40 per cent gelatine dynamite. From the loading chutes the ore is drawn into 16-cu.ft. end-dump cars, which are hauled in trains to the shaft stations by storage-battery locomotives, subsequently to be hoisted to the surface in three-deck cages. Ventilation is mechanical, there being available in the mine a 100,000-c.f.m. electric-driven blower. In the older drifts a guniting campaign is now in progress as a dust-control measure and to prevent air slacking. The company also maintains a small diamond-drill unit, and during 1939 a total of 7,000 ft. of holes was drilled.

As insufficient time has elapsed to gather representative metallurgical operating data, and description of the mill work consequently must be confined largely to the flowsheet evolved after long test work. The lead-zinc-copper ore, with appreciable amounts of gold and silver, is mined at the rate of 3,000 tons per month. Mill capacity is about 125 tons per day. The heads assay 5 per cent lead, 15 per cent zinc, 1 per cent copper, 4 oz. silver, and 0.03 oz. gold. Ore stored in the 75-ton hopper-bottomed steel bin near the mine shaft is transported to the concentrator in large side-dump cars, and reduced to ¾ in. by a Telsmith jaw crusher. Grinding to about 95 per cent minus-200-mesh is done in two ball mills actuated by a single electric motor through two Hill friction clutches and operated in closed circuit with drag classifiers. Flotation treatment is indicated in the accompanying flowsheet. Classifier overflow at 30 per cent solids is treated in a six-cell primary flotation machine, the bulk concentrates produced by Cell 1 going to a 12x8-ft. thickener to be thickened to from 50 to 60 per cent prior to entering the regrind circuit comprising a tube mill and a drag classifier, and the tails flowing by gravity to an 8x8-ft. conditioner. The regrind classifier product (10 to 15 per cent solids and 90 to 95 per cent 325 mesh) goes to the lead circuit, entering Cell 3 of the eight-cell flotation unit available for this work, with the tails directed to Cell 2 of the primary machine.

The final lead-copper concentrates from the lead circuit successively receive treatment in a thickener and a disk-type filter before being delivered to the storage bin at the foot of the mill. Conditioned pulp goes to a six-cell zinc unit, Cell 2 receiving the flow. Final zinc concentrates are thickened in a thickener similar in design and size to that handling the final lead-copper product, the underflow being further dewatered in a disk-type filter before going to the storage bin. Tailings from the zinc flotation machine flow by gravity via a wooden flume to the dump a short distance below the concentrator. Flotation, conditioning, and thickener equipment are of Denver Equipment make. The lead concentrates are shipped by rail to El Paso, Tex., and the zinc concentrates to Amarillo, also in Texas.

Reagents are added at the following points: At the head of the ball-mill intake, classifier overflow, before and after conditioner, Cell 2 of the zinc machine, regrind mill feed, regrind classifier overflow, and to Cells 1 and 6 of the lead flotation unit. Types of reagents used are $Na_2SO_3$; $ZnSO_4$; NaCN; $Na_2CO_3$; CaO; Aerofloat 31-241-208-226; $CuSO_4$; Z-4 and Z-6; Pentasol No. 26; B-23.

New structures completed recently at the mine include a well-equipped machine shop, an engineering office and a warehouse, and removal of compressor equipment from the hoist house to a separate compressor building is now in progress. An electrical repair shop, a blacksmith and drill sharpening shop, a change house, a laboratory and assay office, and carpenter and timber-framing shops complete the surface plant. The general office is at Lowell. J. A. Wilcox is general superintendent, to whom thanks are due for the many courtesies shown me during my recent visit to the property and for the information contained in the aforegoing, and Howard Hendricks directs operations at the concentrator.

# Jig Versus Riffle Concentration in Gold Dredging

*Attention is directed to the comparative ratios of concentration at the various stages*


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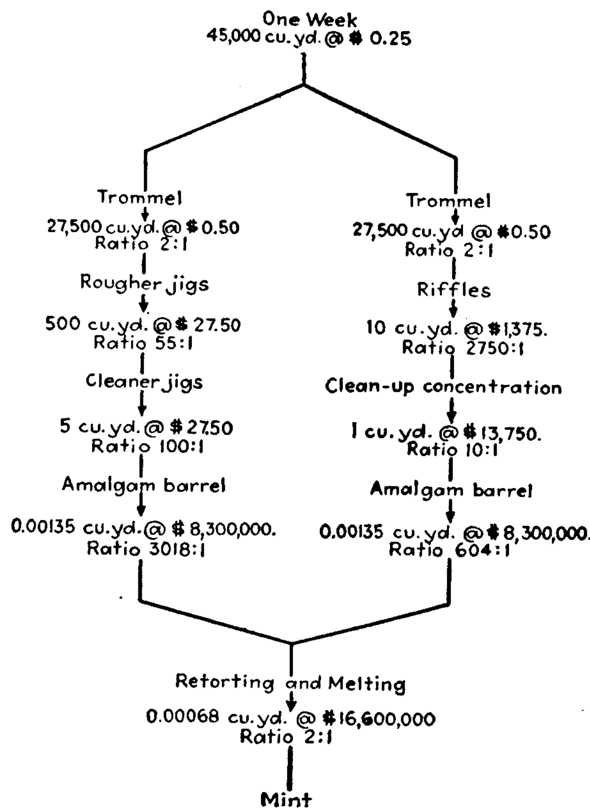
THE ADVENT OF JIGS in the past few years as an advancement over the use of riffles when applied to the recovery of gold in placer mining has resulted in the appearance of many articles concerning their application and efficiency. Many worthwhile points have been presented, but there seems one advantage possessed by jigs over riffles which has not been emphasized sufficiently to enable a more direct comparison to be made between them. Individual dredging properties vary considerably in respect to the distribution of values, character of ground, methods of saving gold, and other factors which influence the extraction of gold values from their original position to one whereby the United States Mint will buy a troy ounce for $35.

The discussion following is based on a hypothetical dredge and should not be applied to any particular property, but it might prove interesting to those who have not realized the enormous task presented to a dredge. It must not only move thousands of cubic yards but extract from each cubic yard, quickly and efficiently, enough values to present a profit to its owner.

Simply stated, a lode or placer mining enterprise has to concentrate the gold in its property to a form which is salable. The methods vary, but the result is the same. In lode milling practice the term "ratio of concentration" is more common; however, the term should and can be equally well applied to dredging. In placer mining it is customary to mention the volume of material treated rather than the weight. It will be assumed here that the gold has a fineness of 1,000. One cubic yard of gold therefore will be worth about $16,600,000 (See Lindgren "Mineral Deposits," p. 17, 1933). Again assuming that a property has an average value per cubic yard of 25c., the dredge will have to treat 66,400,000 cu.yd. to obtain the cubic yard of gold worth roughly $16,600,000, and weighing more than 16¼ tons. In other words, a ratio of concentration by volume of 66,400,000: 1 must be accomplished to obtain the finished product whether jigs, riffles, or any other device is used. The losses can be assumed to occur where high concentration ratios are effected. As the values per cubic yard vary above or below 25c., the assumed value, the ratio of concentration is directly affected. For instance, a value of 10c. per cubic yard would give a ratio of 166,000,000: 1.

The values are usually concentrated near bedrock and the upper portions barren, yet the fact that all yardage is treated necessitates the assumption that each cubic yard contains the same value, and all values 100 per cent recovered. To compare concentration ratios it will be assumed that the gold dredge referred to here has 8-cu.ft. buckets and treats 45,000 cu.yd. a week. Also, before the installation of jigs, which were Pan-American placer jigs as roughers and pulsator jigs as cleaners, the dredge had 4,000 sq.ft. of gold tables equipped with Hungarian riffles.

**A comparison of the volumes of material and ratios of concentration at various points in the flowsheet for one week's operation of an hypothetical dredge equipped respectively with jigs and with riffles**




The volumes and ratios shown in the accompanying diagram only approximate what is to be expected in the average property in one week's operation. Inasmuch as the property has gravel with 50 per cent screen undersize, it is seen in the first stage that a two-to-one ratio is given for both methods of recovery. As the percentage of undersize varies, the concentration ratios in the first and fourth stages obviously are affected, but the final ratio remains the same. As the screen undersize decreases, the less the burden is on either flowsheet.

In the second phase, and one of the most important, there is shown the largest diverse comparison. Here, riffles and jigs treat the same amount of material, but where riffles concentrate by weight, the jigs not only do this but classify the material further as to size, which being relatively free of slime, allows for ease of treatment in later stages. In actual practice the riffles retain many gold values in an exposed condition that allows sudden surges of sand or water to rob them of gold, whereas the jigs, once the gold is caught, allow no loss by these methods. In this stage, riffles are attempting to save the heavier constituents of the material washed, such as gold, black sand, and others, but actual dredging practice with its surges of feed does not allow perfect segregation, and consequently the riffles show a smaller percentage of black sand than that obtained from jigs. If black sand is used as an index to determine the efficiency of either device, jigs far surpass riffles.

Although the third phase still shows a large difference in the ratios of concentration, it should be noticed that the result is only five times as great in jigs as in riffles. Add to this the fact that the 5 cu.yd. obtained from jigs is all black sand and gold, whereas in riffles many of the lighter constituents are also present. Not shown in the diagram, but important, is the fact that with jigs this is a continuous treatment throughout the week, whereas with riffles the dredge must be stopped, and oftentimes too much stress is laid on speed, which at this stage makes the proverb that "haste is waste" a true one.

In the last stage, which shows a difference in ratios between jigs and riffles, the jig flowsheet still has the higher concentration ratio, but it is logical to put the highest concentration in a unit that with present-day practices allows minimum losses. The reduction of amalgam to a gold bar needs no comment here, inasmuch as a 2: 1 ratio is assumed for both concentrating devices. It is shown in the diagram that with riffles the highest ratio comes in an early stage, and under conditions difficult to control; with jigs it comes later on a smaller volume and this smaller volume allows controlled treatment as a batch amalgam barrel or a similar machine.

The preceding remarks have made apparent that the advantages lie with jigs, inasmuch as they reduce the material by stages in a manner that an intelligent operator can adjust without remodeling the dredge. The fact that jigs concentrate the values in a manner that allows the operation involving the highest ratio of concentration to be performed on a relatively small volume of material and under conditions that can be closely controlled has been one of the greatest aids to gold recovery as applied to dredging. It is interesting to note that, if a lode property had ore averaging a recoverable of $15 per ton and a specific gravity of 2.7, it would have a ratio of concentration by volume of about 485,000: 1 compared with the gold dredge ratio of 66,400,000: 1. If weight ratios are compared, then this lode property would have a ratio of 58,000: 1 against the dredge of 66,100,000: 1. (See "Marks Handbook" p. 469, 1924, for weight of 1 cu.ft. of gravel, sand, wet.)

Many factors prohibit a mill flowsheet from being applied to a gold dredge and many methods are available to a mill operator whereby he can obtain his objective economically, yet his problem appears small when compared with that of the placer miner. If placer miners will take the effort to apply the preceding principle to their particular problem, they will be able to use their results as a basis for improvement.

size of the voids determines the effectiveness of sifting. A coarse bed (e.g. $\frac{1}{4}$-in. shot) recovers a coarse concentrate and has a larger capacity but will not exclude sand efficiently. A fine bed (e.g. $\frac{3}{32}$-in. shot) recovers small grains effectively and produces a cleaner concentrate. The choice involves a knowledge of the size distribution of the ore minerals.

*Costs*—The cost of single-cell mechanical jigs varies from $300 for an 8x12-in. unit to $645 for a 42x42-in. unit. The hydraulic type costs somewhat less, $250 for a 12x12-in. unit, $350 for a 24x24-in. unit. The cost of motor, switches, shot, valves, pipe, and freight, and the probable need for installation of amalgamation equipment, will usually bring the total cost to over $2,000 for installing a jig in a 100-ton mill. More elaborate installations such as jig and shaking table, or jig, unit cell and shaking table, will cost from $2,000 to $3,000. Thirty dollars per ton of installed daily capacity should be a safe estimate for jig equipment cost at all but small mines.

Labor is the chief cost in jig operation, unless the hutch product is in a continuous closed circuit with some other process. The concentrate usually is amalgamated in batches every day or every two days. This may require the employment of another man in the mill, or will require at least one-half shift each day from the time of one of the operators. The operation of the jig itself requires very little time, probably no more than ten minutes each shift. If some continuous automatic process of recovering the values in the concentrate is used, jigging costs are greatly reduced.

*Available Types*—If testing shows that jigs will return a profit, and mill conditions are favorable for jig installation, the remaining problem is to select a jig suited to the ore and the mill. Table I showing the distribution of the various makes found in California is printed in Part I, page 42, of the *E.&M.J.* for April. There are two important types, the mechanical and hydraulic. The larger mechanical jigs are dependable and require only a moderate amount of water. The smaller, high-speed mechanical jigs require less water and yield a high grade concentrate, but require careful adjustment to secure optimum operating results. The hydraulic type requires a large amount of water at a steady head, but can treat a larger volume of ore successfully when operated at a high speed. Usually mill conditions will indicate which type would be preferable.

*Acknowledgments*—D. N. Vedensky and P. Malozemoff, of the Pan-American Engineering Corporation, provided ideas and criticisms which have been used freely. Other manufacturers and operators offered information embodied in the text. The laboratory work was performed under the supervision of Professor O. C. Shepard, of Stanford University. His helpful suggestions and continued interest were invaluable.

# Chromate Salts From Domestic Ores

*An objective, as yet unattained, of some recent research work under way in the Pacific Northwest*

THE United States Bureau of Mines is cooperating with the State College of Washington in the State Metallurgical Research Laboratory to make studies and investigations looking to the establishment of new metallurgical industries in the Northwestern States and thus provide a useful outlet for the power generated at Bonneville and Grand Coulee. An account of this work is given in Bulletin V, by H. A. Doerner and others, recently issued by the Bureau and the State College jointly. The tentative results are presented here in condensed form.

Utilization of domestic chromite ores is now of considerable interest to the Bureau. There are deposits of possible commercial value in Montana, California, Oregon, Washington, and Alaska. Development of the California and Oregon deposits has been active in recent years.[1] Use of chromite for making chromates, dichromates, and other chemicals represents only about 10 per cent of the domestic and 25 per cent of world consumption.[1] Present production of chrome chemicals is derived from imported ores. Inasmuch as many ores are not considered suitable for making chromates, there has been doubt regarding the domestic ores for that purpose. This investigation was made to study methods by which chromates and dichromates can be produced from domestic ores and to estimate the economic possibilities of the methods studied. Chromates are produced by only a few companies and details of the methods are not revealed. This investigation was made possible by cooperation between Washington State Electrometallurgical Laboratories and the United States Chrome Mines, Inc.

*Preliminary Investigations*—A report of preliminary investigations of the roasting reactions used to produce chromates was published by the Bureau in 1930,[2] but the work was discontinued because other problems were more urgent. Now out of print, it is summarized in the new bulletin. The most unexpected and interesting results were those obtained with mixtures of chromite, lime, and magnesia. High conversion without the addition of alkali salts such as had not previously been reported was obtained.

The mechanics of calcining is the chief problem in the production of chromates. If a stoichiometric mixture of pulverized ore and soda ash is heated to reaction temperature, the soda ash and its reaction products fuse and the material behaves like wet snow. If rabbled, it packs into a mass having slight porosity. The reaction ceases for lack of oxygen. Large excess of lime will give enough porosity so that frequent rabbling will permit adequate absorption of oxygen.

Small-scale tests do not furnish enough information for judging the feasibility of rabbling a specified charge in a modern hearth furnace. No direct information on current practice was discovered. The patent literature indicates that many efforts have been made to overcome the difficulties experienced when the usual mixtures of ore, soda ash, and lime are rabbled.

As might be expected, the ore-lime-magnesia mixture is much less fusible. The calcine produced usually was bright yellow, in marked contrast to the green color with lime or the brown with only magnesia. The color and the marked improvement in conversion indicate the formation of a double salt.

The extraction and recovery of a chromate salt from the lime-magnesia calcine present difficulties. Calcium chromate is only slightly soluble in water, and the strongest solutions obtained by a water leach contained only 2 per cent $CrO_3$. Dissolution was improved by saturating the pulp with $CO_2$ to convert the lime to a carbonate. This fact and also references in the

[1] Ridgway, Robert H.: "Chromite," U. S. Bureau of Mines Minerals Yearbook 1938, p. 541.

[2] Doerner, H. A.: "Roasting of Chromite Ores to Produce Chromates." Bureau of Mines R. I. 2999, 1930, 29 pp.