argentina	Peso	0.9648
Bolivia	Boliviano	0.3893
Brazil	Milreis	0.5462
Chile	Peso	0.3650
Columbia	Dollar	0.9733
Ecuador	Sucre	0.4867
Paraguay	Peso	0.9648
Peru	Libra	4.8665
Uruguay	Peso	1.0342
Venezuela	Bolivar	0.1930
Europe		
Austria	Krone	0.2026
Belgium	Franc [gs]	0.1930
*Czecho-Slovakia	*Crown	*0.203
Denmark	Krone	0.2680
Finland	Markka	0.1930
France	Franc [gs]	0.1930
Germany	Mark	0.2382
Great Britian (Including Br. Colonies in Aus. & Af.)	Pound Sterling	4.8665
Greece	Drachma [gs]	0.1930
Netherland [Holland]	Guilder [Florin]	0.4020
Italy	Lira [gs]	0.1930
*Jugo-Slavia	*Crown	*0.203
Norway	Krone	0.2680
*Poland	*Mark	*0.238
Portugal	Escudo	1.0805
Roumania	Leu	0.1930
Russia	Ruble	0.5146

* Values obtained from other sources than U. S. Treasury.

Foreign Coin--Cont.

Country	Coin Standard Monetary Unit	Value U. S. Gold Dollars 1920
Serbia	Dinar	0.1930
Spain	Peseta [gs]	0.1930
Sweden	Krona	0.2680
Switzerland	Franc	0.1930
Turkey	Piaster	0.0440
Africa		
Egypt	Pound	4.9431
Liberia	Dollar	1.0000
British Colonies	Pound Sterling	4.8665
Asia		
India	Rupee	0.3244
Indo-China	Piaster [s]	0.7413
Japan	Yen	0.4985
Persia	Achrefi [g]	0.0959
	Kran [s]	0.1264
Phillipines	Peso	0.50000
Siam	Tical	0.3709
Straits Settlements	Dollar	0.5678
	Tael [s]	1.0278
China	Tael [s]	to 1.1449
	Dollar [s]	0.7374
	Dollar [s]	to 0.7455

(Note—Chinese money varies in value between various ports)

Graphite Flotation Plant

Carbon Mountain Graphite Company, Lineville, Ala.

Designed and built by the General Engineering Company

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