Jigging Applied to Gold Dredging

Some of the Problems Involved

P. Malozemoff
Metallurgical Engineer
Pan-American Engineering Corporation, 820 Parker St., Berkeley, Calif.

JIGGING is one of the oldest processes used in separating heavy minerals from lighter gangue. At the turn of this century it was widely used for concentrating base-metal ores and for washing coal. More recently it has been applied for treating placer gravels in recovering tin, tungsten, and gem stones. Its application for recovery of placer gold is of even more recent origin. One of the earliest large scale jig tests on a gold dredge was made by J. W. Neill in 1914 on the Yosemite dredge in California.[1] Subsequently, tests were made by the Natomas company. This company used Neill jigs in fore-and-aft sluices to save some of the gold lost in tailings.

However, these were isolated examples for twenty years, until, in 1932, the Bulolo Gold Dredging Company made some tests, resulting in the equipping of one of its dredges in New Guinea with Bendelari jigs. This proved the practicability of treating the entire output of the dredge (screen undersize) with jigs, and the company took steps to use this type of equipment extensively on its boats. Its engineers designed a new jig, now known as the Pan-American placer jig, and several dredges in New Guinea and Colombia were equipped wtih jigs of this type. These installations being successful, interest in jigging on dredges rose again in the United States, and in 1936-37 installations were made by Yuba Consolidated Goldfields in California, and by Fisher and Baumhoff in Idaho. Several other companies are said to have installed jigs on their dredges recently.

Efforts to improve gold recovery were not lacking in the past. Improvements in the design of riffles and their adjustment were made. Riffles, however, obviously have metallurgical limitations, especially under conditions imposed by dredge practice. Jigging, on the other hand, is free from some of these limitations, and, if properly employed, is capable of meeting even the more exacting dredge conditions successfully. The main purpose of this article is to define in general terms the problems involved in operating jigs on dredges.

Gold lost by riffles is predominantly fine, although sometimes it might be comparatively coarse if flat and hard to amalgamate. Presence of "rusty" gold in the ground usually is indicative that appreciable losses are taking place. Placer operators generally hold that gold which does not amalgamate or amalgamates with difficulty is hard to save by riffles.

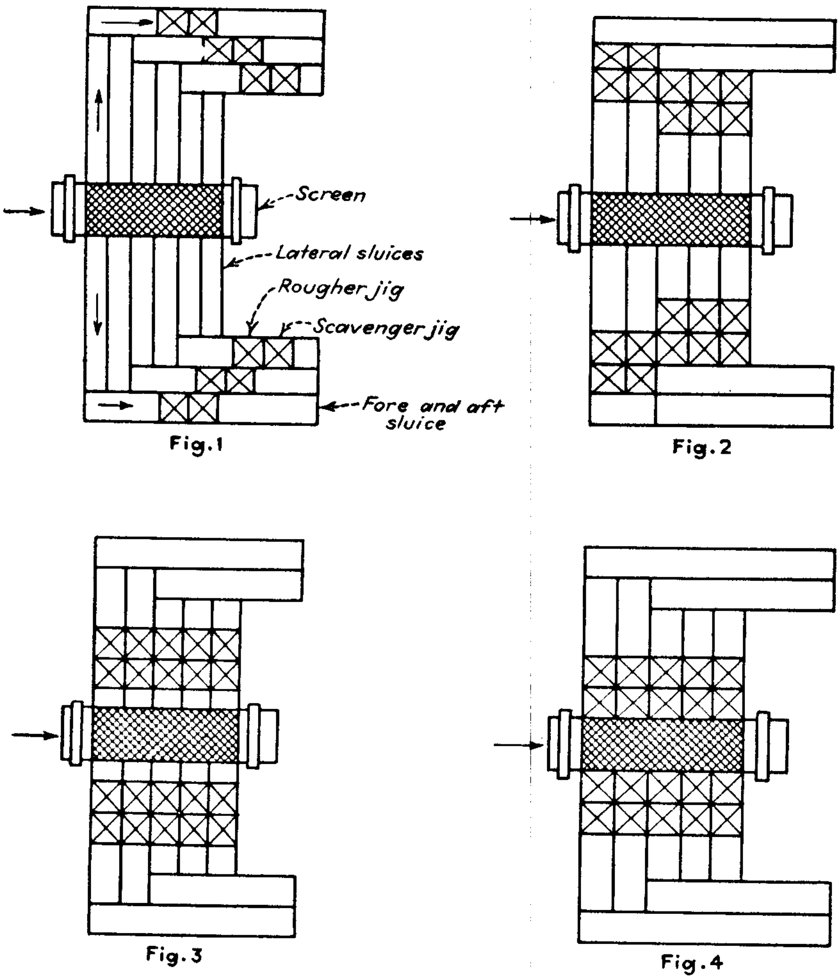
The riffle, as a gold-saving device, has limitations. The gold must settle and be entrapped by it in a current of water swift enough to transport the material, coarse and fine, across the riffles; and the less the velocity, the greater the tendency of gold to settle and be saved. At the same time, the less the carrying power of the water, the lower the yardage capacity of a given area of riffles. Space on a dredge is limited, and only a certain amount is available for riffles. To increase output, yardage is often boosted beyond the optimum capacity of the available sluices, and the amount of water and the slope of the riffles are regulated to induce sufficient velocity of water to transport all the material. Gold recovery will obviously be retarded under such conditions. Still other factors, such as packing of the riffles, especially with heavy black sand, and sudden surges in feed which tend to dislodge and wash out the gold already trapped, are inimical to optimum recovery and cannot always be fully corrected.

The action of the jig disposes of several things that cause loss of gold in the riffles. The jig operates continuously and its bed can be adjusted to permit settling, with consequent trapping of the gold. Once trapped by the jig there is no more danger of losing the gold. Presence of large amounts of black sand, which occasions severe packing of the riffles, will not cause loss of gold when the material is treated by jigs. Furthermore, dilution of the feed to the jigs need not be so great as with riffles, because the transporting of the material is aided by the alternate pulsations, whereas the carrying power of water is the sole transporting agent in the use of riffles. For this reason the conditions on top of the jig bed can be made far more quiescent than with riffles, thus affording a better opportunity for the gold to settle. Naturally, the jig has its limitations also. It is a gravity machine and will recover only that gold which will settle by gravity under the conditions that obtain on the jig bed. Some of the finest gold will be lost too, but at present this loss is generally less than can be saved economically by known methods.

For example, flotation can probably be applied in some form or other to recover fine gold lost even by jigs, but the cost of doing so will come close to, or will exceed, the value of the amount recovered. In 1933, an installation of six standard flotation machines, which treated 300 tons per day, was made on a dredge operating on the American River in California.[2] Three months' operation showed that their recovery of gold from the sand

[1] Neill, J. W.: "Application of Jigs to Gold Dredging." *M.&S.P.*, Vol. 109, p. 839.

[2] A test made by Pan-American Engineering Corporation, Ltd.



FOUR METHODS of applying jigs on gold dredges: Fig. 1, Jigs installed in fore-and-aft sluices. Fig. 2, Jigs installed at end of lateral sluices. Fig. 3, Jigs installed in lateral sluices, preceded by short sections of sluice. Fig. 4, Jigs installed in lateral sluices, next to the screen

wheel overflow, supposed to contain most of the finest gold in the tailings, was only 2 to 5c. per ton on heads of 3.5 to 9c. per ton, based on $35 gold.

One must remember that all placer deposits were formed as a result of the material settling by gravity. In most of those currently exploited, the finest gold had already been eliminated by natural agencies during deposition, except in rare occurrences where the conditions were such that even the finest material settled. For this reason there will be little gold that cannot be recovered by gravity, provided the method of recovery is sufficiently refined to reproduce the settling conditions that obtained during the formation of the deposit when material settled by gravity under natural agencies.

Use of jigs for treatment of placer gravels presents problems, some of which are quite different from those encountered when using them in concentrating base-metal ores. In the latter operation the ratio of the specific gravities of the valuable mineral to that of the gangue is relatively low. For this reason, and in order that the jigs may make proper recoveries, it has been general practice to classify the feed as to size rather closely and to provide a jigging surface that is much longer than wide. With placer gravels, however, the ratio of specific gravities of the gold to that of the sand and gravel to be discarded is much higher than for base-metal ores. Close classification of the feed, though desirable, is not so essential, nor does the ratio of length to width of jigging surface need be so great. Accordingly, the load per square foot of jigging surface can be increased materially without appreciably affecting results. This is fortunate, for otherwise jigging as practiced in metal-mining industries could hardly have been applied on gold placer dredges. Close classification of the screen undersize on the dredge would not be practicable, and floor space is always at a premium, so that the gold-saving machinery used must have a large capacity per unit of floor space.

When attention turned to jigs many different machines used in washing coal and in concentrating base-metal ores were available, but none were designed to conform to the peculiar conditions imposed by the gold dredge. In general, the jigs were heavy and cumbersome, occupying much more space than required by the effective jigging area. One of the first jigs tried out on a dredge, the Neill jig, conformed to the demand for economy of floor space, and the total room occupied was limited to the screen area of the jigging surface.

The first modern jig applied to gold placer dredges was the Bendelari jig, which actuated the water through the screen and bed from below by means of a plunger sealed with a rubber diaphragm. This permitted the floor space to be defined by the screen area of the jig. Somewhat later a new jig was designed by the Placer Development Company engineers and used with success by Bulolo in New Guinea. In this jig, now known as the Pan-American placer jig, a part of the hutch in the form of an inverted cone is moved by an adjustable eccentric to transmit the pulsations through the bed. Free discharge of concentrates and uniform distribution of pulsation throughout the area are thus assured. Weight was reduced to a minimum to meet the requirement of the dredges, especially those of moderate size, for least weight of gold-saving equipment.

In principle, the modern jigs differ but little from the old type of machines, such as the Harz jig. To secure activation of the bed, the water pulsation is transmitted mechanically by an eccentric. In the Harz jig this was done by a plunger working in a separate water compartment outside the hutch, whereas in the placer jig this is done by a movable cone-shaped hutch, and in the Bendelari by a diaphragm inside the hutch.

Jigs for gold placer operations are designed to produce the concentrate continuously as a hutch product. A certain amount of shot bedding is used to reduce the quantity of concentrate obtained. It is important to have delicate control over the suction so as to be able to secure maximum recoveries with the maximum ratio of concentration. This requirement was furnished by a hutch water connection closely controlled by a plug cock. A screen area of 42x42 in. has become standard for the jigs used on dredges.

Testing of Dredge Tailing Losses—Whenever a jig installation is planned it should be preceded by suitable testing which can definitely prove that the jigs are capable of effecting a recovery in addition to that obtained by the riffles. The existence of dredge tailing loss may be qualitatively detected with relative ease, yet to arrive at a definite, reliable figure in cents per yard is a very difficult task. This is apparent when the factors that complicate such a determination are considered.

The values recoverable by jigging usually are low, in most cases less than 5c. per yard. The gold is free and not uniformly distributed, so that even if a sample of several tons were taken it would hardly be representative of the dredge operation as it is conducted from day to day. A quantitative determination of the sluice tailing losses, however, can be made accurately by determining the gold content of a small, continuous cut of the total flow of the tailings, as, for example, continuous jigging of the total flow of one tailing sluice, or of a stream representing a small part of the total dredge tailing flow. Numerous methods can be applied for this purpose. Suffice it here to say that a reliable determination of the dredge tailing losses is possible, and should be made for the border-line cases in which the existing loss is not sufficient to justify the use of jigs.

Large-scale Testing Necessary

Besides determining the amount of gold to be saved by jigs, testing may at times be required for other purposes. For example, a special method of treating the rougher concentrates may be necessary, particularly when the ground contains a large amount of heavy mineral constituents such as black sand and pyrite, or, again, when part of the gold is included within the heavy mineral constituents. Under such conditions large-scale testing may be necessary to devise a suitable method of treating these concentrates for the final recovery of gold.

Factors Affecting Jig Installation and Jig Recovery—The number of jigs necessary, the manner in which they are installed, and the method of treating the rougher concentrates will depend on a large number of local conditions which vary from one operation to another. A few of the more important ones are: Total yardage dug; proportion of screen undersize to oversize; ease with which the ground is disintegrated and washed (which in turn may determine the dilution of the feed to the jigs); the nature of the feed; and the nature of the gold—that is, whether coarse or fine, flat or granular.

Although the mechanical capacity of a 42x42-in. jig has been established at about 30 cu.yd. per hour, the effect of some of the preceding factors may necessitate a radical revision of this figure. A reduction is necessary for sandy ground, when excessive dilution obtains, or when fine, flat gold is present. At times it may be possible to rate the capacity of the jigs to fit the conditions that obtain when the dredge is digging pay gravel even though they will be overloaded when top ground, containing a larger proportion of sand than does the pay gravel, is dug. As long as this material contains little or no gold no harm will be done.

Jig Adjustment Important

Excessive dilution of the screen undersize usually means excessive top water velocity over the jig bed, with consequent loss of fine gold. When this excessive dilution cannot be reduced because a large amount of water is required to disintegrate and wash the material properly in the revolving screen, the jigs should be rated at a lower capacity and some means of controlling the velocity of the top water across them should be provided. Boiling boxes or retarding baffles are the conventional remedy. Another method is to dewater the entire jig feed or some part of it. Although this may not always be possible, it is nevertheless desirable. Dewatering elevators, dewatering tanks, or sumps may seem a complex innovation on a dredge, but they can certainly be justified when jig recovery can be appreciably increased by their use.

After the jigs are properly installed, there yet remains the problem of their adjustment. At times this is a complex matter. The material passing through the screen from hour to hour varies considerably, both as to character and quantity. Inasmuch as the amount of water added to the screen usually remains constant with the variation as to quantity and dilution, the distribution of the load fore and aft will change constantly. The only effective remedy for aggravated cases of this kind is the installation of a central distributing system consisting of a central, preferably mechanical, distributor to which the entire product from the screen is delivered and then evenly distributed among the several jigs on the dredge.

Jigging Practice—This comprises several different operations. The first is the roughing treatment by one row of jigs on each side of the screen. This is usually followed by a second treatment over the scavenger jigs. These are necessary to assure a more complete recovery of the fine gold. Only under special conditions will it be possible to limit the operation to a single treatment by one row of jigs, such as, for example, in which only a small proportion of the total gold in the ground is fine. However, when the gold to be recovered is predominantly fine, the number of jigs installed has to be increased so that each is required to treat much less than its normal rated capacity. In addition to the roughing and scavenging some method of treating the concentrates obtained from both operations must be provided.

Generally, the feed to the jigs, depending on the size of the dredge, will be from 100 to 400 cu.yd. per hour. The ratio of concentration that can be achieved by rougher and scavenger jigs on the average will be 100:1. This means that from 1 to 4 cu.yd. of concentrate per hour must be treated for recovery of gold. Obviously, this cannot be done by batch treatment, but must be done continuously.

Two methods have been developed for this treatment: (1) Concentrates may be treated directly for recovery of gold by grinding in ball mills in mercury and then passing the product over amalgamation plates. Grinding need not be intensive, as the polishing of gold and its ready amalgamation is the sole purpose. (2) A simpler method is to pass the rougher concentrates over suitable cleaner jigs to reduce the amount of the final concentrate to be treated for gold recovery. Recently a hydraulic jig, known as the Pan-American pulsator jig, has been used successfully for this work. It makes possible the production of a cleaner concentrate that bears a ratio of 1:30 to 1:100 to the primary concentrates. The final concentrate is thus reduced to a small bulk that can be amalgamated in batches in an amalgamating barrel, and the product either rejigged or steamed down for recovery of mercury and amalgam. With this method, gold loss in the intermediate products discarded is negligible.

Advantage of Rejigging

With different combinations of the two methods a large number of variants can be used. For instance, the primary concentrate may be rejigged first, then the resulting cleaner concentrate subjected to continuous or intermittent grinding in mercury, and finally passed over a trap and an amalgamation plate for the recovery of mercury and amalgam. The obvious advantage of such a procedure over direct grinding and amalgamation of the primary concentrates is that the size of the grinding installation can be only 1/30 to 1/100 of that necessary for direct treatment.

Installation—Various methods of applying jigs to existing or proposed dredges may be employed. They can be grouped into two classes: (1) Installing jigs as auxiliary recovery equipment, conforming to the existing sluice layout, and (2) installing jigs as essential recovery equipment which may or may not entail the elimination of the existing sluices. In the first case, the jigs may be placed either in the fore-and-aft sluices or at the end of the lateral tables, as explained in Figs. 1 and 2 respectively. When in fore-and-aft sluices, as in Fig. 1, the jigs probably will be required to take more than their share of the load, because the amount of material these sluices handle is greater per inch of width than on the lateral tables. Also, because the riffles require more water than is best for jigging, there always will be excessive velocity of top water difficult to control, besides the fact that headroom is limited at this point. When installed at the end of the lateral tables, as in Fig. 2, the load over the jigs usually will not be excessive, as the width of the total jig installation will be equal to the width of the total table area. But here again, excessive dilution and velocity of top water obtain, and headroom is not always available. Either one of these methods requires a double clean-up. The sluices ahead of the jigs will recover the major portion of the gold and must be cleaned up periodically, and the jigs will yield an additional amount that is cleaned up continuously, and, therefore, separately from the major riffle clean-up.

Place of Jigs in Flowsheet

It would seem preferable, therefore, to install the jigs as close to the screen as possible, so that they may constitute the essential recovery equipment. In this location dilution of the feed can be more closely controlled, the headroom is available in most instances, and only a single clean-up is necessary. If riffled sluices are contemplated below the jigs they will have a much better chance of doing good work because the jigs will remove the heavy mineral constitutents responsible for packing the riffles. Figs. 3 and 4 indicate a possible method of installing jigs as essential recovery equipment. The jigs may or may not be preceded by a short section of sluices, the main purpose of which would be to distribute the feed uniformly across the width of the jigs. These sluices may also be riffled and made to trap out coarse gold and tramp iron. Installation of jigs in this position will not necessarily involve the scrapping of existing sluices, as the jigs may be cut into them.

This article is the outgrowth of the work done by the Pan-American Engineering Corporation, Ltd., at the instance of the Placer Development Company, Ltd., Yuba Consolidated Goldfields, Ltd., and Fisher and Baumhoff, to which companies credit is due for initiating the installation of jigs on dredges recently. Their cooperation and also the helpful guidance given by V. E. Bramming and F. W. Collins are herewith gratefully acknowledged.

Iron Mining In Muscoda No. 6

(Continued from page 32)

the men can step directly into the skips. Material for the mine is loaded by an overhead crane on larries at the surface. The larry is connected to the skip with a flexible-rope coupling, and is lowered down the slope below the skip to a material station 400 ft. above the ore pocket. The material is unloaded from the larries onto a yard. From this point it is distributed throughout the mine by the locomotive haulage system.

Extending across the top of the pocket is a circular haulageway connecting the yards at either end of the rotary dump and so arranged that the movement of all trains is in the same direction. From this circle there are two main haulageways, one extending into the North section of the mine, and the other into the South section. At a point approximately 1,100 ft. from the rotary dump, a third haulageway branches off of the South haulageway toward the East. These haulageways are driven in the ore seam approximately 10 ft. high, 14 ft. wide, and on a grade not exceeding 5 per cent.

All tracks are laid with 60-lb. rail on 4 ft. 8½-in. gage, with a minimum radius of curvature of 85 ft. Three-piece steel sets, made from 12-in. I-beams, are placed wherever necessary in the main haulageways. Mining headings are turned from the main haulageways at intervals of 230 ft., and are driven at right angles to them whenever the topography of the ore will permit without exceeding a grade of 8 per cent. The mining headings are advanced 20 ft. wide to allow for double track, and all stopes are mined from these headings.

All drilling is done with water-type drifters. The machines have 4-in. cylinders and weigh 186 lb. Drills are mounted on tripods. Air is supplied from the 2-in. heading air line through a 1½-in. hose to a line lubricator and through a short section of 1-in. hose to the drill. Water is fed to the drill through a ⅜-in. hose. All steel used is 1¼-in. hollow round with a standard four-point bit. This is made up in sets of four pieces each, ranging from 3 to 10 ft. with bit gages from 2¼ to 1⅞ in. Two drills are used in each stope, V-cuts being followed by slabbing rounds. The ore is broken so that no secondary blasting is necessary. An ammonium nitrate dynamite in cartridges, 1¼ by 6 in., with a stick count of 140 per 50-lb. case, is used. This explosive has a weight strength of 65 per cent and is equivalent to a 45 per cent gelatin dynamite. All blasting is done with fuse and caps and at the end of the shift.

A stope is mined from either two or three upsets turned from the heading. After the upsets are advanced approximately 20 ft. above the upper rib of the heading, they are widened to break through at 45 ft. A two-upset stope is mined 110 ft. wide and 190 ft. in length, with a break-through into the heading above for ventilation. Small pillars 20 ft. in diameter are staggered throughout the stope. Approximately 16,000 tons of ore is recovered in a two-upset stope. (Fig. 7.) A three-upset stope is mined 160 ft. wide and about 24,000 tons extracted.

Separating each stope in a mining heading is a pillar. The width of this pillar depends upon the depth of the overlying cover and is computed from a formula, which takes into consideration the crushing strength of the ore and the weight of the overlying cover. The crushing strength of the ore is 13,000 lb. per square inch. It was determined from tests conducted by the United States Bureau of Mines. A safety factor of 4.3 is used in laying out the pillar system. The present mining system contemplates extraction of pillars after property limits are reached.

Slate or sandstone from the roof and footwall is picked out of the ore by hand at the loading ramps. Three-piece sets with 12-in. square heart-pine collars and 12- to 14-in. round timber legs are used in supporting the roof in the headings. In the face of the advancing headings, where dragging operations are being conducted, it is impractical to stand the timber posts under the collars, and these collars are supported on steel pins set in the ribs. After the face loading ramp is moved ahead and the track extended, the posts are placed under the collars. In the working stopes the roof is supported by round timbers stood in hitches cut in the footwall. (Fig. 8.)

The ore is sampled periodically by channel samples cut from top to bottom of the ore seam. Each railroad car at the outside tipple is sampled. These analyses are compared as a check. The ore seam changes abruptly into shales at the top and bottom, and any of this material mixed with the ore alters its analysis. An average analysis of mine-run ore for the first six months of the year 1937 is as follows: Iron (Fe), 35.80; silica (SiO_2), 12.04; alumina (Al_2O_3), 3.28; and lime (CaO), 17.37.

(To be concluded)