PRACTICAL STAMP MILLING AND AMALGAMATION

Practical Stamp Milling and Amalgamation

BY

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PREFACE

When I first engaged in stamp-milling and amalgamating, like many others I eagerly but unsuccessfully sought for a treatise that would tell me what and how to do and why; that would give the ideas and principles by which millmen were to be guided, and the methods found to be most satisfactory. Later the subject of examining ores and the adjusting of the stamp-mill to their requirements became of interest. This book is an attempt to give in a brief, concise way, information on these points.

It incorporates my own experience and conclusions, and knowledge gathered from other millmen and metallurgists. It leaves theoretical discussions and academic distinctions aside, and goes straight to the details of practical work.

H. W. MacFarren.

Salt Lake City, July 1, 1910.

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Practical Stamp Milling and Amalgamation

PART I

STAMP MILLING

CHAPTER I

The supremacy of the stamp-mill for crushing gold ores and the reason why it has so successfully withstood the attempts of both theoretical and practical men to supersede it or limit its application, lie mainly in its simplicity, reliability, and wide range of adaptability. The modern gravity-stamp has been evolved from the mortar and pestle used by primitive man, and it has remained simple in construction.

At first sight it appears to be a crude machine. All is done by gravity. There is an absence of elevating, conveying, and re-working, which give so much trouble in the other systems of milling. Its range of adaptability is far greater than that of any other crusher. It is used in Gilpin county, Colorado, in the treatment of a gold ore slow to amalgamate, and where its crushing capacity is subordinated in the effort to give the ore the particular treatment required to save the gold, the daily output being reduced to one ton per stamp. In South African practice amalgamation is subordinated to crushing, resulting in a capacity as high as ten tons per stamp, or higher. The stamp is used for disintegrating cemented gold-bearing gravel and for pulverizing the softest rock, as well as for crushing the hardest and toughest quartz. It may be fed with fine material having only sufficient grit to keep the shoes from hammering the dies, up to slabs of rock the size of a large meat-platter and 3 to 4 in. thick. Such rock is often sent through the battery during a break-down of the rock-crusher. It will crush wet or dry; it will deliver its product through a 4 or a 40-mesh screen, or through a still finer one if desired, though the modern stamp-battery is not adapted to crushing to advantage through a screen finer than 40-mesh. No machine can compare with it in amalgamating, or in preparing an ore for concentration, except where the friable nature of the material requires stage-crushing. In the hands of a metallurgist who has made a study of the stamp-mill, a great diversity of treatment can be given an ore in an experimental way, to ascertain the best for adoption in that particular case.

Estimates of the tonnage and costs with a stamp-mill can be made in advance with a close approximation to exactness. So thoroughly can it be depended upon that it has passed into an axiom that a standard stamp-mill has never caused the closing of a property by failing to do good work where good work was possible, and that it has replaced to advantage, at some time or other, practically every other kind of crushing machine. It is true that there are stamp-mills that are incapable of good work, due to careless manufacture, to incompetent millwrighting, and foolish economizing on the part of the company; but despite this the average millman manages to treat a fair tonnage and to make good extraction with them, so that the president of the company in his city office is often unaware that his mill is not up to the standard.

The opponents of the stamp-mill present elaborate statements showing that the cost of installation and the power consumed exceeds that of other processes. While this is often true in certain cases, an average will show the balance to be in favor of the stamp-mill. It must be remembered that exact and correct data of what a stamp-mill will do can be compiled, but that the advance estimates of what other processes and devices will attain is seldom realized under normal conditions. It is in the lower cost of operating and repairing, less loss of operating time, and wider range of treatment at command, that the stamp-mill overshadows all other crushing machines and processes.

It is an object lesson to go into some of the large and small mills that stud the Mother Lode of California so closely that he who travels through the counties of Amador, Calaveras, and Tuolumne, is seldom out of hearing of their roar; to note the ease with which the ore by gravity runs through the mill, the little labor necessary, the cleanliness of the place, and the smallness of the scrap pile, consisting mainly of worn-out shoes, dies, and screens; and then to go to a wet-roll or dry-process mill with sloppy, muddy floors, or dust-covered machinery, jammed rolls, elevators out of order, a small army of mechanics and helpers on construction and repairs, and mountainous scrap-pile of broken and worn-out machinery.

The selection of a mill-site is in some cases a simple matter, in others it is complicated by so many factors as to be a most difficult problem. Erecting the mill some distance away when it could have been built to advantage near the mine, is one of the most common mistakes. Operations should be centralized and concentrated as much as possible. Two operating points, with much of their equipment in duplicate, increases the working costs.

The great cost of installing and repairing transportation lines is often overlooked in making estimates of working costs. Another common mistake is the hauling of ore a long distance to water, when water could be obtained close at hand by a little development, or by further sinking in the mine if the mine water be suited to amalgamation. In a few cases it has not been.

Where ore is supplied to a large mill by an aerial tramway, an attempt should be made to place the mill so that the cable may run lengthwise over the bin, enabling the buckets to be tripped at any point, thus dispensing with a belt-conveyor. With a mill adjacent to a working adit, straight tracks and heavy, well-ballasted rails will enable large cars (3 tons) to be used with ease. At a shaft-mine it is well to place the mill near the hoist when possible. Hoisting may then be done by self-dumping skips into an ore-bin from which the ore may run by gravity to one breaker for a 20-stamp mill, to two breakers, one on each side of the bin, for a 40-stamp mill, or through one rock-breaking system connected by belt-conveyor to more than 40 stamps. The objection to putting the mill and hoist together is that in event of fire, both will probably be burned, and the fire communicated to the shaft timbers.

Efforts should be made to dispense with elevators for both wet and dry material, and to a lesser extent with belt-conveyors. A large part of the advantage from using the stamp-battery is due to the absence of elevating and conveying machinery. Extra expense to secure greater simplicity is money well spent. The stamp-battery is an ideal illustration of the 'unit idea' in construction as well as in operation, and a mill should be so situated that it can be added to, though the proportion of mills that are increased in size is small.

The disposal of the tailing should be carefully considered, and the title or irrevocable right to ground on which it can be dumped should be secured, even if it does not appear that this ground will be needed, for a trespassing tailing, like smelter-fume, can be made a basis for damage suits. It is not necessary to build the mill adjoining a good site for impounding the tailing, or an existing cyanide plant. The tailing can be ditched, piped, or flumed a long distance. Concentrate has been conducted in pipes as small as 1 in. diam. down mountain sides and across rivers to reduction works and storage bins.

Where it is necessary to set a water-wheel so low that it may be in danger during high water, in the effort to secure higher head, the mill may be set higher up, out of the danger zone, and connected with the water-wheel by a rope-drive.

The roof of the mill should not be in one solid sheet, but should be broken by drops at the different floors, that these floors may be well lighted by windows set in these drops.

It should be possible to reach the top and foot of the mill by wagon, so as to unload shoes and dies at the plate-floor, and stems and other parts at the cam-floor.

The common practice in rock breaking is to use a Blake jaw-crusher for 10 stamps, a Blake or gyratory for 20, or two for 40, as one breaker cannot readily spread the ore to more than 20 stamps. A single rock-breaking unit is frequently used for 40 stamps and always for more. Such a unit usually consists of one large coarse-crushing gyratory, which may or may not be preceded by a grizzly, followed by one or two fine-crushing gyratories. In the latter case a revolving screen or trommel is commonly placed between the coarse and fine-crushers. The product is delivered to a belt-conveyor, if the crusher building is adjacent to the mill, for distribution to the bins, or it is dropped into a storage-bin for conveyance by other means.

For breaking ore at a mill containing 20 stamps or less, the Blake jaw-crusher is the cheapest in cost and operation; for more than 20 stamps, the gyratory is the best by reason of the high capacity of the larger sizes. The breaker should be driven by separate power that it may in no way interfere with the running of the stamps, and should be enclosed from the balance of the mill that the dust may be kept out of the bearings and machinery below.

Many small mills are built in which it is necessary for the breakerman to shovel or scrape into the breaker every pound of ore that passes through it. If sufficient height be not available for placing a crude-ore bin above the breaker, then a gyratory breaker preceded by a grizzly should be used, and the ore should be dumped directly upon the breaker. This method of dumping directly and dispensing with a breakerman will not be successful with a wet, sticky ore that 'balls up' in the breaker, nor where the ore-supply does not come in small lots, although the breaker may be buried with a dry, brittle ore having no lumps too large to enter the jaws.

Where it is not desired to dump directly upon the breaker, a crude-ore bin should be used. This need not have a sloping bottom, for should the supply run low, the breakerman can enter the bin and shovel the ore forward. The grizzly should follow this bin, emptying directly into the crusher. An apron underneath the grizzly should carry the fine ore that has passed the grizzly bars to the point where the breaker discharges, that the coarse and fine ore may be well mixed. The placing of the grizzly before the crude-ore bin where the ore from the mine is dumped directly upon it, and the fine ore shunted by the crude-ore bin, or any construction that tends to keep the ore in crushed-ore bin from being homogeneous, is bad and must be condemned.

The height of drop of the stamps in a battery, and the other adjustments, are made for each ore according to character, hardness, and fineness. Where the construction is such that the fine and coarse ore during the day and early evening become segregated, a hard, coarse rock from the breaker is at first fed to the mortars, and the mill works splendidly; but late in the evening, the coarse rock in the front part of the bin being exhausted, the fine from the grizzly begins to come. The stamps having a long drop for the hard, coarse rock, now sink through this fine ore and strike the dies, and from there on the millman has trouble. While the stamp-battery can be adjusted to work well on this fine material, it is obvious that such adjustments for the two classes of ore cannot be made economically twice daily. Besides the trouble in feeding, there is danger in the 'camming' of the stamps that break through the bed of pulp to the die. This fine rock is sometimes many times richer than the coarse, and the millman, engrossed in other troubles, may fail to feed the additional quicksilver or make the extra dressings of the plates that may be required.

The crushed-ore bin, in fact any bin supplying an automatic feeder, should have a sloping bottom of from 40 to 50°. The only real argument in favor of the flat-bottom bin is that it gives a reserve ore-supply, but this reserve might as well be outside the mill, except in the case of accident to the breaker, for it will all have to be shoveled. It has been said that this extra ore by its weight anchors the bin and adjacent parts of the mill. The reply to this is that a well-constructed mill does not require such anchoring. Many arguments and sophistries are advanced that these flat-bottom bins will be kept full and that no shoveling will be required; but actual observation shows that they are not kept full, and that occasional shoveling must be done. This requires an extra man or extra men, and the charges for this item soon amount to 15 to 30 cents per ton. If a millman has to go into the bin, he gets surly, and voluntarily or involuntarily neglects his other work. A sloping bottom is advantageous where a wet, fine ore that will neither roll nor run is being milled, such as 'old filling' from the mine-stopes. By introducing a few pails of water at the top and back of the bin, the whole mass can be started moving slowly into the feed-chutes; care must be exercised in the amount of water used, or the whole mass will move down into the mortars regardless of the feeders, and, unless the stamps are immediately hung up, the screens will be broken out; in either case the excess of pulp or ore will have to be dug out of the mortars. In some mills 1-in. pipes are arranged to deliver a constant small stream of water upon such ore at the chute between the bin and the hopper of the feeder.

A compromise bin where the sloping bottom begins not at the feed-chute door, but halfway back on the bin-sills, does not give the advantage of either the sloping or flat-bottom bin. The bin should have, in addition to its double planking, steel plates at the points of greatest wear, the grizzly apron, the point where the ore drops into the bin, and just above each feed-chute opening. The lower 3 ft. of the planking on the front of the bin should be placed on the outside of the bin-posts, instead of inside, as the remaining planking. This will permit the millman to insert a bar or shovel from the cam-floor and to start the ore when it is low or has 'bridged', or it will enable him easily to enter the bin; a cover of canvas, or a hinged board, between the outside and inside planking will keep the dust back.

It is possible to increase the size of the mill by taking a feed-chute out of the corner of the bin and at an angle to it, to another 5-stamp battery in line with the original batteries. One side of the mill is always free to make such an addition, while the other will usually require some change in the driving arrangements. Where this idea is kept in view in building a 10-stamp mill, and a large high bin is built, it will be possible to turn it into a 20-stamp easily and cheaply.

In battery construction, the back-knee type, where the battery-posts are tied to the ore-bin, and the line-shaft driving the cam-shafts is placed on the streak-sills underneath the feeder-floor, is now given the preference. This style requires the least amount of timber. It is the strongest and most rigid construction, especially in view of the belt pull. It gives a clean-cut and well-lighted mill, with the upper part of the battery and mill in sight from the plate-floor. The objections are that a belt-tightener must be used on the battery belts, but this answers for the friction-clutch with which the pulleys of all horizontal battery belts should be provided. However, the wear and tear on these belts is much greater than on belts not requiring tighteners. It has been feared that tying the battery-posts and framing to the ore-bin would cause them to be thrown out of line by settling of the bin; this can only occur with bins set on a loose, poor foundation, and has seldom given any trouble. Placing the line-shaft on the streak-sills has been criticized as putting it in a place hard to get at and subject to dirt and water. Plenty of head-room should be allowed between the streak-sills and the feeder-floor, that the shaft may be easily reached for repair. Ring oilers should be used and dust-caps of canvas provided. In a well-constructed mill, no water will reach the shaft. The placing of the line-shaft on the bin-sills in the rear of a sloping-bottom ore-bin gives all the advantages of the style previously described, with the additional one that the belt is horizontal and requires no tightener. This style is limited to 20 stamps as the battery belts must pass on the outside of the bin, and it is advisable to make the bins continuous.

In the front-knee type, the line-shaft is placed on a level with the cam-shaft and in front of it on heavy timbers that form a part of the battery framing and brace it independently of the ore-bin, though it can be tied to the bin. It requires more timber, is neither as strong nor as steady as the back-knee type, while the upper platform darkens the mill and does not allow the upper part of the mill and battery to be seen from the plate-floor. It is not suitable for 10 stamps unless tied to the bin, as the tendency of the battery is to sway endwise on account of its comparatively small area of longitudinal anchorage.

The subject of battery foundations is important, and the seal of approval has been placed on concrete mortar-blocks; but while realizing that a good concrete block may be perfect, it must be admitted that in a large number of cases they have been unsatisfactory from defective construction, while the wooden block has given satisfaction in practically every instance. The concrete block gives a cleaner looking mill, and does not decay. By its solidity and non-cushioning effect, it increases the capacity of a battery sometimes as much as $33\frac{1}{3}\%$. It is reputed to break stems and cam-shafts faster than the wooden block, but where the block has been built and the battery-posts assembled in such manner that everything is bolted tightly and securely together, and kept so, and the jar and vibration reduced to a minimum, the breakage of parts is greatly lessened.

The principal troubles with concrete blocks have been: a rocking of the block, due to imperfect setting on the bedrock or to too small a base-area when set on loose ground; a disintegration of the block due to not tamping the concrete sufficiently during construction and to the use of poor material; and to the crumbling of the top-dressing or grouting, improperly put on for the purpose of leveling it, after the block had partly set.

An instance may be given as a good illustration of concrete mortar-block troubles. After the blocks had partly set, they were grouted up 1 in. A short time after the mill began operating, the grouting began to crumble, resulting in the battery-posts dancing and the mortars shifting. Then, within a short time, occurred breaking of parts, such as driving-pulley, plates, cam-shafts, cams, stems, and mortar anchor bolts.

Grouting the blocks has been successful, but in view of the large number of cases in which it has not, it is inadvisable to take such chances. It is necessary to make the surface of the block absolutely true, though it may vary a small fraction of an inch from being level; this can be accomplished by chiseling and scraping the block after it has partly set, or by promptly bolting a wooden frame to the top of the block by means of the anchor bolts, to press it into shape, before it has had time to set.

Anchor bolts should be set in pipes in such a way that should one break it can be unscrewed and a new one inserted. Iron anvil-blocks between the mortar and the concrete are superfluous and seldom used. The concrete block should be quite wide, while the mortar base should be wider and heavier than is usual with mortars for wooden blocks, in order that solidity and strength may be insured. A sheet of ¼-in. rubber is placed between the mortar and the block, not with the idea of cushioning the force of the stamp blows, but to make an even bearing which will equalize any slight irregularities of the concrete surface and one into which water cannot enter, for a combination of moisture and a slight jar or working of the mortar would tend to disintegrate the block. There has been a question with builders as to whether the battery-posts should rest in foot or bed-plates bolted to the concrete, or in streak-sills and other framing as with wooden blocks. With the posts resting on timbers, these timbers will absorb and minimize the jar and vibration to some extent, thus relieving the battery-posts and lessening the pounding between the cam-shaft and its boxes; but given good, wide surfaces in both block and mortar, with the mortar and the battery-posts bolted securely to the block, there will be a minimum of jar and vibration, and to just the extent that this is reduced will the breakages and the wear and tear be lessened.

Mortar-blocks for small mills are usually of wood, consisting of pitch pine of such size that two pieces bolted together make a block, down through various sizes to ordinary planking spiked into a solid block of the desired dimensions. They should be coated with a preservative paint to lessen the tendency to rot. In length they vary from 8 to 25 ft. Where solid rock cannot be secured, a bed of concrete 2 or 3 ft. thick and as wide as 4 ft., is made as a foundation. Even where bedrock is found, a bed of concrete 1 ft. thick is advisable to give a level surface for the block to rest on, and to fill crevices or weak spots in the rock. After the block is set in place, sand is filled around it and tamped down. Pouring in concrete has been tried, but is not recommended on account of its shrinking. The nuts of the anchor bolts, tie rods, and all others about the battery should be frequently tightened after the mill goes into operation.

CHAPTER II.

Mortars are made of cast iron and approximately six or more times heavier than the weight of the stamp to be used in them. In selecting a mortar for rapid crushing it is advisable to get a narrow one, the best known type being the 'Homestake'. All manufacturers make a mortar of this kind. By a narrow, rapid-crushing mortar is meant one having as little spare room in its crushing area as possible. Such a mortar is usually about 12 in. wide at the discharge-lip, and there is no surplus space at the ends. It may be urged that but little inside amalgamation can be done with such a mortar. This idea is erroneous, for inside amalgamation ordinarily varies as the height of the discharge, which is the vertical distance between the tops of the dies and the bottom of the screen. A chuck-block plate, and in some cases a back-plate, can be used in these mortars, though it will require some care and extra trouble. Inside amalgamation, as referring to the catching of a large part of the gold inside the mortar, is going out of use. Capacity is being called for, and the tendency toward outside amalgamation, or at least toward not requiring so large a proportion of the gold to be caught inside the mortar at the expense of capacity, is increasing. It has been suggested that by using a wide mortar it may be lined and thus converted into a narrow one if desired. It is hard, however, to get special liners made that will not give trouble by coming loose. It would be almost impossible to decrease the horizontal distance between the die and the screen. However, the idea has some merit and can be applied to wide mortars now in use. The feed-mouths of mortars should be wide, so that coarse rock may be fed to them during breakdowns of the rock-crusher.

Double-discharge mortars, with a screen opening in front and behind, have been tried, in amalgamating, but are not considered successful. The back-screen is hard to get at, and to hold in place without coming loose. There appears to be so much motion to the pulp that it does not settle on the dies, and in consequence the mortars frequently fill up, especially when feeding fine material. So much water is required that the outside plates cannot do good amalgamating with this dilute pulp. The single-discharge mortar can be made to discharge the pulp about as fast as made when treating ordinary rock. In view of this and of the inconvenience in working with a double-discharge, these mortars are usually found with the backs closed, except with such easily disintegrated material as gravel, where the problem becomes one of screening rather than crushing.

Mortars should be lined, front, back, ends, bottom, and where the feed strikes the mortar at the bottom of the feed slot. The front, back, and end-liner should dovetail; the back-liner may or may not be finally bolted into place. Attention should be given to securing liners that will not come loose. A bottom-liner of one piece is usually a nuisance; sand and pieces of iron creep under the ends, causing the liner to sag in the middle, when a general movement begins which may result in displacing the dies when they become worn down. Two-piece liners act in a similar way. Individual plates or 'false dies' are what is required. Old dies worn smooth answer well. An inch of sand should be placed between them and the mortar below, likewise between them and the 'true dies' above. This has been condemned on the ground that it cushions and consequently lessens the efficiency of the stamp blows, but its use will reduce the chances of cracking the mortar or the dies. The dies should be plumbed exactly under each stamp, and should fit snugly in the mortar, with just enough space intervening that they may be pried out without too much trouble from locking each other. Should there be any surplus room at the ends or sides, the dies should be wedged with a piece of iron or steel. This wedging is likely not to hold when the dies become worn, consequently steps should be taken to secure liners that will completely take up this surplus space, thus firmly keeping the dies themselves in place. There is nothing more annoying than a mortar so large that the dies shift from their proper position under the stamps. In putting in a new set of dies, it is advised to pack coarse rock around them and to run with a heavy feed, that is, with a thick bed of pulp on the dies, for a few hours until the dies have been solidly cemented in place.

If it is expected to use a low discharge in crushing, a shallow mortar should be ordered. Build up the old or partly worn dies by false dies, and use a high chuck-block when starting a new set, decreasing the screen-height an inch at a time, as the dies wear down, by chuck-blocks and wooden strips of various thickness, until at the last lowering of the screen, just before discarding the worn-out dies, there is nothing placed underneath the screen-frame. In short, keep the height of discharge as nearly constant as possible by lowering the screen an inch at a time, as the dies wear, and, if possible, do not move the dies until they are worn out. Where the dies are removed in the monthly clean-up, start the new dies without the false ones, and insert the false dies at the next clean-up after these new dies have been worn down.

Shoes and dies are made of iron and steel of several kinds, going under such names as cast and chilled iron, hammered, forged, cast, chilled, chrome, and manganese steel, and semi-steel. The millman will decide for himself when choosing from these, keeping in mind the local conditions affecting the nature of the ore and the cost of supplies. It is usually cheaper to use steel than iron, despite its increased cost, on account of the smaller consumption of steel per ton of ore crushed and the less time lost in renewals and setting of the tappets. The life of a set of steel shoes and dies may roughly be estimated at four months or less, as against half that length of time for iron, though the life of steel-parts has shown on different ores such wide variations as from 2½ to 9 months, and four times that of iron. A material having the maximum hardness and the minimum brittleness is desired. The limit of hardness is passed when the shoes and dies chip, crack, or break. The remedy in this case, presuming that the feed has not been kept too low or the drop too long for the nature of the ore fed, is to use a softer die; if the trouble continues, keep trying a softer material for the die until the proper limit is reached. It may be that the shoe in use is too hard and brittle, when a softer or another kind should be tried, but not one as soft as the die. The wear is greatest on the shoe, and it should have the hardest metal. With a die softer than the shoe, the two wearing faces adjust themselves well to each other. The variation of life between a steel and iron shoe is much greater than between a steel and iron die. For these various reasons many mills are found using steel shoes and iron dies with great satisfaction. The use of a steel shoe with a semi-steel die is also recommended.

Should the die be found to wear unevenly on one side, it may be due to a soft spot in the metal, which, once started, increases, or it may be due to some trouble in the feeding of the mortar. The die should be turned half-way round in the effort to make it wear evenly. At some mills the dies removed when cleaning up the mortars are returned to the exact place and position, at others they are turned half-way around; in other mills no attempt is made to return them to any particular position. If, on examination before removing, the dies appear to be wearing evenly, and do not exhibit a tendency to wear unevenly in some general direction, it is unnecessary to use care to return them to any particular position, as a shoe and die soon adjust themselves to each other. The shoe generally wears to an even, slightly concave face, while the die wears convex in a corresponding manner, this is called 'cupping'; the parts are said to 'cup'. The evenness of this cupping is due to the rotation of the stamps in falling, to the dies being plumbed exactly underneath the shoes, and to closely fitting guides which enable the shoe to strike the die exactly central at each drop.

No die should be permitted to stand higher or lower than the others, or it will cause that stamp to 'pound' or to 'cushion' through having too thin or too thick a bed of pulp over its corresponding die. In the effort to economize by saving 'steel' (the general term for shoes and dies), the die is usually worn to a thickness of 1 or 1½ in.; at less than this thickness it is liable to break at any time. When a die breaks in a set that is only partly worn out, another of the same height must be put in its place. If no die of this height is available, a new set should be put in, though it is possible to replace the broken die with a shorter one built up by a false or old die. All mills have on hand an assortment of partly worn shoes and dies of various heights for this purpose. The die should be of exactly the same diameter as the shoe or ¼ in. larger, as the shoe, through the looseness of the guides, strikes over an area slightly larger than its face.

For securing shoes in the boss-head, hardwood wedges made from staves of nail kegs or barrels are tied around the shanks of the shoes. Soft wood can be used if it is of a tough, pliable nature, but the shoes come off so easily that its use is not advised. Thick wedges can be used where the space calls for thin ones, by spacing them some distance apart about the shank, and allowing them to be crushed into shape when the shoe is put on. With the old style of iron bosses, having a ring on the lower end, the shoulder of the shoe should not come in contact with the boss or it will tend to loosen the ring. In bosses without these rings, the shoe should be wedged so that it will be driven up flush with the boss, for the shoe can then be worn to almost the thinness of cardboard before breaking. For removing the worn-out shoes, a 'drift' of tough steel is inserted in the key-way in the centre of the boss-head and pounded in, the wedging tension causing the shoe-shank to be forced out of the socket. Where the shank does not extend into the field of the key-way, a 'dutchman,' that is, a piece of metal 2 in. long, usually a broken tappet-key, is slipped in on top of the shank, and the 'drift' is carefully inserted to make a tight fit before driving. The edges of the 'drift' should be greased to make it drive easier. Shoes are also removed by blowing them out with small charges of dynamite. Should the ring of wooden wedges remain 'frozen' to the socket without dropping out with the shank, they should be allowed to remain, and in putting on a new shoe, a square piece of canvas is laid on the shank or a few new thin wedges tied about it.

In putting on a new set of shoes, the stems are first cleaned of the grease below the tappets by passing a long strip of burlap or cloth wet with kerosene or gasoline about the stem and alternately pulling each end of the cloth until the stem is clean. This is necessary as the tappet will now be set in the cleaned part—it would be impossible to make two slippery, greasy metal surfaces hold together. The tappet-keys are loosened and the stem pulled up through the tappet by means of the overhead chain-blocks until the boss is raised sufficiently to allow a new shoe to be set underneath, when the tappet keys are driven in sufficiently tight for security, and the chain-blocks removed. The new shoes are now rolled on a plank up to the mouth of the mortar; they are stood on the mortar lip and the wooden wedges tied about the shanks; then they are slipped in upon the dies underneath the bosses. The stem is now dropped, using a thick cam-stick to increase the height of drop. As the stem drops, the millman places his hand on the tappet that he may be able to tell by the jar if the shoe has been picked up by the boss. He keeps the cam-stick between the tappet and the cam at each lift of the stamp, so as to give the stamp a higher drop, and consequently a greater driving effect. It also causes the stamp to revolve more, insuring a straighter driving of the shoe shank into the boss. As the shoe is lifted the first time, the man at the mortar below throws underneath it a shovelful of fine rock or pulp to cushion the blow and prevent cracking or chipping of the shoe or die. The operation is spoken of as 'driving on shoes', and is followed by setting each stamp to drop the exact height desired. Some millmen, instead of driving the tappet-keys in lightly the first time, set the tappets permanently and do not re-set them after the shoes are on. This results in the height of drop being a little irregular, but some men are able to calculate so closely just how far the shoe will be driven into the boss that the plan is often a good one. When tying wedges around a shoe resting under a boss, it should be made a habit to pull the shoe out sufficiently so that, should the stamp accidentally or otherwise drop off the finger-jack, it will fall on top of the shank instead of encircling it, as many men have had fingers cut off in this way. A safer and more expeditious method is to tack the wooden wedges to a strip of drilling and tie them about the shank of the shoe before placing the shoe beneath the boss.

Should a shoe come off, and the boss continue to drop encircling the shank, the socket of the boss will soon be worn so large that a shoe cannot again be fastened in it. Should the shoe turn partly or completely over on its side, the shoulder of the boss may be so battered that it may be necessary to remove it and chip out the socket.

Instead of doing this, the boss should be set to drop encircling the shoe-shank with a height of 2 or 3 in., after which the entire battery should be run for a half-hour, when the socket should be worn to its normal size.

The boss-head, or 'boss' for short, should be of cast steel instead of iron, as steel is less liable to be split by the wedging tendency of the tapered stem or shoe-shank, or by the blowing out of shanks or broken stem-ends with dynamite. An additional reason is that there is much wear on the lower part of the boss by the attrition of the pulp when the shoes are well worn down, as can be seen by examining the bosses that have been in use for a long time. Steel is better able to resist this abrasion, as is shown by the comparative life of iron and steel shoes and dies.

Tappets should be of cast steel, being more durable than cast iron. They are counter-bored at each end to have a recess of ¼ to ⅛ in. wide and ½ in. or more deep, so that the entire face of the tappet exposed may come in contact with the cam which it rides, and thus wear evenly. As the cam must be placed a fraction of an inch away from the stem, if the tappet were not counter-bored in this way a thin collar of metal would gradually form about the stem as the tappet-face wore down. This collar would interfere with the action of the cam on the tappet.

The tappet should have a slight counter-bore throughout the main bore through which the stem passes, and on the side opposite the gib or small piece of steel enclosed in the tappet which is wedged against the stem, by driving in the tappet-keys. This counter-bore should be of a smaller radius than the main bore of the tappet, and should make the main bore elliptical in form by reaming out one-third of its circumference. When the tappet is secured to the stem by driving the keys against the gib, it forces the stem into the elliptical part of the bore and gives three bearing surfaces equidistant, two where the counter-bore intersects the main bore, and one at the gib, whereas there are only two in a tappet not counter-bored. The use of three bearing surfaces instead of two, with the increased wedging effect, enables the tappet to be firmly fastened without driving the keys excessively tight. Slipping of tappets is one of the banes of a millman's existence, and advantage should be taken of every aid to prevent it. All manufacturers do not counter-bore the tappets in this manner, and this point should always be taken up when purchasing a mill or ordering new tappets.

Gibs that are too soft tend to cut out at the key-ways by the frequent driving of the keys. Placing a thick metal shim between gibs and keys will prevent this though it is much more difficult to keep tappets from slipping when shims are placed between the gib and the keys than when placed between the keys and the tappet as is usually done. The use of a softer metal in the key, such as soft steel or iron, will lessen the cutting tendency. Gibs that are cut badly should be removed. Broken gibs should also be replaced or they will mar and scratch the stems. Tappet-keys are re-shaped and re-pointed at the blacksmith-shop, or by means of a coarse file. An emery wheel is an excellent tool for this purpose, and should be included in the equipment of every mill. For driving tappet-keys, single-hand hammers with handles a little longer than usual, so that they may be used when necessary with two hands also, should be employed. When tappet-keys have to be sledged with heavy double-hand hammers to prevent the tappet from slipping, something is wrong; usually the gibs are cut out at the key-way and the tappets are bored so large in comparison to the diameter of the stem that there is little binding surface. Gibs with their curves bored to a radius slightly smaller than that of the stem exert a good clamping effect.

Tappets should be bored $^1/_{32}$ in. larger in diameter than the stems. It should be possible to move and slide them easily, but no looseness should be apparent. Tappets with a bore of $^1/_{64}$ in. larger than the stem have been used, but too much trouble is experienced in slipping them over irregularities in the stem. The driving of the keys should be done evenly. If the upper or lower key be driven tight before starting the other, it may, in the case of tappets bored too large, throw the tappet out of line with reference to the stem. This may be one of the causes of stamps twirling. It may also serve to explain the lengthening of the drop of a stamp by a slipping tappet, which, however, is rarely seen. Ordinarily, when a tappet slips, it is driven upward on the stem by the repeated blows of the cam, thus lowering the stamp until the shoe touches the die, after which there can be no further lifting of the stamp. Taking the case where the upper key, or the upper part of a broken gib, is driven tight first and the tappet is slipping, the gib will be out of alignment with the stem and the upper part of the gib pressed tightly against the stem while the lower is inclined from it. It is impossible for the tappet to be driven upward as usual, for the upper shoulder of the gib buries itself in the stem and prevents such movement, but the jar and rebound from the stamp striking the die causes the tappet to slip down on the stem a little, where it takes a new grip the moment the cam strikes it, causing it to drop down a little farther when the stamp strikes again. This continues until the stamp begins to 'cam', that is, to fall on the cam from having too long a drop for the speed of revolution.

If the tappet-keys on each battery are all driven in on the same side, that is, all driven in either on the right or the left side of their respective stems, there will be less trouble from the locking or meshing of keys that project out too far, or are slipping out of the key-ways. Tappets are often made with the key-ways wider on one side than on the other, so that the keys shall be driven in from the wide side. This is imperative only when the gibs are badly worn, but in such cases the tappet should be marked by chalk or paint to denote this side, unless the manufacturers have marked it.

For setting the tappets, a special quick-acting clamp is placed around the stem at the required distance above the tappet, which is then resting on the finger-jack, and on loosening the keys the stem drops down this distance; the clamp is then removed after tightening the keys. Otherwise the chain-blocks are attached to the stem to raise, lower, or hold it. In setting the tappets, a man stands on each of the two opposite sides; one places a 'drift' having an eye and a wooden handle against the end of the key and loosens it with a hammer, but does not drive it out, while the man on the other side holds the tappet steady and, with a piece of cloth to deaden the force of the blows, holds the key from being suddenly hurtled out of the key-way by the blow of the hammer. After the stem has been adjusted in the tappet, this second man hammers the keys back into place. Where the tappets are bored to a close fit on the stems, it is customary for one man to loosen the keys slightly, while the other makes a quick drive at one of the keys when the tappet has slipped to the mark; in this way the tappet setting proceeds rapidly. A chalk mark is placed around the stem above the tappet, so that any slipping may be readily noticed. If the tappets stick and refuse to move, a little kerosene or gasoline may be poured into the counter-bore at the top to run down between the stem and the tappet, while the tappet is struck with a hammer on the inside of the collar or on the waist. The outside or wearing face must never be roughened by being struck. The cam-stick may be used if desired so that the blow of the cam may be utilized to drive the tappet upward on the stem without dropping the stamp off the finger-jack. When setting tappets, it is customary to hang up only the stamp that is being set, allowing the other four stamps to continue dropping, with the possible exception of when setting the stamp which actuates the feeder. To lessen the danger to fingers, two stamps may be hung up, the one being set, and its neighbor on the side next to the keys.

Cams should be of steel to insure long life and to lessen the chances of being broken, an undesirable occurrence on account of the labor involved in replacing with a new cam. They are set from ⅛ to ¼ in. away from the stems. Cams are called 'right-hand' and 'left-hand', and are determined by the following rule: when the hub of the cam is toward the observer and the cam rotates to the right, or clockwise, it is a 'right-hand' cam; if the rotation is to the left, or counter clockwise, it is a 'left-hand' cam. The action of the cams upon the tappets tends to cause the cams to move away from the stamps. This lateral thrust of the cams and cam-shaft is greatest at the moment when each cam leaves its tappet. It is overcome in the 10-stamp cam-shaft by making the cams of one battery left-hand, and those of the other right-hand, the lateral thrust of one set in one direction overcoming that of the other set in the other direction. With a five-stamp cam-shaft it is possible to use two right-hand and three left-hand cams, but generally the boss of the cam-shaft pulley is utilized as a collar in connection with other collars to prevent the lateral movement of the shaft.

It is highly important that the cams be properly designed for the speed and length of drop to be used. The design should be such that when the shoe strikes the die of an empty mortar the space of ¼ in. or more will intervene between the faces of the tappet and the cam, near the hub of the latter, and that the cam will immediately engage the tappet at a low but rapidly increasing speed as the tappet is lifted to the point where it drops off the point of the cam. One of the greatest sources of noise, wear and tear, and broken parts, arises from a cam improperly designed and which suddenly engages or violently strikes the tappet.

CHAPTER III.

Stems were formerly made of wrought iron, but now almost always, if not in every case, of mild steel. Stems do not wear out directly, but indirectly by breaking. These breakages occur mainly at the point where the stem leaves the embrace of the boss, but occasionally an old stem breaks near the tappet. Breakages at other points so seldom occur as to be phenomenal. When the stem breaks at the boss it is reversed and the other end is placed in the socket of the boss. When this second end breaks, the stem is sent to the blacksmith-shop to be swaged down again at each end, or to the lathe to be turned down, after which it is returned to the mill to be used again. After so many breakages have occurred that the stem will no longer run in the guides from being too short, a new piece is welded to it, or in the absence of facilities for making such a weld the stem is discarded.

After welding, if bent, a stem may be straightened by laying it, while still hot, in the groove between two old stems or heavy pipes, of a diameter similar to the stem, placed parallel and an inch apart on the ground where they are firmly held by straps or bolts. In this groove the stem may be hammered and straightened.

The breaking of stamp-stems and cam-shafts has been popularly attributed to the crystallization of the metal, the theory being that the continuous jar and vibration to which these parts are subjected causes a molecular change whereby the fibrous structure of the metal is changed to a granular, crystalline form, which, not having the tenacity of the fibrous structure, finally breaks. Many arguments have been advanced for and against this theory, but nothing conclusive has been shown. It is pointed out that the break shows an apparently crystalline structure because it is across the grain of the metal in the stem, and that there is no evidence to show that any change takes place in the structure, either in the case of a broken stamp-stem or in any experiment made in the general way. It is also pointed out that should crystallization take place, the breaks would not be confined so generally to one particular point. The argument has been presented that the jar and vibration from the impact of the shoe upon the die passes into the boss, and that this vibratory motion concentrates to pass into the small cross-section of the stem at the point where the stem leaves the boss, and here is the point of greatest stress. Under the strain the particles of metal lose their power of cohesion; the metal develops 'fatigue'; minute fractures occur; there is a repeated bending stress in different directions from the stamp striking on an uneven surface, as when a piece of coarse rock is lying on the edge of the die; and eventually the minute fractures develop into a break. Conditions prevail in the stem at the tappet, where the breaks sometimes occur, somewhat similar to those at the boss. There is a bending strain from the cam striking the side of the tappet and away from the centre of the stem. As the tappet is continually shifted up and down the stem and its embrace is such that the vibratory motions are not communicated to the stem so constantly at one point as at the boss, the strain there is less and breakages do not so frequently occur.

The practical millman will ask: "If the breakages are not due to the crystallization of the metal, to what are they due?" In the absence of any authoritative reply or positive proof to the contrary, it is as well to continue to speak of them as being due to that cause.

The breaking of stems can be prevented by annealing them, that is, by heating and slow cooling. This fact gives color to the theory that crystallization or some change in the structure of the metal does take place. Annealing is not feasible except when welding or repointing the stems. The breakages have been partly prevented by boring the bosses and making the ends of the stems larger. It is a question among millmen whether steel stems break less frequently than those made of iron. In general, they do break less, and experiments show that mild steel will stand a much greater strain than wrought iron before breaking, yet in some mills where both iron and steel stems are in use, the iron has been found superior. This is because the steel in the stems is of a poor quality.

With a view to reducing the bending strain and causing less wrenching of the stem when striking an uneven surface, stamps have been designed in which the centre of gravity is placed as low as possible. Both guides are bored to a tight fit on the stem, with the lower guide placed near the boss. The stem is made short, using a long boss to make up the required weight, the result being that the stem drops straight and true, and that there is a minimum of bending and wrenching when the shoe strikes away from the centre line of the stamp. The results with these stamps appear to show the correctness of the theory upon which they are built.

Running the stamps with the feed too low or the mortar empty—'pounding steel'—shortens the life of the stems. When a piece of vagrant steel lodges on the top of a die, as is usually the case when a stamp suddenly begins to drop harder and shorter than its neighbors in the same battery, it should be removed or it may cause the stamp to break. A die tipping over in the mortar will cause the stamp to act in the same way and will be productive of the same evil result. Concrete mortar-blocks were formerly supposed to be more severe on stems than wooden blocks, but the results in good installations, where everything is kept solid and tight, disprove this.

In putting stems into bosses, the boss, with or without the shoe, should rest on the die and not on a thick bed of pulp. The boss should be placed exactly underneath the stem, which should be raised just sufficiently to do this or to give the right height of drop after the parts are fastened. Two strips of canvas, 2 in. wide by 15 in. or more long, should be placed across the socket of the boss at right angles to each other and slightly pushed in. The stem is now dropped off the finger-jack into the socket of the boss by means of the cam-stick, and is allowed to be dropped by the revolving cams until the boss is caught and the stem is driven in. The stamp should be rotated while dropping so that the stem may be driven straighter into the boss. Care must be exercised to have the boss placed properly and to see that the guides are tight, so that the stem may drop directly into the socket instead of striking on top of the boss. A chalk mark is placed near the end of the stem to indicate just how far it can be allowed to enter the boss, since should it enter too far, it would be impossible to insert the 'drift' for driving out the 'plug' or broken stem-end, should the stem break again. The stem may be lowered into the socket, and should it appear that it will enter too far, more strips of canvas should be used. It is a practice with many millmen to lower the stem into the socket and drive it in by pounding with a heavy hammer on the upper end. This should never be permitted, as it is certain to spoil the tapered end so that it will not fit well in the socket when reversed, or should it be a broken end, it will 'mushroom' into a jagged end over which a tappet cannot be slipped.

When a stem pulls out of a boss and runs for some time before being seen and hung up, the tapered end is usually pounded out of shape to fit the socket, though it may not be apparent to the eye. If the stem will not catch again, it should be hoisted out of the mortar and allowed to rest on a plank across the top of the mortar, where it can be chipped and dressed with cold chisels and files. It is reported that some millmen do not turn their broken stems, but that two men dress down the broken end, using cold chisels with wooden handles and double-hand hammers; it is doubtful if a satisfactory job could be done, unless the required taper is slight.

Canvas should always be placed in the sockets as it will lessen the number of breakages. When steel is wedged tightly against steel, it becomes as if made of one piece and all the jar and vibratory motion is communicated to the stem at the point where it leaves the embrace of the boss. By placing canvas between the parts, the tendency is for the jar and vibration to be more generally distributed, instead of concentrated at one point. Likewise the distribution of the bending-strain may be over a larger area. While canvas causes the parts to hold together as well or better than if not used, it allows the stem or broken end to be removed more easily by the usual means of drifting, or blowing out with dynamite. Where it is not used, the parts tend to rust together so that sometimes a boss is blown to pieces in the effort to remove it from the stem. When canvas fails to make the stem stick, a shim made of tough metal should be tried, such as a thick screen plate, or thin sheet-iron bent cylindrically and set in the socket; or the metal may be cut in strips and shaped to fit in the socket in the same manner as canvas strips. If the stem still fails to stick, it may be that the taper does not fit the socket and requires dressing down; or both the stem and the socket may be too smooth to catch and bind, in which case a small stream of some fine grit, such as jasper, should be allowed to run into the socket with the stem rising and falling so that the surfaces may be roughened and eventually bind on one another, or the surfaces may be roughened by denting with chisels. Some stems will refuse to hold in the bosses, requiring the utmost patience before being finally fastened. The last resort is to turn the stem or put in another boss. Stems are fastened, whenever possible, through the top of the mortar without stopping the other stamps.

When a stem breaks, the first thing to do is to hang it up on the finger-jack, allowing the others to run until ready to change this stem; should this not be for some time, the boss with its shoe should be removed from the mortar. When ready to change the stem, the battery is 'pounded out' or 'stamped out', which consists in shutting off the feed and allowing the stamps to run as long as may be safe, so as to remove as much pulp as possible from the mortar, the feed-water being shut off just before hanging up the stamps. The screen is then removed, together with the chuck-block, and the boss is inclined outward from the mortar, the 'drift' inserted in the key-way and the broken end driven out, after which the boss is righted into its place. Where the mortar-opening is too small vertically to allow the boss to be thus righted into its place, as is liable to be the case with a boss having a new shoe, a small rope-block is attached to the lower battery-girt and extended down through the top of the mortar, and the boss and shoe are pulled into position, after which the mortar is closed and the other stamps are started dropping. Two or more turns of a stout chain are now taken about the tappet of the broken stem, and the chain-blocks hooked into this chain. The stem is raised until the tappet nearly touches the upper battery-girt. The battery is now hung up and power thrown off from the cam-shaft. Both the upper and lower guides, which have been previously loosened, are now removed, and the stem and tappet are swung clear of the battery-girt. Raising of the stem is continued until it is possible to swing the lower end out on the cam-floor. If it is only desired to reverse the stem, it can now be done and returned to its place; but should it be desired to put in a new stem, one usually being at hand for such cases, the old one is lowered to the floor, and the new one is picked up and swung into place. As soon as the stamp is swung into position, the other stamps of the battery are started dropping. The guides are put back and the tappet is temporarily adjusted for fastening the stem in the boss, as explained before.

Some men are able to turn or change a stem without stopping the cam-shaft and the other stamps, but it is so dangerous to limb, life, and machinery that it should not be attempted. If the plug does not easily drift out of the boss, the boss is removed to a more convenient spot for driving the 'drift', or a new boss, together with the old shoe, is used. Blowing the plugs out with dynamite is a lazy man's refuge and may split the boss, especially when made of iron. At one mill where trouble has been experienced from the plugs not readily drifting out, the boss is heated until the canvas chars, when the plug will drift out easily.

It is customary to allow the stamps to increase their height of drop through the wearing away of the shoe and die, from ½ to 1 in. before re-setting. There are several ways of measuring the height of drop and the amount it must be decreased. One way is to open the mortar and measure the distance between each shoe and die. This is an impractical way, requiring too much labor, while the measurements are unreliable if taken from a spot in the die that has cupped unevenly, or if the finger-jacks are of an uneven height.

Another method of measuring the height of drop is to hold a piece of metal, such as the shims used with tappet-keys, against the stem at the guide and measure the scratch-marks with a rule while the stamp is running; the measurements obtained in this way are also liable to be inexact. A better method is to hang up each stamp, rub off some of the surplus grease above the upper guide, and oil well before dropping the stamp. After all the stamps in a battery have been treated in this way, hang up the feed-stamp or shut off the feed as long as safe. The oil-marks will now show the exact relative drop of each stamp when they are hung up. Should the finger-jacks be uneven, the oil-marks should be measured while the stamps are running. The tappets can be set by these oil-marks and re-checked after dropping again.

The best method of adjusting the height of drop is for the millman to examine the stamps once daily, and by his experienced eye single out those stamps that are dropping too long and too hard. Laying his fingers on the tappets or stems, he feels these stamps striking harder than their neighbors in the same battery, and in consequence he reduces their drop ½ in. He aims to have the individual stamps of a battery strike with an equal firmness, so that all may have an equal or maximum crushing effect, and so that he may be able to feed the battery down to a point where the greatest capacity in crushing effect can be obtained. He also aims to run with the maximum of drop permissible with the speed set. These are some of the secrets of getting a large tonnage through a battery, and attention to them may result in increasing the capacity from 10 to 20%, as against a battery in which one stamp comes down hard, while its neighbor is cushioned, or where the drop is not kept as long as possible within limits of safety.

The inside of the mortar should be occasionally examined to ascertain how the shoes and dies are wearing, and also to look for any fragments of broken steel that may have fallen in, or have come in with the ore. This latter should always be attended to when changing screens.

The friction of the cam against the tappet causes the stamp to rotate while running. This is necessary that the face of the tappet may be worn smoothly all around, and also that the shoes and dies may wear or cup evenly. One complete rotation of the stamp is made in from 5 to 30 drops of the present style of stamps under normal conditions. The data of two extreme cases will give some idea of the cause of this variation. In the Gilpin county practice a stamp weighing 550 lb., dropping 17 in. 30 times per minute, rotates 1½ times per drop. In a certain mill using 1500-lb. stamps, dropping 6 in. and 110 times per minute, the stamps make one complete revolution in 30 drops. The stamps in two mills having the same weight of stamps and the same adjustments, will vary in their speed of rotation, due to different shaped cams and to the amount of lubricant on them. Where the stamps rotate too fast, there is a small loss of power and too much wear on the cams and tappets. This twirling of the stamps may be caused by the wearing parts being devoid of grease, by being roughened through running without grease, or by the tappet being out of alignment with the stem.

Cam-shafts are sometimes of hammered wrought iron, but usually of hammered mild steel. A material is required for stems and cam-shafts that is tough rather than brittle, and is able to withstand the tendency to crystallize and break under impact; a good grade of wrought iron may answer these requirements as well as steel, and such cam-shafts are recommended from experience. Cam-shafts break from the same cause as stems, from 'fatigue' and crystallization of the metal. This is caused by the impact of the cams upon the tappets, and in a poorly constructed mill, where the battery-posts jump and vibrate and are out of line, by pounding in the bearing boxes. The breaking of a cam-shaft is a serious thing as compared with the breaking of a stem, since it involves considerable time and labor, and often a complete loss of the cam-shaft. It was customary to make the shafts for the lighter stamps from 4½ to 5 in. diam. As the weight of stamps has increased, the diameter of the cam-shafts has not always correspondingly increased, and this has been one cause of shafts breaking. A 10-cam shaft for 1000-lb. stamps should be 6 in. or more in diameter, 14 to 15 ft. long, and will weigh upward of 1400 lb. For 1250-lb. stamps a shaft 7 in. diam. and weighing 1800 lb. or more should be used. Five-cam shafts do not require to be so large in diameter for the same weight of stamps as 10-cam shafts. With the 10-cam shafts now in use there are three bearings. These get out of alignment by the shifting of the battery-frame and the great wear and tear peculiar to a stamp-battery, which tends to throw the weight and stress on two boxes or bearings, making too great a strain for a long shaft, so that, as the shaft becomes weakened from the 'fatigue' or crystallization of the metal, it is liable to break, especially when a stamp is 'camming' on it near a non-supporting bearing. The bearing-boxes should be securely bolted to the battery-posts, and when the shaft commences to throw out puffs of air from the boxes, or to 'trash', pound, heat, or vibrate in them, they should be immediately babbitted that they may be in exact alignment and have three good bearings. If cast-iron boxes without babbitt are in use, the shaft should be removed and these boxes aligned. No shimming should be used under them as it will work loose from the jar about a battery.

There is a great advantage in using 5-cam shafts in that there are few breakages. As there are but two bearings, even if the boxes do get out of line there is no abnormal strain at any time. These shafts enable one battery to be shut down to change a stem or for working on the interior of a mortar without interfering with the operation of another. The disadvantages are a slight increase in the length of the mill and the power required, also a doubling of the number of battery belts, pulleys, and, in some mills, the belt-tighteners. There is also the lateral thrust of the cam-shafts in one direction, but this is successfully met by the use of collars. The two-piece or sectional collar will be found superior to the single-piece collar, as it has a clamping effect in addition to that of the set-screws.

Where there is a minimum of jar in the battery-posts, and the bearing-boxes are not liable to get out of line, cast-iron cam-shaft boxes are the best, as there is no loss of time in babbitting, and little trouble from the shaft getting out of alignment or from having an abnormal strain due to the wearing and breaking away of the babbitt. Where there is much vibration of the battery-posts, babbitt, being a softer metal, is preferred for holding the shaft, while the frequent re-babbittings serve for aligning the shaft anew.

To babbitt the boxes, the shaft is raised by means of screw-jacks, chain-blocks, or preferably by two long pieces of timber used as levers. The old babbitt is knocked out by means of chisels, when the shaft is let down into the position in which it shall run. Cardboard luted with clay is placed about the shaft at the ends of the boxes, so that the molten metal may not run out. The melted babbitt is now poured in, and as soon as cold the clay is removed, and also the timber or other supports to the shaft, after which the shaft is started revolving and the stamps to dropping. Should the babbitt give trouble by breaking, especially in the box at the opposite end of shaft from the pulley, it should be softened by adding some lead in the melting. It is well to have on hand a set of half-rings made of iron. These are inserted at each end of the boxes, and the shaft is lowered on them, and should be kept perfectly level, after which the supports are removed. The rings serve to hold the shaft in position while the babbitt is being poured in and to make the shell of babbitt of the right thickness. It may also be necessary to use the clay to keep the molten babbitt from running out. After the babbitt has set, the rings are pried out. Iron caps for these bearings are universally discarded, but dust-caps of canvas should always be used.

When a 10-cam shaft breaks, running is continued with 5 stamps if possible, until ready to remove the shaft. The stamps are then raised by the chain-blocks until a 6-in. block can be slipped between each tappet and its finger-jack. This permits the shaft to be raised by levers, screw-jacks, or chain-blocks, first with chain-blocks removing the pulley, to be rolled out on timbers away from the boxes. If self-tightening cams are used, they are removed, as it is only necessary to strike them with a hammer on the point in the reverse way to which they run. The broken shaft is taken away and a new one is brought. The cams are placed on this shaft, and it is then rolled and lowered into place. If the old-fashioned cams, fastening with keys in a slot cut in the shaft, are used, the shaft and cams are at once removed from the mill and a new shaft, having a full set of cams in position, is placed in the bearings. This method is necessitated by the fact that to remove and to replace a set of keyed cams is a long and laborious process. All well-managed mills keep on hand at least one extra cam-shaft with cams, and several extra stems.

The order of drop of the stamps in a battery should be such that an even bed of pulp is kept over the dies, rather than an excess over one die and too little over another, and that the splashing or wave motion of the pulp be produced evenly along the screen. The first has reference to the crushing efficiency of a battery, while the second refers to its screening capacity, the two factors that make for tonnage. The academic requirement that no two adjacent stamps shall drop consecutively, or in simpler language, that no two stamps side by side shall follow each other in dropping, is fulfilled by only one order, 1-3-5-2-4, or its reverse which is usually spoken of as 1-4-2-5-3, since the custom in numbering is to face the front of the mortar and to consider the first or end-stamp on the left as dropping first. This is the drop usually recommended. Another order of drop and one which is most popular with practical millmen is 1-5-2-4-3. It will be noticed that the third stamp follows the fourth in dropping. The reverse of this drop as determined by counting it from the rear of the mortar and then applying it to the front is 1-4-2-3-5, in which the third stamp follows second in dropping.

Practically every conceivable order of drop has been used, but the above two systems are the only ones that have stood the test of time. Much confusion exists in speaking or writing of the different orders of drop. Thus one man will say that 1-3-5-2-4 is a good order and has been found to be satisfactory, and that 1-4-2-5-3 has been found to be a poor order and unsatisfactory. Since the latter is the reverse of the first, it is difficult to understand how it could be better or worse.

The 1-5-2-4-3 order has been found superior to the 1-3-5-2-4, both generally and where they have been tested against each other. A case under observation will illustrate the difficulties and the disadvantages of the 1-3-5-2-4 order. There was in use a narrow mortar and a 1000-lb. stamp dropping 103 times per minute through a distance of 7 to 8 in. As long as the height of discharge was kept as low as possible, and the feed preferably of coarse rock, little trouble was experienced. The tendency of the pulp to bank under the first stamp and leave the fifth pounding was marked, but in proportion as the feed was kept low and the stamps almost 'pounding steel,' this trouble was overcome. As the height of discharge was raised and finer rock was fed to the mortar, the trouble from the pulp swinging toward the first stamp became so great that when attempting to do fine crushing by the use of a high discharge and a fine screen, the results were most unsatisfactory, both as to tonnage and operation. The first stamp was set to drop 8 in. and the others evenly graded down to 4½ in. on the fifth stamp, but without getting the stamps to strike a blow of equal hardness. The pulp discharged from the third, fourth, and mainly from the fifth stamp, so that it was necessary to improvise a distributing box to get an even distribution across the plates. This difficulty with the 1-3-5-2-4 order, when running with a medium or high discharge, is generally reported.

The 1-5-2-4-3 order gives a more even splash across the screen and a better distribution in the mortar; consequently it gives a higher capacity with less trouble in operating. It scours more severely in the centre of the mortar than the other order, so that it is harder on the screen and chuck-block at this point.

While recommending that the 1-5-2-4-3 order be used, it is advisable that the millman be able easily to change to the 1-3-5 2-4 and thus try both. The mills built today are all supplied with self-tightening cams, as these have been so satisfactory that no one would think of going back to the old-fashioned keyed cam; these automatically lock themselves into position according to a clip on the cam-shaft. The position of this clip is determined by two holes bored in the shaft in which the lugs of the clip are set. By drilling two extra sets of holes in the cam-shaft, making seven sets to a battery instead of the usual five, it will be possible to change from one order of drop to the other. Such a boring would give the drops 1-3-5-2-4 and 3-1-5-2-4. It will be observed that the 3-1-5-2-4 order is the 1-5-2-4-3 with the numbering commencing at the third stamp to enable a simpler comparison to be made with the other order. To change from one order to the other, it would only be necessary to reset the first two cams to the other positions; a thing that can be done easily and quickly. The millman now has actually the first, and in theory, the second of the two orders of drop comprised in each of the two systems spoken of, namely, the first system: 1-3-5-2-4, and 1-4-2-5-3; and the second system: 1-5-2-4-3, and 1-4-2-3-5.

Guides should be of cast or malleable iron and of the individual type, though wooden guides are much used in the older mills. They should be bored to a close fit of $^1/_{32}$ to $^1/_{64}$ in. larger in diameter than the stem, carefully aligned and adjusted when first run, and supplied with a good grade of lubricating oil instead of the usual dirty oil or scrap-grease. They should be kept as tight as possible without heating or rubbing so that the stamp may move truly up and down with little side-play. The wooden guide can never give a close fit without heating, and sooner or later there will be considerable side-play from the wearing away of the wood.

The finger-jacks should raise the tappets ⅜ in. clear of the cams, so that a cam-stick of three and not to exceed four thicknesses of heavy belting may be used. Thicker cam-sticks are too heavy to handle with ease, and are more liable to be cut to pieces by a stamp with too long a drop. One very thick cam-stick should be kept on hand to increase the height of drop of the stamps in putting in shoes or stems and in pounding out choked mortars. A box 3 by 6 in. and 9 in. deep should be fitted to the central battery-post of each cam-shaft for holding the cam-stick. Cam-sticks made of iron with handles of leather or belting, work well, but care must be used in placing them on the cams or they will fly back in a dangerous manner. The finger-jacks should be solid and steady; a stamp resting on a wobbly finger-jack a fraction of an inch too short, and in connection with loose guides, is a dangerous thing beneath which to examine the interior of a mortar.

The suspended type of the Challenge feeder, or one of the so-called 'improved' feeders of the same order, is now almost universally used, as it gives a free floor and is less in the way than the platform type. However, the standard platform type of Challenge feeder is still the strongest and most satisfactory working machine made. The revolving feed-plate should be set 4 in. above the mouth of the mortar, so that a platform of wood or sheet-metal may be attached to the mortar to catch as much of the drippings from the feeder as possible; and also to allow of the introduction of a long tin scoop for catching a sample of the mill-feed as it drops off the revolving plate. This revolving feed-plate should be provided with a false plate or liner that may be readily replaced when worn out. Feeders were formerly actuated by a bumper-rod struck by a cam tappet, but as these rods are liable to give trouble at times, they are not included in the design of a modern mill; a small 'feed tappet' on the middle stamp striking the arm of the feeder is now used. This tappet should be split longitudinally, since in changing a feed stem, putting on the feed-tappet is often forgotten until after the stem is stuck in the boss. These tappets, however, frequently give trouble by slipping, due to grease running down from above, or to the bearing parts being too smooth. Feeders are the only parts in a stamp-mill equipment that are of delicate construction, and they should receive careful attention. If worn out or broken, they should be renewed or rebuilt, as poor feeders cause the mill employees great annoyance, reducing the mill capacity and increasing the breakages.

Screens are made of perforated metal plate or of woven wire or so-called 'cloth.' Perforated screens are either plain or burr-punched; in the first case a piece of the metal is punched out to make the hole, while in the second the metal is bent inward instead of being removed.

Burr-punched screens require to be placed with the burr or ragged edge inside the mortar so that the grains of pulp may not wedge in the orifices, and thus reduce its capacity. The sheet-steel, whether punched with round or slot-openings, is the strongest; its life is so long that it must sometimes be removed before breaking on account of the openings becoming enlarged by wear. The slot-screen gives less trouble from clogging than the round punched. Even the perforated screens have a slight burr on one side, which should be turned inside the mortar. The Russia iron needle-punched screen is used to quite an extent, though it does not facilitate discharge as does the wire screen. Brass-wire screens have been found satisfactory for fine crushing. They cannot be used when crushing in cyanide solution, as the screen is attacked by the solution, and soon breaks. Contrary to the usual opinion, they do not amalgamate to a prohibitive extent. After receiving the treatment usually accorded old screens for removing any adhering amalgam, they can be melted into a bar. Where a stronger screen is required, as when crushing with a low discharge, iron and steel-wire screens are used.

A most satisfactory screen is made of 'tinned iron.' This coating prevents its rusting before being put into use, and may prevent an acid battery-water or pulp from attacking the screen later. It has also been suggested that the coating of soft tin protects the screen from the impact and attrition of the pulp by presenting a yielding malleable surface. Some millmen remove the coating by heating the screen to redness over a forge or gasoline burner; which is supposed to strengthen the screen by annealing it. As it oxidizes the surface of the iron, it should not be done where the battery-water or pulp is acid. Experiments can easily be conducted on the same screen-frame to prove the value of annealing. The tinned-iron screen gives the least trouble from clogging. This is because of the thinness of the metal. A grain of quartz that will lodge in a hole in a Russia iron or steel-plate screen, will pass the same size of opening in a tinned-iron screen, or will be jarred through by the splashing pulp within. The tinned-iron has been given preference in many mills after being tested against the thicker perforated and the woven-wire screens. The character of the rock is one of the determining factors in the choice of screen to be used. The tendency to clog with a hard, splintery quartz is great, and it is sometimes possible to run a 40-mesh tinned-iron screen on an ore where it is impossible to use one of woven-wire that is finer than 30-mesh on account of the clogging.

When crushing through to 40-mesh, the brass wire is a good screen to use. Should it clog much, the tinned-iron screen should be tried. For crushing between 16 and 30-mesh, the tinned-iron is satisfactory, except where the discharge is carried too low to allow these screens to have a reasonable length of life, when the diagonal-slot thin steel screen may be substituted. For crushing to 12 or 16-mesh with a low discharge, the diagonal-slot thin steel screen will probably give the best results. The value of woven-wire screens increases as their tendency to clog becomes less. Steel screens of special thinness, and the needle-punched type, have been tried against the tinned-iron with satisfactory results, but have not come into general favor.

When screens clog, they are scraped, brushed, and slapped in an effort to keep them clear. Wire screens are removed when badly clogged and left to become dry, when they are brushed and slapped. Tinned-iron screens are not as strong as the iron or steel-wire or plate-screens, but they are cheaper. Perforated screens usually break close to the screen-frame. In such a case a piece of wood 1½ in. square, and slightly longer than the break, is covered with canvas or a piece of blanket on two sides, and attached to the frame by one or two short nails to cover the break until it is convenient to remove or turn the screen-frame.

A strip of canvas or gasket-rubber between the screen and the frame will prolong the life of the screen. A good way in which to attach screens to the frame is to punch them over a template to fit small bolts in the screen-frame, bolting in place by means of strap-iron, using a hand socket wrench for the nuts. Strap-iron at the top and bottom of a screen is a good protector. Some success has been attained by having two heights of screen-frames, so that when the screen is well worn at the top and bottom, after turning the screen-frame, it may be transferred to a narrower frame, the worn parts now coming in contact with the frame.

It has been found advisable to set the screen in the mortar at an angle from the vertical, in order that the pulp, besides being driven through the screen, may fall on it and run through as it flows down after the splash. An angle of 10 to 13° from the vertical has been considered sufficient. It would appear that the proper angle of inclination of the screen would be dependent upon the manner of operating the battery, whether using a high or a low discharge.

CHAPTER IV.

The feed-water for a battery should be introduced into the top or into the feed-mouth of the mortar, using a pipe on each side because it may be thought necessary to introduce more water toward one end of the battery than the other. The valves should be accessible from the front of the mortar, and there should be two to each pipe; one being a globe-valve by which the exact quantity of water used is regulated, and the other bibb or plug cock. When it is necessary to shut off the feed-water, the plug cock is used, and when starting again, it is thrown wide open. No time is thus lost in adjusting the amount of water, as that is provided for by the globe-valve. The water-supply should come from a tank having a constant head, for there should be no variation in amount of water flowing over the plates. Where the water is returned for re-use, or is received in a storage tank, this tank should have large area in order to avoid a rapid reduction in the head. The main water-supply pipes entering the mill and running the length of the batteries should be of large diameter so that the amount of water passing into one mortar may not be decreased or increased by starting or stopping the flow into the other mortars. When crushing in cyanide solution, the pipes should be of large diameter and easily taken apart as they become gradually encrusted. Launders have been used instead of pipes.

Attempts have been made to introduce the water in the front or rear of the mortars and on a level with or just below the tops of the dies. The arguments advanced are that the finer material is thus floated up and out of the mortar, and that the pulp just below the face of the die is kept active, permitting the amalgam to sink into it and be caught. It would require a higher head of water than can ordinarily be obtained, and in fact higher than it is desirable to use, to overcome the violent pulsations imparted to the pulp by the falling stamps and to give a classifying effect in the mortar; and should it overcome these pulsations, the result would be to interfere with the even distribution of the pulp over the dies. On account of the wearing of the dies, it is impossible that the feed-water should enter at the proper point in relation to the face of the dies for any great length of time. Where the water has been introduced in the rear of the mortar, it has been found that when the dies are nearly worn out and the screen is consequently set low, the water shoots across the mortar and through the screen. Furthermore, it is almost impossible to maintain a water-tight connection between a pipe and a mortar.

Should the feed-water be shut off, the stamps must be hung up with all possible speed, for they will sink down through the pulp to the die and continue falling until the mortar is full. Owing to the absence of water, the pulp does not run out nor splash back under each stamp.

The amount of feed-water used in a mortar is gauged by the flow of the pulp over the plates, the water being used in such quantities as to give ideal conditions for amalgamating on the plate-tables, rather than to supply the quantity that will give the greatest crushing and screening effect in the mortar. The amount of water used per ton of ore stamped varies from 4 to 10 tons. Where effective amalgamation takes place on a short apron-plate, 6½ tons will be about the average amount. The crushing capacity of a battery increases with the amount of water used, up to the point where a good splash or wave motion on the screen can no longer be secured. This increase in capacity is more noticeable in a mortar with a deep discharge than with a shallow one, for such a mortar sizes and discharges to a much greater extent than one with a low discharge. If large quantities of water are used the amalgamation is usually not so effective, long outside plates and auxiliary amalgamating devices then being required.

The height of drop to be given the stamps depends on the size and hardness of the ore, on the weight of the stamps, and to some extent on the treatment required for the ore. Hard ore will require a heavier blow and consequently a longer drop than soft ore. Similarly a small piece of ore will not require as hard a blow or as long a drop as when coarse. Consequently a hard, tough ore should be broken finer in the breaker than soft, brittle, friable material. The stamp-battery does not crush altogether by catching each particle of rock between the shoe and die, but mainly by the attrition of the particles of rock upon each other flying from the impact of the falling stamps. This is the reason why the limit of economy can be passed in fine crushing in the rock-breaker. It would appear that the size to which the ore should be broken in the breaker would have some relation to the thickness of the bed of pulp, but in actual practice the softness and nature of the ore is the determining factor. Millmen prefer to have the ore broken to what may be termed 'a medium coarse size,' rather than pulverized fine, as such ore feeds better and causes the battery to work more evenly. Also some ores that are soft or brittle rather than hard, tough, and close grained, appear to crush faster when containing coarse material which increases the attrition. This point should be investigated in determining the proper size for preliminary crushing in the breaker. To crush a hard rock to a size approximating ¾ in. diam., and a soft rock to 1½ in. would appear ideal, but in practice it is all crushed to a maximum diameter of 1½ to 2½ inches.

For a hard ore a drop of 7 to 10 in. is usual; for a medium ore from 6 to 8 in., and for a soft ore from 4½ to 6½ in. Increasing the weight of the stamps, and breaking the rock finer in the breaker permits a shorter drop to be used. As the height of drop is lessened, the stamps should be run faster on the principle that they should drop as fast as possible; the increased speed thus offsets the loss of crushing power through shortening the length of drop. A short drop and higher speed indirectly increases the capacity by keeping the finer material in better suspension and by washing it out of the mortar faster. Too short a drop may not allow the die to become covered with pulp. The speed at which stamps can be run safely has been worked out mathematically, but the millman desirous of maintaining a high tonnage will run the stamps as fast as possible up to the point where the tappet just stops short of falling on the cam when the stamp is at its maximum height of drop.

In the older mills the stamps weighed 500 to 750 lb.; this has been increased until in America the weight of a standard stamp with a new shoe is 1000 lb. Extended experiments made in some large mills have indicated that to be the best weight. The reason given is that a heavier stamp crushes more ore than the plates can handle. In South Africa the tonnage has increased with the weight of the stamps, the favorite weight of stamps now being 1500 to 1750 lb. Capacities higher than 10 tons per stamp with coarse crushing are reported. A large mill is now under construction that will have 2000-lb. stamps. Attempts have been made to show theoretically that this is beyond the economic weight for a stamp, but only actual experience can demonstrate this.

The weights of the different parts of a stamp are approximately: stem, 43%; tappet, 15; boss, 26; shoe, 16. The weight of a stamp may be increased in two ways, by placing an extra tappet on the stem, either above or below the upper guide, or by using a false-shoe; this shoe is identical with the regular shoe used, with the exception that it has a socket similar to the shoe-socket of the boss. The false-shoe is first put on in the usual way, after which the crushing shoe is put on. It has been impossible to get millmen to take an interest in any of these ways of increasing the weight of a stamp when the shoe is worn down, though the decrease in capacity is readily noticeable, especially with the lighter stamps.

What determines the weight of stamp to be used? Properly, the hardness of the ore and the tonnage desired, but ordinarily, custom. That custom regulates the weight is proved by the fact that though it has been fully demonstrated that the tonnage increases with the weight of the stamps, hardly any attempt has been made to increase their weight in the many installations made in the past few years where amalgamation is not practised. Most of these stamps have weighed 1000 lb., a few 1250, and more rarely 1500. Even if amalgamation is to be practised, heavy stamps should be employed, as some system of handling the pulp can always be devised. Heavy stamps cost so little more to install and operate, that their increased tonnage capacity comes almost as a gift. A stamp lighter than 1000 lb. should only be ordered for an extremely soft ore, for should the stamp break through the bed of pulp and strike the die, a shorter drop can be used. The heavy stamp is well adapted for coarse crushing, and with the increasing use of Chilean and tube-mills for fine grinding it may be expected that heavier stamps will be used. There is no reason why a modern stamp-mill should not be equipped with 1500-lb. stamps, and arrangements made to divide the pulp between two amalgamating tables placed one in front of the other.

The capacity of a first-class modern stamp-battery in America can be estimated at 4 tons per 24 hours through a 30-mesh screen. There are so many varying factors that the tonnage ranges from 3 to 6 tons, but 4 will be found the average capacity.

The height of discharge to be used depends upon whether coarse or fine crushing is to be done; whether an attempt is made to catch much of the gold in the mortar or not; whether it is desired to prepare the gold for amalgamation by keeping it longer in the mortar, as with 'rusty' gold requiring abrasion; also whether capacity is desired or the crushing is being done for concentration.

When the discharge is kept as low as possible without punching or wearing out the screen too fast, that is, with a 1½ to 2-in. discharge, the greatest capacity results, and the sizing is more evenly done up to the point where the screen openings are enlarged by the violence with which the pulp is forced through them. The minimum of sliming is then done, and consequently the low discharge is the best for concentrating purposes, as it affords the best opportunity for the sulphide liberated from the gangue to be discharged from the mortar as soon as crushed to the screen size, instead of being crushed and slimed still finer, as would be the case with a high discharge. The loss in concentration is mainly in the slimed sulphide.

As the height of discharge is raised, the pulp becomes finer, is slimed more in comparison to the size of the screen used, and is more unevenly sized. A large amount of pulp is retained in the mortar, perhaps two or three times as much as with a low discharge, so that the gold remains longer subjected to the action of the stamps, and has less prolonged contact with the quicksilver and inside plates. The gold also receives more abraiding and polishing by the stamps and pulp, which may or may not be an advantage, depending upon the amenability of the gold for amalgamation. As this pulp is hurled less violently through the screens, and washes over a lesser area of the screen-surface, and consists of the upper, more dilute, finer portion, the capacity is reduced. The sulphide from its higher specific gravity tends to settle upon the die and is crushed finer than the gangue from which it is liberated, in proportion to the height of discharge and the slowness of the drop. This is seen in the Gilpin county, Colorado, practice where a 16-in. drop, with 30 drops per minute, and a 13-in. discharge, together with a wide mortar, are used so that the sulphide may be thoroughly slimed and may thereby liberate its mechanically-held gold for amalgamation. Where concentration is to follow crushing the exact reverse of this practice is used.

A high discharge, 5 in. at least, is necessary when using a chuck-block plate, that scouring of the plate may not take place. Where considerable wood enters the mortar with the ore, a low discharge is sometimes used that the wood may be caught under the stamps and thoroughly reduced to pulp for passing through the screen; or a high discharge is used where the shoes are not lifted out of the water so that the wood may collect in a line along the screen and be removed by the hand or a straining spoon of wire introduced through a curtain or swinging wooden door above the screen.

A mortar having a low discharge where the faces of the shoes are raised out of the water and the pulp is violently splashed over the screen surface is called a 'splash' mortar or battery; while a mortar having a high discharge where the shoes are not lifted out of the water and the pulp runs along the screen in waves is said to be a 'wave' mortar or battery.

In feeding a battery the feed should be kept 'low', as can be ascertained by feeling the stem as the shoe strikes. Should the stamp strike a well-cushioned blow, the feed has been too 'heavy', and there is too thick a bed of pulp on the dies to get the maximum crushing effect. Should it strike with a jar, or rebound, the feed has been too low, and there is too thin a bed of pulp on the dies to get the maximum crushing effect, or to prevent the shoe and die from chipping, and the life of the stem will also be shortened. The stamp should strike a hard, firm blow, just barely cushioned on the pulp, without jar or rebound. The beginner in feeding should first set the feeder so that it works at every drop of the feed-stamp without over-feeding the mortar, then by adjusting first one way and then another, in connection with feeling the stem, a point will be found where it is apparent to the eye that the maximum that the stamps can crush is being delivered into the mortar. By feeling the stamps now, it will be found that they are barely cushioned on the pulp from jar and rebound.

The power necessary for operating a stamp-battery is made up of three factors. The first is the nominal horse-power required to raise the stamps without reference to friction; this is the power directly expended in crushing. By remembering that a horse-power is the expenditure of 33,000 foot-pounds of energy per minute, the horse-power can be computed at any time without the use of a formula by multiplying the weight of the stamp by the length of drop in feet and this by the number of drops per minute, which will give the number of foot-pounds expended in lifting the stamp during a period of one minute, and dividing by 33,000. As the stamp appears to rise slightly higher than its drop, as measured and computed when at rest, it is best to use the maximum height of drop rather than the average in computing.

The second factor is the power-demand due to friction—that of the stem in its guides, which is small and is mainly due to the side-thrust of the cam striking the tappet away from the centre of the stem; the friction of the cam on the tappet, and to that of the cam-shaft in its bearings. This power requirement is somewhat variable, but according to the generally accepted formula of Henry Louis, it amounts, in a 10-stamp battery, to 20% of the nominal horse-power required to raise the stamps. The sum of these two powers is the amount that must be applied to the pulley of the cam-shaft. Special attention is called to the fact that in the literature dealing with the computation of power required by stamps, reference is made to this power only, which is usually spoken of as the theoretical horse-power.

The third factor is the power consumed by the friction of the driving belt between the line-shaft and the cam-shaft, the belt-tightener, the line-shaft itself, and by the belts and intermediate shafting between the line-shaft and the source of power. The power consumed in the driving engine or motor in overcoming its own inertia and friction, and in the conversion of one form of energy into another, may be included in this, though properly it should form a fourth part. This third part of the power is extremely variable, and may range from 10 to 40% of the entire power consumed. Consequently the greatest care should be exercised in designing and constructing a mill and in selecting the machinery, that the amount of power required may be at a minimum instead of expending a large part in uselessly racking, wearing, and tearing the machinery and building. The abnormal loss of power in this way as observed in stamp-mills, outside of that lost in the engine or motor (the type and size of which needs to be carefully looked into), may occur from a multiplicity of belts and shafts, shafts located too close together, and of too small a diameter, narrow belts and pulleys of small diameter, loose and slipping belts, belt-tighteners excessively tight, insecure foundations, and unstable framework. When a bearing-box is running warm, power is being unnecessarily consumed. A change of lubricants, or a change to ring oilers or to constant-drip oil-cups, may effect a saving. Where a mill is built of green timber, the boxes will need occasional readjustment, owing to the warp of the timber. Dust from the breaker and from dumping ore in the bins settles in the cam-shaft boxes, and on the faces of the cams which increases friction and the power consumed.

The examination and correction of power-losses is a painstaking task and is often neglected, especially in the smaller mills, not being apparent, and through not realizing the amount that a small saving in this direction will reach in the course of a year.

It can be understood that it is impossible to give any accurate coefficient that will give the sum of these three parts of the power, or of the actual horse-power consumed by a battery having an independent source of power. It may be approximated by saying that in a good installation of say 40 stamps, this actual horse-power consumed will amount to 1.35 of the nominal horse-power required to raise the stamps, but that in a small installation, or where the efficiency of the engine or motor is low, it may amount to more than this figure.

Various types of 'individual' stamps have been brought to the attention of the mining fraternity, but they have been generally more or less unsatisfactory, partly through inherent defects in the idea, and partly through the general mill details being improperly worked out. The first disadvantage of this type is that they are built in units of 2 or 3 stamps each, each unit requiring the same space as one standard 5-stamp battery. A summing of the extra parts required to make up the equivalent of a standard 5-stamp battery with individual units will show that the cost of the finished individual-stamp mill may be nearly double that of the standard type of the same number of stamps.

The great argument has been the increased screen surface. This cannot be denied, but in answer to the question as to whether it is desirable, or not, attention is called to the large number of double-discharge mortars in use with their back discharges closed up. In the 5-stamp mortar there are from 500 to 550 blows struck per minute, divided evenly all over the mortar; this results in the pulp being splashed over the screen surface all the time, the whole length of the screen being in continuous use. Whereas, in the individual mortar there is only one-fifth the number of blows and consequently the screen surface is not in continuous use. The action of the pulp within the mortar should be carefully studied in comparing the individual stamp with the standard.

With the quadruple-discharge, there are four screens and one feeder to each stamp, or 20 screens and five feeders to be given attention for each 5 stamps, in comparison to the one large screen and feeder of a standard 5-stamp battery. It is impossible to keep an even height of discharge with the quadruple-discharge mortar, and this results in severe wear and tear on the screens before the dies are worn down. They overfeed easily, particularly when running on fine ore and using a short drop; this may be due to the large screen area, as the same trouble has been noticed in the double-discharge 5-stamp mortar, or to the fact that there are no neighboring stamps to throw the pulp back on the die. It is almost useless to feed quicksilver into the mortar and it is seldom attempted.

The reports of those using these stamps in actual practice is that they give little if any increased tonnage over the ordinary stamps. Where they have been run to an advantage has been with a large quantity of water and with heavy stamps, conditions that are enabling the

South African millmen to obtain a capacity of from 7 to 9 tons per stamp. The good showings in capacity and absence of slime has been made by using a minus height of discharge and with so much trouble from screen breakages that no experienced millman would attempt to run a standard battery in that way.

Until the claim of increased capacity is positively proved, it will be contended that the cost for power per ton crushed is higher rather than lower than with the standard battery, for the reason that the cam-shaft of the individual battery is identical with that of the standard, with the exception that it raises 4 or 6 stamps instead of 10. Consequently the power per stamp required to drive the shafting, independent of raising the stamps, in the individual mill is from 1⅔ to 2½ times that required for the standard battery. It is only fair to add that a material increase in the capacity would offset this increase in power required per stamp.

The cost of operating the individual stamp is much higher than with the standard. This is due to the extra cost and loss of time from screen troubles and to an excessive amount of general repair work. Also from the fact that they are harder to operate than the standard. In a certain large individual-stamp mill not practising amalgamation, and where the arrangement and construction is good and operations are well-systematized—one batteryman with a helper attended 54 stamps—equivalent to one man running 27 stamps. Under identical conditions with the standard type, one batteryman would be running 80 or 100 stamps. At another, an amalgamating mill of the individual type having 18 stamps, one man was barely able to handle the mill on the evening and midnight shifts, and when wet ore began interfering with the operation of the small feeders, two men were required for these shifts.

While the individual stamp is a unit that can be repaired without stopping the adjoining stamps, the loss of running time in such a mill is actually greater than in the standard mill, due to the extra repairs, changing screens, and other work. There is an extra loss of time through the increased number of plate dressings required in outside amalgamation, the number of dressings being double that required when quicksilver is fed to the mortars. The advantage of the individual mortar is that the feed of each stamp can be regulated to get the greatest crushing effect, whereas with the standard battery and a lazy millman, a few stamps in a battery may be dropping hard and crushing fast while the others are being cushioned and crushing little.

In crushing for concentration, an ore, the sulphides of which exhibit a tendency to slime, the individual stamp may be an advantage; but in most cases, and especially where amalgamation is to be practised, it cannot be recommended.

Part II

AMALGAMATION

CHAPTER V

Mercury is classed as a metal, and is unique in that it is liquid at ordinary temperatures. It is commonly called quicksilver on account of its color and activity; in mills it is also spoken of as the 'silver' or the 'quick'. It is 13.6 heavier than water. It freezes at —40°C. It vaporizes little or not at all at ordinary temperatures, but the tendency to vaporize increases with increase of temperature until at 212°F. there is danger of salivation in approaching it. It boils at 680° F. It is insoluble in water, but violent agitation causes a little of it to be taken up mechanically in a fine state of division by the water. It combines chemically with certain substances to form two series of compounds, mercurous and mercuric. It combines mechanically with other metals to form alloys called amalgams. Mercury is readily dissolved by strong nitric acid, and slowly by the dilute acid. It is not dissolved by hydrochloric acid. It is dissolved by hot concentrated sulphuric acid, but not by the cold acid. Metallic mercury is slowly dissolved by weak or strong solutions of potassium cyanide or of sodium cyanide; the rate of dissolution increasing with the strength of the solution; the compounds of mercury are more readily attacked by these solutions.

Mercury alloys directly with most of the metals to form amalgams. When the proportion of the mercury is small, these amalgams are hard, solid, and crystalline; as the proportion of the mercury increases the amalgam becomes pasty, and finally liquid. Gold, silver, copper, lead, zinc, tin, cadmium, bismuth, tellurium, sodium, and potassium unite directly with mercury; the latter two requiring heat to combine actively. Iron, especially when in a fine state of division, can be caused to unite with mercury by means of sodium amalgam. Antimony and arsenic unite with mercury when heated. Chromium, manganese, platinum, aluminum, and nickel will unite with mercury by the employment of the electric current and by other indirect means.

Pure mercury is not affected by the air at ordinary temperatures, but when impure, its surface becomes coated and tarnished with compounds of the base metals, oxides, sulphates, chlorides, and sulphides, and probably to some extent by mercuric oxide and sulphide. Impure mercury can readily be recognized, since its surface will not appear bright, nor its globules spherical and tending to quickly unite with one another when brought together. When rolled about, the globules will be sluggish and will elongate to a tail and leave a black film behind. Oils and organic substances also tend to render mercury impure. When it breaks up into extremely minute globules, it is said to have 'floured', and will readily float on water and when these refuse to coalesce again, the mercury is said to be 'sickened'. Shaking the mercury in the presence of detrimental substances, or stamping in the mortar energetically, promotes 'flouring', and in the first case 'sickenening' as well. Each one of the 'sickened' globules of mercury is surrounded by a film of foreign substance, quite often an oxide or other compound of a base metal. Various methods are used to restore the mercury to its normal condition. Cyanide of potassium is beneficial through neutralizing the grease, and abstracting the oxygen from the oxides. Likewise sodium, by its affinity for oxygen, reduces the oxides of the base metals which are coating the globules of mercury, and as sodic oxide is soluble in water, it can be removed by washing, while the base metals enter the mercury forming amalgam. After treatment with these powerful alkalies the mercury is in condition to do good work, but owing to the tendency of the base metals to again oxidize, the relief is only temporary; consequently an attempt should be made to remove the base metals entirely. Retorting will best accomplish this, if carried on at moderate heat, though probably not completely, as some of the base metals, such as lead and zinc, may distill over, particularly at high heat. Purification by chemical means is easier and better. This can be accomplished to some extent by employing sulphuric acid; better by hydrochloric, and still better by nitric acid; the acid being dilute in each case. For this purpose the mercury should be placed in a glass or glazed vessel that will not be attacked by the acid, with a solution of one part nitric acid and from five to ten parts of water, and allowed to remain for at least 48 hours with frequent stirrings that all the base metals may be dissolved. Besides dissolving the base metals that contaminate the mercury, the acid will also dissolve some of the mercury, when, should it crystallize, more water and a little acid should be added that the mercuric nitrate may be kept in solution. The mercury in solution as mercuric nitrate will be precipitated when more impure mercury is added, by the base metals replacing the mercury to form nitrates of themselves. By suspending a piece of copper in the solution, the mercury in solution can be completely precipitated. The mercury should be washed to remove all traces of the acid before being used. Since impure mercury does not attach to gold with the facility that pure mercury does, and as it is liable to become 'floured' and 'sickened' and thereby result in loss of both gold and mercury, as well as to cause base metals to enter the bullion, the purification of the 'quick' should always be given the necessary attention.

Mercury 'wets' those substances with which it amalgamates just as water wets an ordinary substance, forming a thin film of amalgam about them by the absorption of the mercury. The surface tension of mercury is very high and its tendency is to pull within itself, or below the surface, any substance that amalgamates with it; in this way the particles of gold arrested on an amalgamating plate disappear below the surface. In the case of those substances with which it does not amalgamate, its surface tension acts negatively and it is strongly repellent to them. Gold amalgam containing 90% of mercury is liquid, with 87½% pasty, and at 85% mercury, the amalgam crystallizes.

In crushing an ore for amalgamation, the aim should be to crush just fine enough to liberate the gold from its matrix of quartz or other mineral that these golden grains, or flakes, may be exposed to and caught by the aid of mercury. Too coarse crushing will result in the gold not being liberated, but still enclosed in the gangue rock so that the mercury is unable to reach it. Too fine crushing may result in beating the gold up into flakes so fine that it can hardly be brought into contact with mercury, or may possibly coat it with a film so that it will not readily amalgamate.

Mercury is fed into the mortar that it may come in contact with the gold as soon as liberated from the rock by crushing. The action of the stamps causes the mercury to become finely divided and to be intermingled throughout the pulp, thus 'wetting' a considerable amount of the gold. Part of this gold sinks about the dies as amalgam, part is caught upon the inside plates, if any are used, and part passes out through the screen. That gold which comes in contact with the mercury while in the mortar and which passes through the screen, is, in virtue of its being encased in an envelope of mercury, larger than the original native golden grain before being coated by the mercury; this, in connection with the coating of mercury, enables the lip or apron plate to easily catch it. Gold that is not so 'wetted' is harder to catch and may travel farther away from the mortar.

The part of the gold which is won from the mortar-sand is found, not in the sand resting on the dies when the mortar is opened, but in that below the level of the face of the dies. Where no mercury is fed to the mortar, this will be as coarse gold, but where mercury is fed into the mortar, it will be found as amalgam. This amount of gold retained in the mortar-sand will vary with the time the gold has been accumulating in the mortar and with the height of discharge. A wide mortar with a high discharge carries double or treble the amount of pulp a narrow mortar with a low discharge will carry. In such a 'wave' mortar it will be hard for the coarse gold and amalgam to escape as their higher specific gravity will cause them to sink down through the pulp rather than to rise and pass out through the screen, while in the 'splash' mortar they will be thrown through the screen with little regard to their specific gravity. The amount of gold retained in the mortar will also vary with the size of the particles of gold; thus, with fine gold there will be very little caught in the mortar-sand, while with coarse gold the percentage will be relatively high.

The 'chuck-block' is a piece of wood fastened to a strip of the same material, the latter resting beneath the screen in the screen-frame slots of the mortar. Its purpose is to fill a portion of the surplus horizontal space between the dies and mortar lip and screen frame. The chuck-block is sometimes lined with a copper amalgamating plate, called a 'front inside plate' or 'chuck-block plate.' Its function is to catch and hold upon its surface as much gold in the form of a hard amalgam as possible. On account of its close proximity to the stamps, this plate is subjected to much scouring action by the pulp, which increases as the chuck-block is moved nearer the stamps, or the height of discharge is lowered, so that mortars for using inside plates are wide, 14 to 18 inches across inside of mortar at the lip.

The height of the chuck-block can be varied by inserting beneath it and in the screen-frame slots, strips of wood of varying thickness, usually 1 in., and these may be removed as the die wears down, thus maintaining the height of discharge uniformly with reference to the top of the die. It is not an uncommon practice to fasten securely a strip of iron ⅝ by ½ in. to the face of the chuck-block, extending horizontally its entire length. Where the ore is low grade and the discharge low, amalgam will accumulate along the upper side of this iron rib, in the angle formed by it with the copper plate.

The common form of a curved chuck-block is apparently wrong, for it is this curved part or 'belly' that is in the best position to be scoured. A good method of making a chuck-block is to take a piece of 2 by 6-in. sugar pine and rip it diagonally across the ends, making two triangular sectional lengths. Attach one of these to the strip that rests in the screen-frame slot by bolts a foot apart, using a piece of strap-iron in connection with these bolts to hold the lower end of the plate in position and as a protection against its being torn loose. Scouring can largely be prevented by protecting the plate with a heavy wire screen of quarter or half inch mesh, spaced from the plate by a nut on each bolt that attaches this screen to the chuck-block.

A copper plate is sometimes bolted to the back of the mortar, this is called a 'back inside plate'. On account of its location it is hard to handle and to get at, and consequently is seldom used. These 'inside plates' were formerly used in nearly all mills, while today they are seldom seen; the tendency of modern milling is to eliminate them entirely. A chuck-block plate can be 'run' in the narrow mortar, twelve inches wide at the lip, generally used today, by employing a sufficiently high discharge and considerable care. A back plate can be used in these mortars if it can be set six inches above the dies. It should be bolted through the mortar and have two sets of bolt holes, that it may be adjusted to the wear of the dies.

These plates are usually of raw copper $^3/_{16}$ to $^1/_4$ in. thick, that they may not easily be dented or worked out of shape and may stand the excessive wear. As they are cleaned of the amalgam by being chiseled and are liable to be scoured, silver-plating is an unnecessary expense. They are cleaned every 10 to 30 days on low-grade ore. Where the mortar sand is not removed at this time, an extra chuck-block is kept on hand and is merely substituted for the enriched block after being burnished and dressed with mercury. These plates must be carefully watched. They are especially hard to start and may give the amalgamator some anxiety before a film of amalgam is deposited over the whole plate. No bare spots should be allowed as they tend to spread.

These plates should not be kept soft or the amalgam will slough off, neither should the amalgam be kept hard to the point of being brittle, for such amalgam will not withstand the action of the moving pulp to the extent that a softer, more tenacious, slightly yielding one will, nor so readily catch the gold and amalgam. When using inside plates, mercury is fed to the mortar according to the appearance of the lip plate outside and an occasional examination of the inside plates, usually that on the chuck-block. This examination of the chuck-block can be made without removing the screen, by using a canvas curtain instead of a board to close the opening in the mortar above the screen; the feed water is shut off and as soon as the water is stamped out of the mortar, the stamps are hung up; a small stream of water is run along the screen to wash off the chuck-block, when the curtain is removed and the plate inspected. Should there be a bare spot, it is burnished and a little mercury or soft amalgam is well rubbed in. After some experience the amalgamator is able to roughly judge the condition of the amalgam by reaching in with his hand and feeling the amalgam without stopping the battery. When using inside plates the greatest care should be exercised that the feed is kept just right and that no over-feeding or choking of the mortar occurs. For this purpose careful chuck-block operators remove the splash board from in front of the screen, that any change in the splash or wave of the pulp may be readily discernible; over-feeding is indicated by a line of pulp appearing, 'banking', at the lower edge of the screen and gradually rising.

The use of inside plates increases the saving of gold inside the mortar, by catching and holding a large part that would otherwise pass out through the screen. This was formerly considered desirable practice, but the use of narrow mortars, heavy stamps, and low discharge have individually and collectively made good inside plate work difficult, so that the sentiment is now rather against their use. The two claims made in their favor are, that they should be used when running on high-grade ore with the idea that the smaller the amount of amalgam to be handled on the outside plates (referring especially to the apron plates), the smaller the loss will be, and that by their use fine or refractory gold can be caught that cannot otherwise be saved. The arguments against their use are, that they necessitate a high discharge which cuts down capacity and may cause overstamping, and that they place the gold, or rather the amalgam, where it can be easily scoured off and lost should the mortar overfeed. On opening a mortar that has been overfed, and has run choked for some time, the upper part of the chuck-block plate will usually be found to be freshly scoured, sometimes down to the copper. This scoured amalgam being hard and dry, has been found difficult to arrest on the plates unless they are quite wet with mercury, consequently some of the amalgam passes beyond the plates and traps and is lost.

Inside plates should only be used where it is proved that more gold can be caught by their use than without them, and such cases will be rare. In all ordinary cases, more gold will be saved per ton, a greater tonnage crushed and more satisfaction in operating obtained without their use. When they are needed, it would appear well to employ both a front and back plate with the idea of getting all the advantage there may be in their use; usually there is no back plate on account of their trouble and inconvenience due to their position; moreover, they cannot be placed in some mortars.

CHAPTER VI.

The 'splash-plate' is placed in front of the screen, being fastened to the mortar or battery posts, so that the pulp flowing or splashing through the screen may fall or impinge upon it, run down its surface, and drop on the head of the 'lip-plate', which is a copper plate resting on the lip of the mortar and held in place by the chuck-block, the screen frame, or otherwise. The advisability of the splash plate is a matter of individual opinion usually, and is not used in all cases. The conditions under which work is largely done today are with a fine gold, low-grade ore, and a required large capacity, necessitating a narrow mortar and low discharge, which in general prohibit the successful use of inside plates, or of the catching of much gold in the mortar sand. The amalgam on the splash and lip-plates is hard, with little tendency to run and slough off, or to granulate and break away, consequently here is a good place to hold it—a better place than on the inside, or on apron plates, but not as good as in the mortar sand. Various forms of splash-plates are in use. Besides that the pulp, after passing through the screen, shall impinge upon this plate and run down to the upper part of the lip-plate, the general requirement is that they be easily handled when necessary to remove them to open the mortar, and that in connection with the lip-plate they present a large surface.

The function of the lip-plate is the same as that of the splash-plate, to catch and hold the particles of 'wetted' gold and amalgam that have passed through the screen, and consequently their purpose, condition, and treatment is in every way similar. Due to the hardness and dryness of the amalgam on these plates, it is supposed that but little native gold, without any wetting of mercury is caught here, since there is no surplus mercury to wet the particles. The lip plate is as long as the mortar lip on which it rests and ordinarily six to seven inches wide, which is entirely too narrow. Every mortar should be so built that a distributing or collecting box can be fitted to it at the lip. This is an iron box bolted to the mortar to extend the lip. This gives a firm backing to the lip-plate which may be as much as 18 in. wide. These boxes distribute the pulp across the head of the apron plates through from 8 to 16 holes, so that by plugging up some of the holes, if necessary, an even distribution can be secured where the discharge is not uniform across the full length of the screen. They form a projection over the apron-plates, preventing leakage; and by not requiring close contact with the mortar, prevent the apron-table from being jarred. The lip and splash-plates are burnished and dressed with mercury when put in position after being cleaned up. They receive no further dressings unless their surfaces become fouled with some base metal such as zinc, lead, or babbitt that has accidentally fallen into the mortar, or by some compound in the ore itself. In such case the plates will receive a stiff brushing to remove the foul film and all loose material on the plates will be collected and saved for treatment at clean-up time. The lip and splash-plates have their amalgam chiseled off semi-monthly when running on low-grade ore. An extra lip-plate is kept on hand that the battery need not be stopped longer than to make the change.

Like the inside plates, the lip and splash-plate need be of unsilvered copper only. The lip-plate is subjected to considerable abuse and should be ¼ in. thick, while ⅛ or $^1/_{16}$ is sufficient for the splash-plates.

Following the lip-plate and independent of the mortar is the 'apron-plate', mounted on a platform called a 'table', usually built of wood. This plate is slightly wider than the lip-plate and from 8 to 28 ft. long and sometimes longer, in which case they are built in two or more sections in series. The apron-plate is not intended for catching the bulk of the gold, except where no mercury is fed to the mortar, but more particularly for that which has escaped being caught on the plates above. Consequently it requires the greatest care and attention to keep it in good condition to catch gold. The flow of the pulp on the apron-plate is distributed in such manner as to best enable each particle to come in contact with the plate. Sufficient mercury is kept on it to render the amalgam soft enough to wet any amalgamable gold that may come in contact with it; while the amalgam is kept bright and in an active condition by frequent dressings of the plate.

It is in the care of the apron-plate that the amalgamator takes his greatest pains and pride. Here is found a striking difference in the ideas and methods of different millmen. Some keep the apron-plate hard, even to the verge of the amalgam breaking away, the lower end of the plate becoming quite 'blue', for the purpose of preventing the mercury from working down the plate into the trap and eventually into the creek below. These are said to be amalgamate 'dry', as the plate is kept comparatively dry of mercury. Others keep the amalgam soft and plastic, sometimes overfeeding mercury or dressing the plate so soft that it collects in globules, 'tears', which work down the plate carrying a little gold with it into the traps from which a part of it will usually be lost. This is said to be 'wet' amalgamation, as the plate is kept wet or moist with mercury.

A coarse, easily amalgamable gold will be readily caught on a hard plate, but fine gold requires a soft, plastic sheet of amalgam. A hard plate is not as active in catching gold as a soft one, since it cannot so readily wet the gold, and the surface tension in absorbing the gold into and below the surface of the amalgam is not so great on account of the amalgam being crystalline. The coarse gold, because of its greater weight, sinks through and is dragged along the bottom of the film of pulp, coming in repeated contact with the amalgamated plate beneath, so that with coarse gold this plate need not be so active in wetting and catching it; whereas the fine gold is carried along distributed throughout the pulp and only occasionally comes in contact with the plate, consequently the plate should be in the best condition to wet the gold at the first contact. The coarse gold is more liable to be wetted in the mortar, and when in such condition should be quickly arrested, on even a hard plate. If a particle of hard amalgam or of gold is brushed over a hard, dry amalgamated surface, it will probably not be caught, but if brushed over a soft, wet spot it will quickly attach itself to it. This leads to the inference that a wet plate is the best amalgamator. By keeping them soft they form the best amalgamating surface but if the narrow margin of safety is overstepped, the water or mercury will run off, carrying with it the gold with which it has combined and herein lies the difficulty with wet amalgamation. Given an easily amalgamable ore, the amalgamator may approach dry amalgamation and save the greater time and attention required for wet amalgamation without increasing loss in the tailing.

For cleaning-up and dressing the apron-plates amalgamators who practise wet amalgamation and employ considerable refinement in their methods, use a rag. They remove part of the amalgam once daily when treating an average ore, so that a constant amount remains, taking no more off on clean-up day than on any other day. In this 'rubbing up' some mercury is first sprayed on the plates where needed. It is well rubbed into the amalgam, which is loosened and softened down to the silvered surface. The part of the amalgam to be removed is pushed up to the head of the plate by means of the rag, where it is removed with a scoop. The plate is now well rubbed again, that the amalgam may be softened down to the silvered surface with a view to preventing the formation of a hard film or scale of amalgam; that the consistence and texture of the amalgam may be such as is desired, that the mercury in the amalgam be more securely held by it, and that the amalgam be worked into an active condition. After distributing the amalgam evenly over the plate, it is smoothed down at right angles to the flow of the pulp by using a soft and long-straw whisk-broom. This practice of riffling, or roaching, across the soft amalgam has been condemned by some as wrong for the reason that these riffles catch the fine iron and steel from the battery and sulphide as well, and thus coat or foul the amalgamating surface. The fact that these tiny grooves do act thus, speaks well for their function in catching gold. However, these riffles can be avoided by smoothing the surface of the amalgam with a fine-haired paint or calcamining brush. An experiment should be conducted by brushing one side of a plate crosswise and the other lengthwise to the flow of the pulp. Care is used that all the particles of amalgam are well set, for this reason many amalgamators finally run the brush up and down on each side of the table where there is liable to be loose amalgam in the corners.

They keep a good bed of amalgam on the first section of the apron-plate and less on the following plates. This amalgam, especially that on the first plate, should be of such consistence that it can be pushed up with the finger and remain without flattening out; that it be soft and plastic like putty; that the brush lines do not run or disappear; that it does not run or slough down the plate, as indicated by its being caught lower down than usual and piling up at the drops between plates, and that no tears of mercury appear or hang to the edges of the individual plates. The idea is to keep the plate as wet as possible without losing any of the mercury or amalgam. The loss of mercury carrying away gold is the main argument against wet amalgamation and the greatest care and study should be given to prevent any abnormal loss and yet keep the plate moist. In appearance this amalgam should look neither hard and dead, nor like a mirror, but have a white frosted appearance. It has been said that the plate should have the appearance of a silver dollar; this is correct if the kind of a dollar is stated. The peculiar whitish lustre of a newly minted silver coin is the appearance the amalgam should have; but should the amalgam appear like the ordinary silver coin that has lost its 'youthful bloom', it is too hard, too dead, too crystalline for the good amalgamation of gold that is at all difficult to catch.

The apron-plate is examined at its head at intervals of one-half to two hours, usually hourly, clearing it by means of a stream of water for the purpose of learning how amalgamation is progressing and how much mercury must be fed into the mortar. At first the amalgamator will press or mark the amalgam with his finger to learn its consistence, but in a short time will be able to tell by its appearance alone. After examining the plate, mercury is fed into the mortar; the amount being judged by the appearance of the plate. It should be sufficient to keep the plate in good condition until the next examination. Should the plate upon this inspection have its amalgam of the proper consistence and be wet with mercury to the proper point, a normal amount of mercury, as indicated by experience with that ore, is fed to the mortar; should the amalgam appear hard and dry, an extra amount of mercury is fed; should the plate appear too soft and wet, no mercury is added that it may harden to the right condition by the time of the next examination. The mercury is weighed each morning to ascertain the amount fed to the mortars the previous day. After the plates have become saturated with mercury and loaded with what may be termed their constant of amalgam, the amalgamator divides the ounces of bullion recovered during a stated period by the number of ounces of mercury fed to the mortars during that time and the result becomes a factor by which he estimates the amount of gold amalgamated each day and from this what the month's run should be. With an amalgamator who uses care in feeding mercury and a gold that does not vary greatly in the size of its particles, this is a fairly accurate factor and a satisfactory method, being equal to the haphazard methods of sampling, assaying, and estimating that obtain in many mills.

While it is well to inform the amalgamator whether low, medium, or high-grade ore is being put into the mill, he makes but little use of this information except in corroboration as it is so often unreliable and he is also unable to know when this ore of a different nature is going to reach the mortars. At the hourly examination of the plates, he is able to see how much amalgam is being deposited or built up on the plates, and this is a true index of the gold content of the ore, unless it has suddenly become base or unamalgamable. When mercury is fed in the right quantity and at the proper intervals, very little additional mercury is required in dressing the plates. Where inside plates are used, the lip is used as the outside indicator of the amount of mercury to be fed to the mortar to keep the inside plates in condition; should the apron-plate become dry, a little mercury can be sprayed on the dry spots at the head of the table from a bottle or bag without stopping the battery. If one side of the plate is dry and the mercury is fed to that end of the mortar, the larger part will come out on that side if the mortar is of the splash or low-discharge type.

Amalgam, or mercury containing gold, has a greater affinity for gold than mercury alone. Mercury that has the gold only partly strained out of it is better for amalgamating than gold-free mercury. A bed of gold amalgam is a most active catcher of gold—superior to silver amalgam, and the plates should always be covered with it. Amalgam acts tenaciously in holding the mercury on the plates. New plates dressed with mercury do not give the best results until a bed of amalgam has spread over them, as has been proved by sampling and assaying the pulp after passing over plates when in this condition; consequently close clean-ups with chisels should be avoided unless some of the amalgam is returned to the plates. Such clean-ups, however, in connection with thoroughly rubbing and softening the amalgam, prevents the formation of hard layers of amalgam, but the close 'skinning' of the plate is detrimental to the silver-plating, and some amalgamators will not use even a rubber for removing the amalgam. A rag requires more labor to use and is harder on the hands than a brush, so that whisk brooms are commonly used in dressing the plates, the soft amalgam being pushed to one spot by a worn down or cut off whisk. The last plate, or plates, are kept free from soft amalgam, the object being to run them harder, in which condition they are better able to retain the mercury and soft amalgam that may run down from the upper plates.

Where 'dry' amalgamation is practised, the procedure does not differ materially. In dressing the plates, no efforts are made to soften the bottom part of the amalgam or to keep it soft in comparison with the silver-plated surface; the efforts being confined to putting the surface of the amalgam in good condition for catching the gold. Any soft amalgam that may be considered as surplus is removed, or only that which loosens and breaks away in the dressing, the 'crumbs', is removed; the balance being allowed to remain and become hard until the monthly or semi-monthly clean-up, when it is removed by being chiseled and scraped off, care being used not to reach into the silver-plating. After the chiseling, mercury is rubbed in to soften the remaining amalgam, which is scraped together by a 'rubber'—a piece of pure rubber or rubber belting. At many of the mills where dry amalgamation is in vogue, the plates are 'sweated' at intervals by pouring boiling water on them, or by placing a cover of wood or blankets over them and turning steam or boiling water in underneath. This results in loosening the film of hard amalgam that will always form, especially when amalgamating dry, so that it may be scraped and scaled off. A large amount of gold that would be otherwise locked up on the plates is secured by 'sweating,' but it is destructive to the silver-plating and dangerous on account of the possibility of salivating the workmen. The paternal laws of Australia prohibit approaching a 'sweated' plate until after the lapse of a certain length of time, which makes the 'sweat' of little avail.

As to the relative merits of wet and dry amalgamation: Dry amalgamation answers where the gold is coarse and easily amalgamated, and as it requires less labor and attention, and usually entails a smaller loss of mercury, it may be advisable in some cases. As the gold becomes finer and more difficultly amalgamable, the necessity of amalgamating wet increases. The life and good condition of the plates is increased by amalgamating under the wet conditions described. Where amalgamation is done altogether outside, the plates should be kept wet, certainly wetter than is usual with dry amalgamation, since the gold, not being wetted in the mortar, will have a tendency to slip farther over the dry surface.

For amalgamating on the apron plate, the feed water used in the mortar should be just sufficient to carry the pulp down the table in waves that appear retarded, almost but never stopping, rolling over and over and breaking up, that each part and particle of the pulp may be brought in contact with and dragged over the amalgamated surface of the plate as much as possible. The coarse gold sinks to the bottom of the pulp and is caught, usually on the upper section of the plate, within 2 or 3 ft. of the mortar lip, while the fine gold is carried along by the sweep and rush of the pulp, and being unable to sink through it, must wait until the turning over and breaking up of the pulp finally brings it in contact with the plate. A difference has been noticed in the proportion of the gold to the silver in amalgam caught at the head of the table as against that caught at the foot. This has been credited to the greater ease with which gold is amalgamated than silver, but a sizing of the gold particles in the ore might reveal that the fine gold caught farther away from the mortar contains a higher proportion of silver.

Where difficulty is experienced in amalgamating the gold, or where the plates appear to be too short, less water should be used in the mortar, even if the grade of the plates has to be increased, that the pulp may be dragged and rolled over the plates rather than sluiced. The fall of plates now in use varies from 1½ to 3 in. per foot, and should not be less than 2 or 2½ in. A low fall requires too much water in the mortar to keep the pulp from banking on the plates, to give good apron-plate amalgamation, especially if the ore contains much sulphide or other heavy material. It is better to make the grade too great than too little. There are various methods of constructing plate tables that allow the grade to be easily changed, and it is well to use such construction. Where the pulp has banked on the plate, the careful amalgamator does not hose it off with a large volume of water, thereby losing any gold caught in the pulp or only lightly attached to the plate, or any spikes of crystalline amalgam; he turns on a light stream and slowly and gently washes the deposit away. Some millmen place a stick of wood diagonally on the plate above a bank of sand, diverting the stream of pulp, and thus washing the sand away.

It was customary years ago to use a spray of clear water from a perforated pipe or distributing box at the head of the table to slightly retard the pulp and to cause the gold to settle and attach itself to the plate. The crushing capacity at that time was small, due to light stamps and wide mortars, but with the reverse of these conditions now, all the water that it is safe to use should be introduced through the mortar in the effort to pass the material through the screen as fast as possible. Wherever extraordinarily long plates are required, it will be found that an excess of water is being used, or that the gold is extremely fine. Where extra plates are needed or much amalgam is caught on the last plate due to an excess of water, the pulp should be divided between two short extra tables rather than one long extra table, so as to induce the rolling of the pulp so necessary to good plate amalgamation. Where the plates are so long that the lower plate scours, and much mercury is required to keep it in condition, while it returns no amalgam, the plates may be shortened, or the use of more water in the mortar can be tried. This last should cause the gold to be caught lower down and the lower plates to keep in condition while the amalgamator can salve his conscience for this departure from good amalgamating practice by the increased tonnage due to the use of a larger quantity of water.

A plate requires the constant addition of mercury and gold to keep it from being denuded by the pulp. Running on dumps of extremely low-grade ore, as is so often done before the final shutting down of a mill, has been unsatisfactory in many instances for the above reason. Also, coarse crushing is generally resorted to in the effort to compensate for the low value of the rock thereby increasing tonnage, whereas the gold is usually finer and may require finer crushing to liberate it. Should the plates scour when running on this low-grade rock, a small amount of water should be used in the mortar to induce the gold to be amalgamated on a short length of plate, while removing the lip and splash plates may assist in keeping the apron plates in condition. Clear water will carry off mercury and amalgam and when allowed to run over a plate for some time, the amount should be reduced to just sufficient to keep them wet and prevent oxidation and discoloration.

At many mills running on low-grade ore, or where the value is largely in the sulphide, it is customary to clean and dress the plates without stopping the battery, thus saving the considerable labor involved in hanging up the stamps and the loss of duty in stopping the battery. This can be easily and satisfactorily accomplished by dividing the plate into two sections by placing a strip of wood permanently down the center, and directing the entire flow to either half of the plate by plugging the holes on one-half of the distributing box, usually also cutting down the amount of water entering the mortar. If no distributing box can be bolted to the mortar, the plate table can be built so that a wooden trough distributer can be set beneath the lip of the mortar. At the Empire mill, Grass Valley, California, the tables are so fitted to the mortars that when dressing a plate, a launder of sufficient size and length to carry the flowing pulp to the plate of an adjoining battery is inserted under the mortar lip. At first sight it would appear that overloading a plate in this manner would be bad practice, but the actual experience has been so satisfactory that experiments by sampling and assaying the tailing under the different conditions should be made before condemning this practice at any mill. Mills using these systems generally have long plates. In view of the Empire mill practice, it should be possible to deflect the pulp to a launder or pipe leading to an extra plate set over the concentrating floor or at the side of the mill.

The plate table should be as free from jar as possible, preferably carried up from the ground independent of the flooring and framework of the mill. It has been claimed that the jar is beneficial in promoting amalgamation and attention has been called to the excellent work of shaking plates mounted on vanner concentrators after removing the belt and following the apron plates. The motion these shaking plates receive is an even, gentle, vanning motion like that which causes the gold to settle in the gold pan; while the vibration to which a plate table is subjected from coming in contact with the mortar, or from the jar of the floor, in a poorly built mill, is quite different—one that causes the mercury to exude from the amalgam in globules, and the amalgam to granulate.

Plate tables are commonly built of 1½ and 2 in. plank, laid either lengthwise or transversely, with side pieces of the same material 10 to 12 in. wide. A better method is to use 2 by 4, 4 by 4, or 3 by 5 in. planed, well-seasoned lumber, placed lengthwise of the table, either spiked together or bolted across the width of the table every three feet, and put together with a thick waterproof paint. With such a table there should be no leakage. When drops are introduced they are made shallow, the material being cut out as required. The supports beneath should be as simple as possible, except where rendered complicated by introduction of means for changing the grade. The table should be dressed down to make the center $^1/_6$ in. lower than the edges, or the pulp will riffle toward each side of the table forming washes there and leaving it too shallow in the center.

Drops between the plates are introduced as the gold tends to collect where the pulp strikes the plate; also the farther the pulp travels down a straight plate, the greater its speed becomes, one of the visible indications of which is the increased size of the waves at the lower end of the table. A drop serves to start the pulp off anew and prevent the acceleration of the speed of the pulp, wherefore it is preferable to decrease the grade of the lower end of the table; it also breaks the flow of the waves, thereby giving the fine float and suspended gold a better opportunity to come in contact with the plate, and also induces a more even distribution of the pulp. As the amalgam piles up at these drops, they are much in favor; the general idea being that by increasing the number of drops, the length of the plates may be diminished. This idea is not entirely correct for the amount of amalgam collected at these drops will depend upon how the amalgamation is being conducted. Where too much mercury has been used in dressing the plates or fed through the mortar, the amalgam will run and slough off and collect at these drops, so that the amalgamator when examining the plates, should also use the drops as an indicator. About the only objection to drops is that they interfere to a slight extent with the quick dressing of the plates. A drop of one-half inch is sufficient to give the desired results, and more than three-quarters of an inch is liable to cause scouring. Where a drop scours, a strip of wood should be used as a baffle-board to ease the pulp to the plate.

Blankets can be placed underneath the plates if necessary to even up the table. The sides of the plates should be turned up and the ends slipped well under one another that neither the water nor the mercury may work through to the floor. It is preferable to have the plates held down by side strips and overlapping without the use of screws. Designing the tables so that the plate adjacent to the mortar may be rolled away from the mortar and over the remaining part of the table, or that the entire table may be moved forward is an unnecessary expense, as advantage of this is only taken when removing a mortar or repairing a mortar block.

At one time sluice-plates were in vogue. Following the lip-plate and mortar was one apron-plate the width of the mortar and 4 ft. long. The plate table was then narrowed down to hold three or four plates of half the width of the apron-plate. Only the heavier gold and amalgam could sink down through the flood to which the pulp was contracted while running over these plates, also the tendency of the pulp to scour the plates was increased. These sluice-plates were extensively used at one time, but have been entirely discarded.

The pulp falling from the last apron-plate is collected by a 'tail-box' delivering to a mercury trap or launder. The tail-box should be fitted with what is known as a 'treasure-box.' This is simply another compartment in addition to the one collecting the pulp for the launder; a swinging door, or lid, enables the pulp from the plates to be directed to either compartment. The plate is washed down with a heavy stream of water, preparatory to dressing, into this second compartment; after dressing, the plate is again washed down, this time with a light stream. The function of the treasure-box is to catch the particles of loose amalgam that might otherwise be lost, and also the rich sulphides that have attached themselves to the plate by reason of the amalgamating of an exposed face of contained gold. This box is very necessary when running on rich ore. A portable trough that can be set beneath the lower edge of the plate is used to serve the same purpose. The treasure-box is a handy accessory when the mortar is opened, as the pulp and rock that always litter the mortar lip and upper apron plate at such times is sluiced into the box to be returned to the mortar without getting into the traps or on the concentrators.

A plate should be tried in the tail-box, in the launders, and on the distributing box of the concentrators, but these plates must be dressed at intervals and kept in good condition to enable them to catch anything. Riffles should be placed in the launders or made by notching the bottom plank of the tailing flume, as even with the most careful amalgamating a little amalgam escapes which can be occasionally gathered from them without expense.

Patent amalgamators placed following the apron-plate have been successful in many instances, but it does not appear wherein they are superior to plates except that they may present a larger amalgamating surface, opposed to which is the more refined manipulation that can be practised on the ordinary plate. It is better to make a trial of them rather than an outright purchase. Too often such machines do not get a fair test, due to the inexperience of the millman and to his proceeding on the theory that their introduction in the mill is a reflection on his ability as an amalgamator, as, in truth, it often is.

Where the mercury is fed inside the mortar with the object that the particles of gold may be wetted and that sufficient mercury may come through the screen in the form of amalgam, or in a finely divided state, to keep the 'outside' plates in proper condition, they are said to practise 'inside amalgamation,' though formerly this term had more particular reference to catching and holding the gold on the inside of the mortar. Where no mercury is fed to the mortar, but all is added on the outside plates, and the gold comes through the screens as native gold unwetted by mercury, they are said to practise 'outside amalgamation.'

Outside amalgamation involves no radical departures from the general methods of plate amalgamation, when mercury is fed to the mortar. Lip and splash-plates are dispensed with, all the gold being caught on the apron-plates. A common fault, where outside amalgamation is practised, is that the plates are dressed too wet and then allowed to become too dry before dressing again. This can be avoided and the plate kept in condition by sprinkling a little mercury from a bag on the dry spots at the head of the table without stopping the battery, but it must be carefully done. Of coarse gold the greater part can often be caught on the first 12 in. of the plate surface if mercury is dropped on as required. When mercury is not fed as needed and the plate becomes hard and coated, as quickly happens when treating rich ore, the gold will tend to slip over the dry part and be caught lower down. With outside amalgamation the plates will usually be dressed from two to three times as often as when the mercury is fed through the mortar. Outside amalgamation is interesting and affords excellent opportunity to study plate-work; some experience with it will cause the amalgamator to incline toward wet amaglamation.

As to whether outside or inside amalgamation should be the practice is properly dependent on the ore and the crushing machinery, as indicated by the amount of mercury lost, the increase or decrease in the amount of gold saved, and the ease with which amalgamation can be conducted; but in most cases the prevailing local custom is followed without testing the merits of the other method. The stamping of the mercury in the mortar comminutes it into fine globules; moreover, the tendency of mercury in the presence of water and agitation is to form small globules to some extent which may be carried away mechanically in a finely divided condition. This natural tendency of the mercury to 'flour' is increased when it is impure, or its association with deleterious substances in the ore, so that great loss may result from either of these causes. With a clean ore, the loss of mercury in the practice of inside amalgamation is usually about double that occurring when doing outside work, and with ores containing substances that are detrimental to the mercury, the loss may be five or six times as great. It is impossible to say how much gold is carried off by this vagrant mercury, but it should be less than that indicated by assaying the mercury caught in a newly cleaned mercury trap, as the larger part must be lost in the form of a finely divided mercury that has amalgamated with but little gold. Oil and grease, talcose and clayey ores, arsenic and the compounds of arsenic and antimony are the worst enemies to amalgamation—coating the floured mercury with a film so that is becomes permanently floured, in which condition it is said to be 'sickened.' Oil and grease are particularly bad and every effort should be made to prevent them from coming in contact with the ore, or mortar, or the plates.

Amalgamation in cyanide solution presents no difficulties within the requirements made on it—a close saving on the plates not being essential. The loss of mercury is high as it is dissolved to be precipitated in the zinc boxes. This deposition on the zinc appears to assist the precipitation of the gold and silver, due to the formation of a galvanic couple. The mercury cannot be recovered economically under ordinary conditions. The strength of the solution should be kept down to one-half pound of potassium cyanide per ton of solution to prevent the too rapid dissolution of the plates and mercury, though a solution of two-pound strength has been successfully used. As the life of the plates is limited from six to nine months and the amalgamation rather roughly carried on, silver-plating the plates is an inadvisable expense. No aids or methods of prolonging the life of these plates has yet come into use, notwithstanding the item for renewals is an important one. The lower plate and lower part of each plate is corroded first. As the amalgam is cleaned up the closest from these places, it gives weight to the natural conclusion that a thick coating of hard amalgam would prolong the life of the plates. The cyanide keeps the plates beautifully free from stains as it dissolves the copper compounds as fast as formed, and owing to its low strength does not harden the plates to the extent that might be expected. The plate tables should be built water tight that neither the mercury nor solution may run through, for the plates are corroded irregularly and it may not be convenient to remove them when the first spot appears. Iron tables or those having the bed of plate-iron or steel and water tight would be excellent. Raw copper plates of extra thickness with backs covered with a thoroughly solution-proof paint, in two-foot sections with a drop between each, the sections to be easily and independently removable or changeable, are the lines along which these tables should be designed. The plates should not be allowed to project beyond their backing as the ends are gradually dissolved down to dangerous knife edges. The solution being weak does not injure the hands of the workmen, though it may make them rough at times. Rubber gloves are not required. In designing and building a mill for crushing in cyanide solution, every effort should be taken to prevent the leaking and spilling of the gold-bearing solution, while the floors should be arranged to catch and carry any such solution to a sump tank. The loss from this source is high in some mills.

The apron plates may be of raw copper, but those plated with silver are much preferred. The amount of silver used per square foot varies from 1 to 3 oz. One ounce is sufficient for the upper plates, but the last one should have a heavier coating as the scouring action over it is much greater than above where more amalgam is deposited. These plates are from 52 to 56 in. wide—slightly wider than the discharge to them—and can be obtained in lengths of 12 ft., but are commonly used in sections of 4 ft., and such a section is usually spoken of as a plate. The usual thickness is ⅛ in., though plates $^1/_{16}$ in. thick are in use, but such plates are easily dented by objects falling on them. The best Lake Superior or electrolytic copper is used to insure purity and softness. As these plates are rolled out, which makes the surface dense, in purchasing raw copper plates it should be stipulated that they be annealed; annealing softens the surface of the copper that the mercury may be better absorbed. They can be softened by heating over a fire, but this, if not evenly done, is liable to buckle the plate, so that it is better not to try it, but to use the plate as it is.

Silver-plated apron-plates are used in most mills, and are preferred by amalgamators as being easier to care for. Experiments have shown that a greater saving can be made with silvered plates than with the raw copper. Still, the amalgamator who has handled both and who knows how to care for the raw copper plate, believes that he can amalgamate as well with one as with the other. It appears that the personal equation of the amalgamator's ability becomes a greater factor with raw copper than with silvered plates.

One objection to the use of raw copper plates is the trouble necessary to get them in suitable condition. It requires a few weeks before they become saturated with mercury and while there is not a large amount of gold carried into the copper, there is quite an amount on the surface of the plate which it is not desirable to remove as being prejudicial to the further good working of the plate. The silvered plate has a suitable surface already prepared. The mercury sinks slowly through this silvered surface, so that the plate on the start does not have to be dressed with additional mercury as often as the raw copper, but eventually it absorbs as much mercury as the raw copper plate. The amount of gold carried into the copper has been found to be small, assays of plates in long use showing about one-sixth ounce of fine gold per square foot, consequently the great amount of bullion coming from old plates is from the hard scale of amalgam on the surface, and the amalgamator should aim to keep this as small as possible. Once a raw copper plate is well started and in the hands of a good amalgamator it should do first-class work, but the bullion returned for the first month in operation will be less than if a silvered plate were used. The difference is not lost—the gold is held on the surface of the plate.

To prepare a raw copper plate for amalgamating, it is necessary to clean the surface of all impurities and copper compounds, and to a lesser extent, to soften the copper, after which it is amalgamated by rubbing mercury in. The cleaning is done by thorough scrubbing with fine sand, wood ashes, or slime, using wood blocks, rags, or whisk brooms. Immediately following the burnishing, weak solutions of potassium cyanide, sal-ammoniac, nitric acid, or caustic soda or potash is used with a view to softening the copper. The plate can be amalgamated without any softening in this way, but the mercury is not so readily absorbed and consequently it is a longer process. For this reason one of these chemicals is used in the initial process of amalgamating of a new raw copper plate, even by those who are prejudiced against the use of chemicals on the plates under other conditions. After burnishing, the plate is scrubbed with a 5% solution of nitric acid followed by another scrubbing with a 2½% solution of potassium or sodium cyanide—the acid being washed away thoroughly that it may not re-act to neutralize the cyanide; the cyanide is washed away and followed by spraying mercury (to which it is well to add a little sodium-amalgam), over the plates and rubbing for a long time; mercury is added from time to time and the rubbing continued until the plate will hold no more. With the passing of time mercury is absorbed into the plate as the process is continued until the plate is saturated with mercury, which will take about two weeks, when they are ready for the dropping of the stamps. After the first amalgamating no acid should be used on the plates though the cyanide solution may be used if the mercury does not readily amalgamate the copper. Following the first amalgamating or just before dropping the stamps, the plate should be coated with silver amalgam or the ordinary amalgam, if either can be obtained; this will cause the plate to get into condition quickly and to become a good catcher of gold almost from the start.

Silver-plated copper plates require but little preparation. They should be washed with a weak solution of lye to remove any grease on their surface, and they may be polished with a little slime or ashes, though the latter is not necessary. A long and thorough rubbing in of mercury is desirable. Silver amalgam or the ordinary amalgam should be applied, if obtainable. If amalgam is not applied, then some sodium-amalgam should be added in the mercury to make the plate more active at the start. When starting new plates, a low-grade ore should be run through first, preferably one having a coarse, easily amalgamated gold, certainly never a high-grade ore as the catching power of a new plate is low. After a bed of amalgam is started, a better grade of ore can be milled.

A much discussed question is how to prevent the locking up of a large amount of bullion in the plates. To melt the plates into a bar requires a new set which is costly. While the old set will more than pay for the new, all would prefer some way by which they could 'eat their cake and still have it.' Of this locked-up gold, relatively only a small part is absorbed in the plates, probably $^1/_6$ or ⅛ oz. of fine gold per square foot, and most of it on the surface copper. The major portion of the gold is in the form of a hard scale of amalgam; to remove this scale the copper must be laid bare and will thus have its amalgamating tendency reduced for some time, which means a loss. To resilver the plate is expensive. The wet amalgamator attempts to keep the thickness of this scale at a minimum by softening the amalgam down to the silver-plating, the dry amalgamator accomplishes it by chiseling the amalgam off at intervals; but the scale is certain to accumulate unless they are willing to ruin the silver-plating and thereby lose its advantages. Certain mills use raw copper plates, with the exception of the last plate which is silvered on account of the scouring action of the pulp. These copper plates are periodically sweated and in this way there is little hard scale left on the plates. Where a part of the amalgam is spread back on the plates, the practice is a good one, but where the stamps are started up with the plates bare, it must be condemned.

Where it is considered necessary to use silvered plates, and it is still desired to secure this bullion, it is more economical to scale the plates and have them resilvered than to melt them into a bar for shipment to the bullion buyers. There is no really good method for removing this scale. Besides sweating and chiseling, the plate can be given repeated scourings with pumice stone and mercury, and it is surprising the amount of gold that can be taken from a plate in this way. 'Burning' the plate is resorted to, which consists of driving off the mercury by heating the under side of the plate, after which the gold can be scaled off. To induce the scale to more readily come off, the plate being burnt, may be subjected to a scouring with, or a bath in, some chemical that will form a compound with copper, thereby softening the surface copper. Burning a plate causes it to buckle and puts it in such bad condition that plates to be resilvered or re-used should not be treated in that way unless the heat applied is moderate or there are facilities for restoring the plane surface to the plate again.

Many experiments have been made with varying temperature of battery water, and the best results have been secured when it is at a temperature between 45 and 70° F. Below that temperature the amalgam tends to become hard and crystalline, and poor amalgamation may result, though the heating of the feed water is seldom attempted. Above 70° the amalgamation of the gold by the plates appears to be promoted, but the amalgam becomes so liquid that it is hard to retain it on the plates, much of it running down into the traps. Amalgamating in water of either an unusually high or low temperature bears a certain analogy to amalgamating wet and dry. A high temperature causes any acidity of the battery water or the ore to act more promptly in staining the plates by the formation of various compounds with the copper. The amalgamator usually manages to do good work with water of either a high or low temperature by keeping the amalgam at the proper consistence, but where the water has a considerable variation of temperature during the twenty-four hours, it is impossible to vary the practice accordingly.

How often shall the plates be dressed? Just as often as needed to keep them in good condition; where the conditions are not greatly variable this will be reduced to dressing at stated periods, generally 12 hours apart. Where the ore is low grade, 'plating' $1.50 to $3 per ton, the plates are dressed once daily in the morning, though the night shift may soften and dress the upper plate of each apron if it becomes hard. This refers to a large mill, in a small one two dressings will be made, even if the plates are in fair condition, on the principle of giving the night amalgamator something to do. With ore amalgamating $4 to $8, two or three dressings will usually be made during the twenty-four hours, while with rich ore they occur a few hours apart. The clean-up of the amalgam is made when the plates are dressed in the morning. At the time of other dressings only the loose crumbs of amalgam are removed unless the ore is rich. The plates should be rubbed sufficiently to secure an even texture of the amalgam, in theory stopping short of the silver-plating, while allowing as little of the hard scale to form as possible. The amalgam should be worked into its most active condition with a view to catching gold, and further rubbing is superfluous. Two men will dress a plate 16 ft. long in from 5 to 12 minutes, depending on the care and refinement used. The grade of ore is not the only factor determining the number of dressings. The appearance of stains, or the coating of the plate by galena or other sulphides, or by the semi-amalgamation of tellurium or some base metal will at once call for a dressing to remove the fouling substance. Plates that have been treated with strong cyanide solution do not hold mercury well, and some time after the dressing the mercury may collect in drops, or tears, that work down the plate, when the plate is said to 'run,' and should be dressed at once.

Some amalgamators are troubled by the amalgam on the apron-plates becoming abnormally hard. The exact reason for this cannot be given, though it is often due to certain substances in the ore, but usually it is the combination of a bare plate, dry amalgamation, and the too frequent use of cyanide in dressing the plates. The amalgamator, in his effort to prevent this hardening of the plate, may dress it wet until it resembles a mirror, but in a short time the mercury begins to form in visible globules and drain off, leaving the plate hard. To correct this trouble all chemicals should be dispensed with, and the principles of wet amalgamation practised by keeping a thick layer of amalgam on the plates and dressing them often, giving the amalgam a long and hard rubbing. This amalgam should not be kept too wet or it will increase the tendency for the plate to run. Unless the trouble lies in the ore or water, the plate will regain its normal condition under this treatment.

The placing of the plates at a distance from the mortars instead of immediately following them has not been generally successful; the first reason being that it is hard to distribute the pulp evenly across the width of the plates. The gold appears to become coated with slime in the short time that elapses between its leaving the mortar and reaching the plates, so that it is rendered less readily amalgamable. During its passage the pulp, to some extent, loses its homogeneity, just as in a tailing flume the coarse sand settles to the bottom. When the pulp in this condition reaches the plates, the coarser sand tends to segregate, while the finer and more dilute portion of the pulp passes on and over the plate; thus a steeper grade of plates and more water are required. The pulp flows down over the plate in a sheet, or flood, rather than with the rolling over and over wave motion, so desirable, and amalgamation must necessarily be poor, especially with a gold difficult to catch. The pulp as it leaves the mortar is homogeneous, though the tendency of the coarse and fine particles to separate is noticeable toward the foot of a long plate.

Where the ore has been dry-crushed and subsequently watered and run over plates, the results have been unsatisfactory in many cases, partly for the above reasons and partly because the gold has become fouled, retarding amalgamation by being coated with dirt, or air bubbles, in the process of being crushed.

In placing plates at a distance from the mortars, well considered arrangements should be made for securing an even distribution of pulp to and across the width of them. Comparative tests should be conducted against a plate set in front of the mortars. Sufficient mill space should always be provided to allow plates to be placed directly in front of the mortars, if thought desirable. With a clean ore that slimes but little and coarse gold, it should be possible to amalgamate satisfactorily at a distance from the mortar, but with a sliming ore and fine gold it is doubtful. Possibly the practice at the Homestake mills at Lead, South Dakota, is an exception, as there has been in use an auxiliary 'plate house' of large dimensions entirely separated from the mills, in which successful amalgamation is carried on with an ore notorious for its sliming proclivities. However, the usual plates are in use in front of the mortars in the Homestake mills. In this connection the question of what constitutes satisfactory amalgamation presents itself, and it may be remarked that there is a difference in millmen. One man will be satisfied with the percentage of gold he is saving and claim that no more can be saved, while another man, on taking the same mill and recovering the same percentage of the gold, may be dissatisfied with results and consider that more gold can be saved by greater refinement of methods. In cyanide practice it is possible in a majority of cases to determine by laboratory tests the extent to which the gold can be dissolved, and the metallurgist can be required to closely approximate this in the actual work. But in amalgamation by small tests it is impossible to determine even approximately the maximum amount of the gold that can be amalgamated, and the results that can be attained in actual mill practice are the only real index as to the ability of the millman and the thoroughness with which the amalgamation is being accomplished.

For carrying the tools used in dressing the plates and for holding the amalgam recovered, a deep iron kettle is used, or sometimes a gold-pan. A wedgewood or glazed sheet-iron bowl for cleaning the amalgam is also required.

For spraying the mercury on the plates, a strong bottle with a piece of canvas or a double thickness of muslin tied over the mouth is used. Suitable bottles may be made of iron by screwing a cap over one end of a 1½ or 2-in. iron pipe. Mercury is also occasionally tied up in a canvas bag in quantity about the size of an egg; such a bag is kept in a cup to prevent loss of the mercury. For feeding the mercury into the mortar, an amalgamator's spoon is used to measure it from a cup; this spoon is of wood, much like a mustard spoon; the bowl is bored or burned in it to hold mercury to the size of a small pea. The amalgamator throws the quick into the mortar through the feed slot at the back, a half or full spoon, or more, according to the amount he considers necessary from the appearance of the plates. Some head amalgamators make use of a chart having a blank space for each battery, and write on these blanks the amount of mercury to be fed to each mortar by their assistants on the different shifts. This is an unsatisfactory method and seldom found, for even an inexperienced man can learn to feed mercury properly under instruction in a short time.

As few chemicals as possible should be used in the treatment of plates. Their continued employment is analogous to the use of stimulants by a man. Apparently beneficial, their after effects usually more than counteract their fancied or real temporary advantages. The mercury should be 'pickled' in weak nitric acid to remove impurities, as has been explained before, but all traces of the acid should be washed out before applying the mercury to the plates. Greasy plates should be scrubbed with a weak solution of lye, which will neutralize or remove it.

Potassium cyanide has been used extensively in the past, but its use must be condemned as wrong in theory and harmful in results. Cyanide of potassium solution neutralizes grease, in which it is beneficial; it also dissolves the compounds of copper, allowing them to be washed away, in which it is also beneficial; but it goes farther; it dissolves the metallic copper itself and thereby pits the surface of the plate. This pitting of the plate and the formation of compounds of copper and cyanide that are only partly removed by the water, increases the tendency of the plate to readily absorb mercury (is said to soften the plate), but these beneficent results are only temporary, as the plate becomes still harder and the mercury tends to ooze out of the amalgamated plate, as may be observed in plates that have been continually treated with strong cyanide solution, while the copper compounds that have been formed, oxidize to tarnish the plate at every opportunity. When the solution is used, it should be weak, that only the copper compounds may be attacked, and that the raw copper may be unacted upon, and it should be thoroughly washed away immediately after using, that none of the copper compounds or salts may remain. A 2½% solution—less than one-half ounce potassium cyanide to a pint of water—is the strength generally used, and a still weaker solution is preferable. Plates that have been long treated with strong cyanide solution are difficult to handle, especially if little amalgam is kept on them, and that in a hard condition. In general, any acid or chemical that will form a compound with copper should not be applied to the plates, while the copper should be kept well covered with amalgam that tarnishing due to oxidation by the air or indirectly by the acidity of the water or ore may be minimized. Where the pulp is acid from the water or the ore, it is claimed that iron strips down the side of the plate will cause the acidity to affect the iron instead of the copper, keeping the plates free from stains in addition to exerting a helpful galvanic effect, but it is doubtful if it would be of material advantage, as only a small part of the pulp comes in direct contact with the iron.

The stains, the so-called 'verdigris,' which appear on the plates and are a source of grief to many amalgamators, are in nearly every case an oxide of copper, though they may be carbonate in some instances. These stains are due to copper in the amalgam which is turned into an oxidized compound by the air or water. This copper may be amalgamated together with the gold from the ore, or its salts may have contaminated the mercury, but ordinarily the stains rise from the plate due to too thin a film of amalgam, to the use of chemicals, or to the pulp containing substances that have formed copper compounds which have later oxidized. An important source of this copper is the shells of detonators used in blasting. The remedy is to use purified mercury, dressing the plates as often as the stains appear until a good film of amalgam is accumulated over the plate, and especially over the spots which most frequently tarnish. Solutions of potassium cyanide, sal-ammoniac, and of the acids are used, especially the first, to dissolve these stains that they may be washed away, but as it is impossible to prevent the chemicals from continuing to act further, they should not be employed. The use of silvered instead of raw copper plates will ordinarily obviate this trouble. However, it largely depends upon the ability of the amalgamator.

Bare spots on the plates are due to the amalgam having been removed too close to the copper by chiseling, or they may be started by a tarnishing spot. They also may appear on the lower apron plate due to the scouring of the pulp as has been mentioned before. These spots require careful treatment for a little while. The copper should be burnished with fine grit, such as wood ashes or slime, until the pure copper is exposed, when the adjacent amalgam should be worked over it and rubbed in well. The deposition of the amalgam should be coaxed from the edges to the center. A little sodium can be used to advantage in the mercury and this compound, sodium-amalgam, applied to these spots, as it will promote the attachment between the amalgam and the plate and aid in the recovery of additional amalgam. Cyanide and acid solutions should not be used on these spots.

Amalgamators have various 'dopes' and nostrums, secret and otherwise, for applying to the mercury and plates the action of which they themselves but little understand, especially in regard to the chemical reactions from which they must derive their virtue, if they possess any. It is best to dispense with them all. There is only one 'dope' or panacea for the ills of amalgamation, and that is a thick bed of amalgam, kept in an active condition and free from foreign substances. This, together with a vigorous application of 'elbow grease,' produces the best results.

The mercury is sometimes 'loaded' by adding sodium amalgam, up to the point where the mercury just commences to amalgamate a bright nail. Sodium amalgam is prepared by heating the mercury in a glazed dish, or better still, a quicksilver flask, the top of which has been cut off, forming a deep pot. The making of sodium amalgam is attended with danger and should be conducted carefully.

Heat the mercury to about 300°F. and cut small chips, the size of a good-sized pea from the stick of sodium, handling with a pair of tongs. Drop but one chip into the heated mercury at a time. A slight explosion should follow. If it does not, stir it gently with a wooden paddle, which will hasten the flash. Then add another chip in like manner, up to 3% of the weight of the mercury to be thus treated. This will crystallize, forming a solid amalgam when cold. Keep the face away from the flask, both on account of the flashing sodium and to avoid the mercurial vapor that is likely to arise from the heated pot. This amalgam should be kept in air-tight bottles that it may not decompose, and should be added in small quantity to the mercury as required. The effect of the sodium in making the mercury so active in amalgamating is not fully understood, but is supposed to be largely due to its reducing action. It reduces the oxides and other compounds of the base metals, causing them to amalgamate with the mercury. It is but little used by practical amalgamators as it causes the amalgam to 'freeze' to the iron and steel surfaces of the mortar through amalgamating with them, while so much fine iron and steel and sulphide are caught with the plate amalgam, that these surfaces become foul. It is productive of an increased quantity, but a lower grade of amalgam. Besides being useful in covering bare spots, it is of benefit in starting new plates—making them more active.

Silver amalgam can be prepared by dissolving silver coin or other silver in dilute nitric acid. To this solution add the mercury and a few bright nails, keeping the acid weak. The silver will be deposited on the mercury forming an amalgam. Unless the amount of copper in the silver is large, its presence is not material. This copper can be removed by precipitating the silver from the nitrate solution by adding a solution of common salt up to the point where no more precipitation occurs, then washing the precipitate until all green color of copper is gone, after which very dilute nitric or sulphuric acid, mercury, and bright nails are added. The finely divided precipitated silver may be separated by filtering and worked up with the mercury later. A rough method of making silver amalgam is to reduce the silver to filings and amalgamate it by mixing with mercury.

After the amalgam is removed at the daily cleaning of the plates, it is necessary to clean it by removing the sand, iron, sulphide, and base metal dross. This is done by grinding it in a wedgewood or iron bowl with enough mercury to make it quite liquid. The impurities rise to the top where they are carried over the side of the bowl into a gold pan in which the bowl sets, by a stream of water from a hose, or they are taken off by a coarse sponge. After the quartz and dirt and dross—impure and foul amalgam—has been taken off, a magnet is passed through the liquid amalgam several times to remove the fine iron and steel. It is now poured into a wet canvas or a double thickness of stout drilling lining a bowl. The cloth is gathered up by the corners and twisted tight forcing the mercury through the fabric, leaving the amalgam behind in the cloth. This process of squeezing or wringing the amalgam is continued, the globules of mercury being washed off by aid of water into the bowl beneath. When all the mercury has been expressed that the operator can wring from it, the cloth is spread out exposing a ball of hard amalgam within. The ball is rolled around in the cloth to pick up the loose flakes of amalgam; after which the ball is weighed, wrapped in paper on which is usually marked the date and weight, and locked up until the monthly or semi-monthly retorting and melting. The mercury passing through the cloth will carry some gold, but this is not considered undesirable as such mercury is more active in promoting amalgamation than that which is gold-free. The amount of gold so retained can be reduced by sqeezing the amalgam through a less porous material, such as chamois.

Some amalgamators clean the amalgam by adding sufficient mercury to make it soft and mushy, when it is dumped upon the upper apron plate, where it is puddled by the fingers, or a rubber, until it sticks to the plate in one mass. Water is turned on from a hose which, in connection with the puddling washes the amalgam clean. After using the magnet, the amalgam is scooped up and transferred to the straining cloth. This is a poor method though the amount of amalgam lost is small when the treasure box is used; it causes a loss of running time and leaves a wet spot on the plate. The easiest way is to use a gold pan having an amalgamated copper bottom, when removing the amalgam from the plates. Then, when at leisure, work this amalgam up at the clean-up sink in the same manner as on an apron plate. Grinding with an excess of mercury in a wedgewood bowl gives the cleanest amalgam. The dross or impure mercury and the rich sulphide collecting from the daily cleaning of the amalgam should be ground with mercury when a quantity has collected. All of the debris and refuse from these cleanings should finally go to the tank of the clean-up sink, to be run through the clean-up barrel later, or sent through the mortars in the absence of a clean-up barrel.

At the monthly clean-up the apron-plates are cleaned before the mortars are opened. Where there is considerable gold in the mortar sand, this sand is removed once a month or on general clean-up day. The battery is stamped out and hung up. A platform of boards with cleats to fit the apron-table is placed over the first plate to work upon without marring it. The screen is removed. The splash, lip, and inside plates are removed to the clean-up room to be chiseled and scraped, which is done by means of old files forged down to chisel ends and ground sharp on a grindstone. A putty knife is a useful tool for this purpose. The pulp lying on the dies is shoveled into boxes or tubs to be returned to the mortar, it usually containing too little amalgam to be treated. The sand about the dies is dug out with bars and together with that underneath the dies is carried in pails or tubs to the clean-up room, or to the clean-up barrel or pan. The dies are pried up and removed to get the amalgam-bearing sand around and beneath them. After cleaning out all the sand and knocking off any amalgam adhering to the sides of the mortar, or to the shoes and bosses, the dies which have been washed and examined for any deposits of amalgam are returned to the mortar; the height of drop adjusted, chuck-block, screen, and plates put in position, and the battery started up. It is aimed to put the new shoes and dies in at this time whenever possible, and the mercury traps are also then cleaned. At some mills the battery sand from all the mortars, when low in amalgam, is sent through one mortar having a high discharge, and only the sand from this mortar is taken to the clean-up room, but it is not considered good practice. At the clean-up room this sand is either panned down in an ordinary gold pan or is run through a rocker to separate and collect the amalgam, the sand tailing being fed through the mortar before the next clean-up.

Where a clean-up barrel is used, the mortar and mercury-trap sands, together with that in the clean-up sink from the daily cleaning of the amalgam, are put in the barrel with 40 lb. or more of mercury—sufficient to insure the amalgam being liquid—also sufficient water to make a sludge or thick pulp. To this is added a little lye to 'cut' the grease and keep the mercury in condition, and many pieces of iron and steel to act as grinders or mullers, such as cannon balls, broken stem ends and shoe shanks. Pieces of hard quartz or other rock answer well. The barrel is now revolved from 3 to 8 hours, depending on the ideas of the amalgamator and time available, at a speed not exceeding 15 revolutions per minute—the higher the speed, the greater the tendency of the amalgam to flour. After grinding, the barrel is slowed down in order that the soft, liquid amalgam may collect; it is finally stopped with the manhole uppermost and a small plugged opening below. The manhole is opened first to give vent to any gases that may have formed, after which the plug below is removed to allow the amalgam to run into a deep receptacle set underneath. The sand is slowly sluiced out of the barrel with sufficient water to make a thin pulp that will not carry away any amalgam. It is run through a coarse screen to remove nails and other small fragments of iron, to riffles and an amalgamated plate for catching any escaped amalgam, and is finally caught in a box or tank. A batea, a shallow wooden bowl, is superior to riffles or a plate for catching any amalgam that has overflowed from the pail. The batea may be characterized as a mechanically-operated gold-pan that retains the amalgam and pans off the sand. The amalgam recovered is cleaned of iron by the magnet and strained into balls through canvas in the usual manner. The sand is eventually carried back to the mortar as it always contains a little amalgam. Grinding pans are used at some mills instead of barrels for cleaning the sand and amalgam; the only variation in the general treatment being that necessitated by the difference in their construction; both are dispensed with at many mills as they are considered by some to flour the amalgam, while on the other hand some mills are equipped with both. The amalgam chiseled from the plates, or that panned out of the sand, is ground up in a large wedgewood bowl or in an iron hand-mortar with an excess of mercury. Warm water is often used in cleaning the amalgam that it may become softer and liberate more freely the impurities mechanically held or suspended in it, and that it may be squeezed drier. Some amalgamators, though not many, add the amalgam chiseled from the plates at the clean-up to the sand in the barrel and clean it in that way, but it is not good practice to thus take any chances of its being lost or stolen.

CHAPTER VIII

The amalgam is retorted to free the gold from the mercury. This is accomplished in a closed cast-iron vessel having a tube leading from it to carry away the volatilized mercury and deliver it to a kettle re-condensed in liquid form. These vessels are called retorts, and may be either large cylinders solidly set in a foundation of brick over a fire-box, or they may be small portable affairs that are placed over a fire made in a temporary furnace of brick or stone, or even in the open air on the ground. The inside of the retort is lined with three or four thicknesses of paper, with chalk, or with wood ashes, to prevent the gold from sticking to the sides. In the retort the balls of amalgam are placed so that it will not be more than three-quarters full when the cover is placed on. If the 'sponge,' as the metal after retorting is called, is to be shipped without being melted into a bar, the amalgam is packed down tight to make a solid mass of it, and a hole is forced down through the center to enable the mercury the better to escape from within the mass. If the retorted metal is to be melted into a brick before shipping, the balls are put in loosely since that will allow the volatilized mercury to readily escape and the sponge to be easily broken up for convenience in handling before melting. A ring of lute made of fire-clay, wood ashes, and a little salt is placed between the cover and body of the retort to insure an air-tight joint. The retort is set in a furnace, on a tripod, or is carefully propped up in the open, and a slow wood fire started about it. This fire is gradually raised until the retort finally becomes cherry red; the heat being applied all about the retort, not on the bottom alone. The pipe coming out of the retort passes through an outer pipe, and in the space between them cold water is constantly running which condenses the volatilized mercury to the liquid state. When using small retorts gunnysacks wrapped about the pipe, to which cold water is continually applied, may successfully be used. A vessel filled with water is placed at the lower end of the pipe to catch the condensed mercury. A cloth should be wrapped about the end of the tube forming an extension of it. This extension should dip beneath the surface of the water with which the pail is filled to overflow as the mercury condenses. Care should be taken that the lower end of the pipe itself does not project into the water as there is a tendency for the atmospheric pressure to force the water up into the pipe at times, due to the diminution of the volume of gas in the retort caused by the fire being checked or dying down; in such case the cloth will be drawn against the pipe and air drawn through the pores of the cloth, whereas, if the end of the pipe were in the water, the water might ascend into the retort and an explosion result. If the end of the pipe were exposed without the cloth, some volatilized mercury might escape if the condenser was not working properly, endangering salivation. Retorting will take from 2½ to 5 hours. The fire should be continued for 20 minutes after the mercury ceases to condense in the pipe as ascertained by tapping the pipe and watching for the mercury to drop out. When distillation is complete the fire is withdrawn and the retort allowed to cool. There is always danger of salivation if the retort is opened while hot. It is practically impossible to drive off the last of the mercury and it should not be attempted by raising the heat, as such heat may result in a partial fusion of the gold causing it to stick to the retort, and is also destructive of the retort. Retorting with an assay furnace or on a blacksmith's forge invariably results in using too high a heat. Where the amount of amalgam to be retorted is large the oval or cylindrical retorts of large capacity above referred to are used in specially built furnaces. The amalgam is placed in cast-iron trays or separated by partitions of plate iron in these retorts, these trays or plates being well chalked or painted with ashes or other mixture and well dried to prevent the gold from sticking to them.

If the amalgam has been properly cleaned and retorted, the sponge will show a gold color and require a minimum amount of flux in the melting. Blackness indicates that the amalgam was poorly cleaned. A pale whitish color shows that it still contains mercury, and a bluish color generally indicates the presence of lead, usually babbitt. Retorting should be done in the open, or with the windows of the retort room open, to lessen the danger of being salivated, though there is little danger if proper precautions are taken.

The percentage of metal that is obtained from the amalgam by retorting and melting it into a bar depends upon the amount of impurities in the amalgam, and to a much greater extent on the size of the particles of gold. Coarse gold does not require as much mercury to amalgamate, or cement it, as a fine-grained gold. About 30 to 40% is the usual amount of bullion obtained from the amalgam of ordinary gold. With coarse gold as high as 65% of bullion has been obtained, while with an extremely fine gold the amalgam may run as low as 20% of bullion. Harder squeezing in the canvas does not materially lessen the excess of mercury. The use of sodium amalgam will increase the amount of amalgam by amalgamating the fine iron, steel, and sulphide. In one case, with a fine gold that ordinarily retorted 22% bullion, sodium amalgam was used in starting new plates, resulting in an increased yield from these plates that assayed only 12% fine bullion.

Before melting the retorted metal, the black-lead crucible must be annealed by driving off all the contained moisture, or the sudden heating of this moisture will burst the pot. For this purpose the pot is kept in a warm place, such as under or over a stove or boiler for a week or more, when it is placed directly in the stove or in the boiler fire for some time, after which it can be used with safety. The pot is placed in the furnace fire and when sufficiently heated to melt the metal, the flux is added. After the flux has become molten, the retorted metal sponge is added in pieces as fast as it melts down until the whole is melted, employing a long scoop or blower in handling the pieces of gold sponge. The quantity of the flux and its character will depend upon the cleanness of the sponge after retorting and the nature of the impurities. The amount of flux used and the proportions vary with each melter and can be determined only in an empirical way, by knowing the theory of fluxing and then guessing at the amount and character of the impurities. Should the amount of flux appear too small, as melting proceeds, more can be added at any time, while an excess does no harm, nitre excepted. The pot should be provided with a cover which is kept in place during melting, except when removed for observation or for stirring the melt.

The experienced melter on a clean retorted metal will use little or no flux, while the novice may use, on a somewhat base retort, flux to the amount of 5 or 10% of the metal. The average melter employs borax-glass and bicarbonate of soda in approximately equal proportions by bulk. The professional melter confines himself largely to borax-glass. The principal impurities to be fluxed off are oxide of iron, sand, and a little sulphur. Borax dissolves the metallic oxides forming borates of the bases; soda acts as a desulphurizer and forms sodium silicates with the sand; together they slag off the impurities and cause the metal to melt down rapidly. Theoretically one part of base requires about two of borax-glass, and one part of silica (sand) should have about five of bicarbonate of soda. It is preferable to use an excess of borax-glass.

For taking care of small or medium amounts of iron, in addition to the use of borax, silica in the form of fine, granular quartz tailing, may be used to form an iron silicate. Theoretically one part of iron requires about 0.6 parts of silica. Where the retorted metal contains a large amount of iron, sulphur should be added to the surface of the molten metal at the sides of the melting pot, and stirred in with a plumbago stirrer to form a matte of sulphide of iron. Theoretically 175 parts of iron require 100 of sulphur.

Should the amalgam have contained some sulphides, the molten metal should be 'poled' by allowing a heated iron rod to remain in the pot for a little time to slag off the sulphur as iron-matte (iron-sulphide). If the amalgam contained much metallic iron this 'poling' will not be required. If the quantity of iron sulphide formed is small, it will be dissolved by an excess of slag; if large it will form a matte between the bullion and slag. This matte should be saved and after a quantity from several melts is collected, should be fused with borax and soda to form a button of gold and a bar of clean matte, or should be cast into a bar and shipped.

Nitre (potassium-nitrate) is used to oxidize the base metals that they may pass into the slag, but it also oxidizes the carbon of the crucible, corroding it badly, consequently nitre should only be used by the experienced melter. Silica tends to increase the grade of the bullion, but if not used in the right proportion the slag is liable to become viscous and contain shots of gold. An excess of soda makes a liquid slag and one that separates easily from the bar; a large excess can easily be detected in cold slag, especially when slacked or chilled in water, from having the characteristics of soda. An excess of soda will attack the crucible while an excess of borax will not.

For melting an ordinary retort sponge a small amount of flux consisting of two or three parts by weight of borax-glass and one of soda, and poling with an iron rod, if the amalgam contained much sulphide, is all that will be required in the way of fluxing. After the metal and slag have subsided to quiet fusion the mass is stirred with an iron rod that has been previously heated red hot that no gold may adhere, the object being to settle any shots of metal in the slag and to render the gold homogeneous. The crucible is then lifted from the fire by means of suitable tongs and its contents are poured into an iron mould, which has previously been well smoked inside and heated. The slag rises on top of the metal and may overflow the mould without doing any harm, if it be quite fluid. It is improbable that any shots of gold that will not settle while in the furnace will do so after pouring, so all slag from gold melts should be carefully examined for shot gold.

The mould should be smooth and clean on the inside, all rust, old slag, or metal should be removed. It should be given a coating on the inside, preferably of carbon. This may consist of a mixture of lampblack and lubricating oil having the consistence of soft butter. Or it may be a coat of soot given by inverting the mould over burning pitch pine, rosin, or oiled waste as indicated above. Whitewash can be used. Thick oil has been used, but sputters while pouring and afterward burns with a disagreeable smoke and odor. The purpose of this coating is to prevent the gold from sticking to the sides of the mould and to allow the bar to come out easily. The mould should be well warmed, but not excessively, before being used, that it may not be cracked by the introduction of the hot metal and that the gold and slag may not be suddenly chilled, interfering with forming a neat smooth bar. The mould is finally leveled that the bar may be of an even thickness. Usually the mould is placed at a right angle to the flow from the melting pot, but a neater, easier pour can be made by setting the length of the mould parallel to the flow. Greater homogeneity can be given the bar by continually moving the entering stream of metal up and down the length of the mould in pouring.

After the gold and slag have cooled sufficiently to become solid they are dumped out of the mould into a tub or sink of water, which usually causes the slag to separate easily from the gold. The bar is cleaned by knocking and scrubbing off any bits of slag, or by setting back in the melting pot until hot and then plunging it, first into dilute sulphuric acid, and then into water. Nitric acid is also used. If the bar looks very base and dirty, it may be re-melted and re-fluxed. Two opposite corners are chipped off for assay, or it is bored in from four to eight places with a ⅛-in. drill, rejecting the surface borings; the latter method of sampling is to be preferred. Some use graphite rods for stirring the molten bullion, these are either purchased or are made by cutting a section out of an old or condemned crucible in the shape of the lower part of a golf club. A small hole is bored in the toe of the stirrer. After stirring the bullion, the gold caught in the hole, amounting to half a gram or more, is poured into a basin of water, this is repeated three or four times and the bullion assay made from the granules obtained in this way. A dip sample taken in this way is more accurate than any bar sample.

The slag from the meltings, likewise old melting crucibles, are saved and eventually run through the clean-up barrel in a separate charge to recover any shots of gold. The slag can be sent through the battery if there is no clean-up barrel available, but the crucibles should first be panned, as the graphite is harmful to the plate amalgamation. After this treatment the tailing should be assayed as it may still contain sufficient gold to warrant shipping to a smelter.

The wood removed from the mortars, together with old screen-frames, and all wood or canvas likely to contain any amalgam should be burned and the ashes put through the clean-up barrel, or the mortars, in lieu of a barrel or pan. The worn out screens should be thoroughly scrubbed and pounded after being taken from the frames, to remove any amalgam, and then placed in a heap. Shoes and dies and pieces of iron from the mortars should be scrubbed and hammered and the 'eyes' of amalgam in the blow holes picked out by means of old round files tapered down to a point, finally being consigned to a pile. The fine iron removed from the amalgam should be placed in shallow tubs. The oxidation of these screens and coarse and fine iron and steel should be promoted by occasionally adding salt and frequently wetting with water. After being reduced to rust as far as possible, that material which will enter the clean-up barrel should be ground up in it with a small amount of mercury and finally dropped into water, puddled, and the finer iron removed by a magnet. It may be necessary to re-wash this finer material. The screens and coarse iron receive a thorough scrubbing and pounding before being finally thrown out. Roasting or burning the screens and fine iron is a quick way to loosen the adhering amalgam and to promote oxidation.

Part III

GENERAL

CHAPTER IX

The loss of gold in amalgamation may be due to:

(1) Free gold included in or surrounded by the gangue rock.

(2) Gold that is free and chemically combined in the sulphides and tellurides.

(3) 'Float' gold that is carried along on top of or suspended in the pulp and which does not come in contact with the amalgamated plate.

(4) 'Rusty' or coated gold.

(5) 'Overstamping.'

(6) Poor amalgamation due to the methods in use.

(7) Poor amalgamation due to deleterious substances in the ore.

First: If the loss is in the free gold included in or surrounded by the gangue rock, a sizing test will reveal it by the higher value of the coarser sands. In some cases the coarser sands can be crushed finer in a hand mortar and panned to show a 'prospect' of free gold. The correction for this is to crush finer, not the ore in general, but these coarser grains. This crushing is better accomplished by using a finer screen with the same or a lower height of discharge. Running two batteries with different size screens in competition with each other and comparing the tailing assays will determine in an empirical way, but sizing tests in connection with this is necessary for a true diagnosis of the ore.

Second: Gold in association with tellurium is chemically combined and can only be saved by cyanidation along special lines, by chlorination, or by smelting, and rarely by concentration.

Gold in the sulphides is mainly in a free state, finely divided, and mechanically held by the sulphides. This gold is usually saved by concentration, and in some cases by cyanidation of the tailing without concentration. However, a part of it can be amalgamated, as in the Gilpin County practice, by the use of a wide mortar, deep discharge, long and slow drop, and an attempt to catch the gold inside the mortar. Here the sulphide because of its higher specific gravity sinks to the bottom and is held longer in the mortar than the balance of the pulp, allowing the gold to be liberated by the thorough sliming of the sulphide, and to be brought in long contact with the mercury and inside plates. This process has had slight application outside of the locality mentioned, where it was necessitated by a large proportion of the gold being contained in the sulphide that was of too low a grade to ship and smelt profitably. Part of the loss in the tailing may be due to sulphide crushed so fine (slimed), that it cannot be caught on the concentrators; this will be considered under 'Overstamping.' The amalgamation of the gold in the sulphides has been accomplished by grinding them in amalgamating pans or arrastres, but the extraction has never been high, so that it is now preferable to cyanide them if they contain no interfering elements, or to ship them to the smelters.

Third: 'Float' gold really refers to that gold which occurs in flakes so light and thin that it is floated along on the surface of the pulp, perhaps buoyed up by a bubble of air, but in most cases it will be found to be gold so fine that it is carried suspended in the pulp and gets no opportunity to come in contact with the amalgamated plate. When an ore containing visible gold is pounded up in a hand mortar and panned, the gold is found to be pounded into scales or into infinitesimal bits, depending on the nature of the gold. It is doubtful if much gold is overstamped to an extent producing scales so thin that they will float on the surface of water like gold-leaf, although such gold has been found in both mills and placers; but it can be understood that gold which is powdered fine may be carried along in the pulp clear of the plates, though it really does not float. The loss attributed in a tentative way to float gold is found by assaying the flocculent slime of the tailing. Should this show a value as high or higher than the sand, it would indicate overstamping, and adjustments calculated to prevent this should be made. A part of the value lost in the tailing and assigned to float gold is in the slimed sulphide, but only a part of the loss can be rightfully ascribed to this. Increasing the grade of the plates and using as little water as possible in the mortar to secure a better wave motion and contact between the pulp and the plates, together with making the plates longer and keeping them covered with a bed of soft amalgam, will aid in saving more of the fine and float gold. If the battery water is being re-used it should be well settled, for as the water or pulp becomes thicker and more slimy it will carry off more of this light gold. Patent amalgamators for catching this kind of gold should be tried. It is practically impossible to determine the form or condition of the gold in these slimes where the amalgamation and concentration has been capably done, or to hope to promote any further extraction by laboratory and amalgamation tests.

Fourth: 'Rusty' gold is free gold covered with a film of some substance other than air or the gangue rock in which it is contained. This may be due to an oily or greasy mineral peculiar to the ore, like graphite; to an oxide of iron or copper, or to other compounds of the base metals; to silicates of magnesia or alumina, or to slime arising from crushing the ore. This film prevents the gold from coming in direct contact with the mercury. Rusty gold can sometimes be detected by panning the tailing and examining the concentrate with a microscope. This gold should be caught by the concentrators, or in the cyanide plant if not too coarse, also by the use of riffles or blanket tables. To amalgamate this gold it must be scoured. This can be done by using a high discharge, preferably with a coarser screen and a narrow mortar that the tendency to overstamp may be reduced. With a low-discharge, rapid-crushing mortar, the ore is in the mortar an average of four or five minutes, this length of time can be doubled or trebled by increasing the height of discharge, so that the particles of gold, especially the heavier ones, are subjected to the scouring and attrition of the stamp and the pulp for an increased length of time. Sodium amalgam in the mercury should be tried. If any of this gold is retained in the traps, they should be cleaned often, perhaps at each plate dressing, the sand being ground in the clean-up barrel with some additional mercury, to scour and amalgamate this gold. Theoretically, coarse crushing in the mortar followed by regrinding and amalgamating in a pan or roller mill should be successful. It is considered that the pan amalgamator will amalgamate gold that no other method of amalgamation will save.

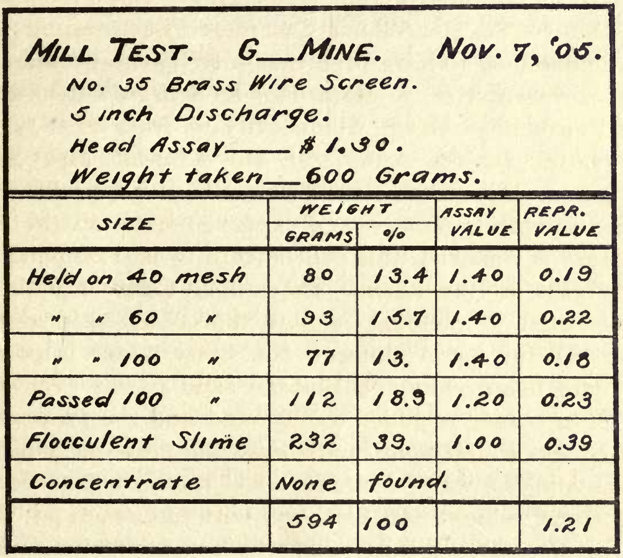
Fifth: 'Overstamping' is holding the pulp longer in the mortar subject to the action of the stamps than is necessary, thereby pulverizing it finer than required or than is beneficial. While the capacity is reduced, the term properly has no reference to that, but to the treatment the ore receives causing it to give a reduced extraction. Experiments have shown that a hammered gold is not readily amalgamable, which further experiments tend to prove to be due to the gold being covered with a film of dirt and grease in the process of hammering, which in connection with its increased density, does not allow it to be so easily wetted by the mercury. As has been observed under float gold, it is improbable that much gold which can be hammered into a scale is rendered non-amalgamable by stamping in the mortar, especially in the presence of mercury; while there is no doubt that gold in the allotropic form of being brittle can be stamped so fine that it is hard to catch in the mortar or on the plates, particularly if it is covered with slime. The danger of overstamping is augmented with increase in the grade and percentage of the sulphide. The Gilpin County practice is an ideal illustration of overstamping sulphide.

As to whether the ore is being overstamped or not is judged from the sizing-test assays taken in connection with the tonnage and operating expenses. If the assays of the slime and fine sands closely approach or are higher than those of the coarser sands, adjustments should be made that will reduce the percentage of fine material in favor of a higher tonnage. If it is an actual case of overstamping, resulting in the gold being rendered less amalgamable by being hampered, broken up, or coated with a film, or to the sulphide being slimed, the proper change of adjustments should reduce the assays of the slime and finer sands. The changes of adjustment have one object in view—to get the pulp out of the mortar as quickly as possible after having been crushed to the proper size to liberate the gold and sulphide from their matrix.

Sixth: Poor amalgamation, due to the methods in use, may keep the amalgam so hard that it becomes crystalline and breaks away, or that it reduces the tendency of the gold to catch; in keeping the plates so wet that the mercury and amalgam run down into the trap; to the gold not catching due to stains, bare spots, plates cleaned too close, too much water used, too small a plate area; loss of amalgam by not removing or bedding down the crumbs when dressing the plates; use of impure mercury; grease falling into the mortar and contaminating the plates; in fact, to bad practice in any of the various details connected with amalgamating.

Seventh: Poor amalgamation due to deleterious substances in the ore does not often occur. Arsenical and antimonial ores are the worst offenders in this regard. They tend to foul the mercury and amalgam, coating it with a film of the slimed material so that the mercury does not readily amalgamate with the gold, but is sickened and a large part of it lost. This trouble is liable to occur to some extent with any base and heavily sulphuretted ore. The principal remedy is to practise outside amalgamation. Clayey, talcose, and other slimy ores sometimes give trouble in a similar way, or by coating the gold.

In making mill tests two batteries should be selected that receive a feed as nearly identical as possible. Comparative tests should be made simultaneously with the different adjustments. Sizing of the tailing samples from these two batteries should exhibit the characteristics of the ore under the different treatments. These tests may be conducted in the following manner. Each tailing sample, understood to have been carefully taken and in every way representative, is drained of its settled water, dried and thoroughly mixed. A quantity of from 30 to 60 oz. is removed for the sizing test, also a 'head' assay sample taken. All assays should be made in duplicate. The sizing sample is panned and repanned until all the concentrate is removed, this concentrate to be examined for rusty gold and amalgam. The sample together with the water used in panning is now thoroughly stirred and after settling for a moment, the slimy water is poured off, care being exercised that no sand passes over with it. More water is added to the sand and the process repeated again and again until only the granular sand remains and the water contains slime that is a true flocculent slime, is light and feathery, with agglomerates, does not readily settle in water, and which makes water muddy, in contra-distinction to sharp, granular sand which readily settles and does not make water muddy. The sand is sized, either before or after drying, into a coarse, medium, and fine sand. Where comparative tests are not being made on two batteries, a fourth size, an extra coarse sand, should be made. Thus, when crushing through a 30-mesh screen, by making an extra coarse size out of that held on a 40-mesh screen, we may be able to judge how the ore passing it will act when crushed through a 40-mesh screen. The sand, slime, and concentrate are now dried, weighed, and assayed, after which the results may be tabulated. The following is taken from a note book, and is an actual test made on a small lot of tailing that was dried before being weighed for the sizing test:



MILL TEST. G___MINE. NOV. 7, '05.
No. 35 Brass Wire Screen.
5 inch Discharge.
Head Assay____ $1.30.
Weight taken___600 Grams.

SIZE	WEIGHT		ASSAY VALUE	REPR. VALUE
	GRAMS	%		
Held on 40 mesh	80	13.4	1.40	0.19
" " 60 "	93	15.7	1.40	0.22
" " 100 "	77	13.	1.40	0.18
Passed 100 "	112	18.9	1.20	0.23
Flocculent Slime	232	39.	1.00	0.39
Concentrate	None	found.		
	594	100		1.21

The deductions from the above test are that the concentration is nearly perfect, but that the ore is being crushed too fine for the purpose of economic amalgamation, since the assay of the slime is comparatively high and the quantity abnormally large, while the coarse sand, that held on '40-mesh,' assays no more than the finer sand.

The results of a single sizing test should not be taken as conclusive, but a series made. The capacity may be obtained by catching the pulp in a tub or barrel for a certain length of time and weighing the dry pulp. Where cyanidation follows amalgamation and concentration, the adjustments of the battery will be determined by the sizing tests of the cyanided tailing, which indicates how fine the ore should be crushed to get the maximum extraction by the cyanide solution.

Generally too little attention is given to testing and studying an ore before erecting a mill, though the stamp-battery, thanks to its wide range of adaptability, can usually be made to do satisfactory work, consequently the change, if any, usually takes place in the concentrating and cyaniding departments. The usual procedure is to take a sample of the ore which is seldom representative of the run-of-mine ore. This ore will probably come from a dump, or near the surface, and be an oxidized ore, while the assay value will be high. After making a trial run at a testing works, a mill will be ordered by the directors of the company, the details of the mill being left to the machinery supply house. The mill-site may be selected and the mill designed by a man who has had little or no experience in milling. Finally, the mill is completed and turned over to the millman who must then spend considerable time in changing and rearranging. It is incomprehensible why mining companies so seldom employ competent metallurgists, independent of machinery supply houses and special process companies, to examine the ores of their mines and to design and build a mill suited to those particular ores and conditions. The cost and loss of time in changing, rearranging, and providing for those things that have been overlooked would pay for the metallurgist, to say nothing of the daily saving that may be effected in a properly designed mill. Such a man should more than save the expense of his fee by knowing what, how, and where to buy.

The metallurgist should himself take representative samples of the different ores and make laboratory tests in amalgamation, concentration, and cyanidation, together with sizing tests, that he may thoroughly understand the ore. For making amalgamation tests, two methods can be followed. The first is to place six or eight assay tons of the ore crushed to the desired mesh in a large glass bottle with sufficient water to make a thin pulp, adding ½ oz. of mercury. The pulp is rolled around in the bottle, is lightly shaken, and is given a panning motion for some time, that all the free gold may be amalgamated. The contents are finally washed out of the bottle, panned and repanned until the amalgam is separated from the pulp, when the tailing is dried and assayed; the difference between the head and tailing assay representing the amount amalgamated. If mercury that contains no gold has been used in this test, the gold in the amalgam can be determined and the amount amalgamated ascertained in this way. The amount of gold is found by boiling the amalgam in dilute nitric acid until only the pure gold remains, when it can be washed, dried, annealed, and weighed as usual in the gold assay; or the amalgam may have the mercury driven off by heating it in the open where there is no danger of salivation, and cupelling the resulting sponge. Mercury entirely free from gold can seldom be obtained, but can easily be prepared by dissolving it in dilute nitric acid, when the gold remains undissolved and can be filtered off, while the mercury can be precipitated by suspending a piece of copper in the solution.

A better method of making an amalgamation test is to work the ore as a thin pulp in a gold-pan having an amalgamated bottom, assaying before and after treatment; the pan being used to separate any sulphide present at the same time. Laboratory amalgamation tests, as a rule, will not give as high an extraction as will be obtained in actual mill practice. This may be due to the fact that in preparing ore for such a test, it is screened frequently, resulting in an evenly sized material, whereas in actual practice a large proportion is crushed much finer and should give higher extraction. It is also possible that the dry crushing may coat the gold with dirt or slime so that to some extent it resists amalgamation.

The points it will be necessary for the metallurgist to know are: what percentage of the gold will amalgamate under ordinary crushing, and what increased extraction can be obtained by regrinding and amalgamating a second time; what percentage of concentrate there is in the ore, its nature, value per ton, and amenability to cyanide or other treatment; what extraction can be secured from the ore on the plates, on the concentrators, and from the tailing by cyaniding with coarse, medium, and sliming crushing; and the nature, occurrence, and condition of the gold in the ore. Making tests with a few pounds of ore has been decried, but while such small tests are not conclusive, they are a reliable guide when the sample represents the ore fairly and the tests are conducted by a metallurgist experienced in the processes. They will enable a system of treatment to be outlined that should be tried out by treating a few tons of the different classes of ore at a testing works under the personal direction of the metallurgist. The extent to which the testing should be carried varies with the nature of the ore and largely to the degree to which the metallurgy of similar ores in that locality has been worked out. There are some districts where it seems hardly necessary to test the ore for a process, such as the Mother Lode of California. There are other districts, however, where the working out of a successful treatment system seems to almost require a full-size mill operating under the actual working conditions, such as was seen in the case of the silver ores of the Tonopah district of Nevada.

The taking of mill samples should be done as automatically as possible. A sample of the battery feed taken by picking it from the revolving plate of the feeder by hand is absolutely unreliable on account of taking too large a proportion of the coarse ore. The sizing of a battery-feed sample through a quarter or half-inch-mesh screen will usually show that the fine material assays three or four times as much as the coarse, and may, in some rare instances, show the reverse. A long tin trough or scoop that can be placed beneath the revolving plate and catch all of the ore as it drops from the feeder will give a much better sample when taken hourly or half-hourly, especially if the fine and coarse ore is well mixed in the bin. Where outside amalgamation is practised, the sample of the battery feed is obtained in front of the mortar just before the pulp strikes the plate.

The tailing sample should be taken automatically by a device for that purpose, and the millman should be under instructions not to put it out of use during the period of dressing the plates. The millman fears that loose amalgam will be washed away to 'salt' the sample; but if amalgam to this extent is being lost, immediate steps to prevent it should be taken. Where the samples are taken by hand they are liable to become 'picked' samples, as, for instance, where the concentrator man carefully adjusts each machine before taking the tailing sample. For catching the tailing sample from an automatic sampler, the usual gasoline can may be used with a light tin pipe 3 or 4 inches in diameter fastened to a few pieces of wood which allow it to rest on the can with its bottom end projecting into the can. The pulp flows into the can through this pipe, and when the can is full the clear water commences to overflow without any attention from the man in charge, who finds the pulp well settled when he comes to remove the sample.

Where the gold will amalgamate to the extent of 20% or more, amalgamation, preferably in water, may be practised. If the ore will not amalgamate to this extent and requires cyanide treatment, amalgamation had better be dispensed with unless some of the amalgamable gold is coarse and escapes the cyanide plant. Crushing in cyanide solution is a great aid to cyaniding, as the ore is brought promptly into contact with the solution, and under conditions that cause the value to go into solution quickly, thus requiring less tankage for dissolving the gold. It also permits using a certain amount of water in washing the dissolved value out of the pulp to compensate for the moisture discharged in the tailing. This makes a saving in the amount of cyanide mechanically lost, and in practice also effects a saving in the amount of dissolved gold mechanically lost. Crushing in solution has its disadvantages in that the solution throughout the mill is carrying quite an amount of gold; and a little of this solution is constantly being lost, even in well-designed mills, by the leakages, overflows, accidents, and otherwise. Another disadvantage of crushing in cyanide solution in a mill where amalgamation is being practised is that a part of the gold goes into solution which would be amalgamated if the crushing were done in water. If this gold were amalgamated, practically all of it would be returned, but by going into solution the proportion returned is lessened, both through the losses above referred to, and through the indifferent washings of the filtering devices used. The amount of gold going into solution that could otherwise be obtained by amalgamating in water will vary with the size of the particles of gold; thus with an extremely fine gold crushed in strong cyanide solution as much as one-third or one-half of the amalgamable gold may be dissolved so quickly that it cannot be amalgamated. In such a case it is inadvisable to crush in cyanide solution. Where the gold is coarse and but little of the amalgamable gold enters the solution, crushing in solution may be advisable, depending on the character of the cyanide plant and the perfection of its operation in gathering all of the dissolvable value into the clean-up.

Where the sulphide is amenable to cyanide treatment and is small in amount or low in value, it may be expedient to cyanide with the sand without concentration, offsetting the decreased extraction from this sulphide by the lessened cost of treatment. At one prominent property operating along this line, a high discharge is used to retain the sulphide longer in the mortar, that it may give a higher extraction in the cyanide plant, through being crushed fine, while a large amount of water is used in the mortar to increase the tonnage.

Economic problems must be studied when considering amalgamation and cyanidation. With a small mill of 10 or 20 stamps obtaining a good extraction by amalgamation and concentration, it may not be advisable to put in a cyanide plant taking the pulp directly, on account of the high cost per ton of capacity for installing and operating a small plant of this type. It may be better to run the tailing into a pond and later put in, at less tonnage expense, a leaching plant of large capacity. With a pulp crushed through a 30 or 40-mesh screen and properly impounded, it is possible to extract practically all of the dissolvable value. In a country of average working costs, an impounded tailing having a value of 80 cents per ton and giving an extraction of 80% will return a good margin of profit. As the plate or concentrator tailing becomes higher, the necessity for a plant to treat it directly increases, since the tailing pond will hold a large amount of money that is not available, and there is a loss from the sand blown away and an occasional breaking of the dam. A tailing pond is sometimes a desirable thing to a manager, or promoter, as when it figures prominently, too prominently usually, in the report of the assets and possibilities of the company's property. Regrinding of the pulp followed by amalgamation (secondary amalgamation) may reduce the value of the tailing to a point so low that it may not be profitable to cyanide it. For this purpose some form of grinding pan, a Chilean mill, or the slow-speed roller mill, that will admit of amalgamation within the mill, may be recommended. The tube-mill has been found the most satisfactory machine for fine grinding for cyanidation. It has generally been considered a poor machine for amalgamating purposes, since any mercury fed to it, as well as the gold which is liberated, is supposed to come out thoroughly slimed. However, excellent outside amalgamation can be effected after the tube-mill, as, due to the fineness of the pulp, a beautifully thin flow can be had over the plates. When crushing in cyanide solution the grinding and sliming action within the mill causes so much of the gold to go into solution that it is usually not worth while to try amalgamation afterward.

From a theoretical standpoint it would appear that where amalgamation or concentration is to follow the tube-mill, the mill should be run at a speed that will cause the balls to be carried part way around and to crush by their falling impact, rather than the slower rate of speed whereby comminution is effected by the attrition or rolling and grinding of the pebbles alone. The first is a case of cracking open the grains and liberating the gold, or sulphide, as a relatively large angular particle susceptible of easy amalgamation, or concentration, whereas the second results in the scaly, impalpable, unmanageable slime produced by attrition. The first is illustrative of the principle of the stamp, the second that of the grinding mill. An appreciation of these principles will lead to a better understanding of the reason for the supremacy of the stamp-mill.

Within the past few years fine-grinding and 'all-sliming,' invariably connected with crushing in solution, has rapidly come into vogue. In most cases it has been advisable, but in many instances these methods have been employed because it is the fad, or because filtering devices were installed that required them. This is clearly wrong. Fine-grinding should not be carried beyond the economic point. The cost of finer comminution increases rapidly, whether by stamp, Chilean mill, tube-mill, or other device. The degree of fineness that will give the highest extraction in the laboratory is not necessarily that which will give the most profit. The milling and cyaniding machinery should be susceptible of adaptation to the economic requirements, and the millman or metallurgist should possess the ability to find them.

It may be given as a rule of broad application that the higher the grade and the baser the ore, the better adapted it is for all-sliming and crushing in solution, while the lower the grade and the less base it is, the less adapted it will be to these methods, since their cost hinges mainly on the degree of fineness and their application generally. While the percentage of additional extraction made by these methods usually increases with the grade of the ore, yet even in those cases where it may be essentially the same, on either a high or a low-grade ore, with a lessening grade, a point is soon reached where the additional extraction will not pay the increased cost.

It is a fact that crushing in solution has been generally unsatisfactory on low-grade ore, and there do not appear to be any plants operating under such conditions today—or at least any that are widely known outside of the Black Hills—yet there are many plants employing final cyanidation on low-grade ore. The question now comes, if crushing in solution has to give way to other methods on low-grade ore, why are not these other methods more economical on higher grade ore? Various factors enter into the consideration of this matter, but the principal reason why no satisfactory answer has yet been made appears to be that the metallurgists who should give us the answer are too busy boosting special processes in which they are interested.

There have been a number of mills built to employ these methods, which have not proved successful. These have usually been small mills, either not elaborately and carefully designed or embodying some rather new and untried devices. The best way to handle these 'novelty mills' is to go back to proved methods. Crush in water and amalgamate, following with regrinding and secondary amalgamation. Get all that can possibly be obtained by amalgamation, for that will be 'absolute,' at least in so far that possible loss of amalgamable gold cannot be detected after the careful amalgamator, except by the 'eyes' of amalgam appearing in the tailing flume. Then, take the tailing to the cyanide plant and do the best that can be done with the machinery available.

The latest idea in stamp-milling, outside of the increased interest in heavy stamps, is to employ Chilean mills as intermediate grinders following stamps. With the viewpoint that the tube-mill finds its greatest efficiency in reducing 30 or 40-mesh material to 200-mesh, the Chilean mill in medium grinding, and the stamp in coarse crushing, it is proposed to use heavy stamps crushing through a 4 to 12-mesh screen, delivering to Chilean mills grinding through a 30 or 40-mesh screen to tube-mills sliming to the desired fineness. Without doubt the general, if not universal, success will attend this method, but there is the possibility that it may not in every case be an economic success, since Chilean mill grinding in the roll-mill process has a reputation of being comparatively costly.

CHAPTER X

The men who are in charge of stamp-mills are almost invariably good mill mechanics, a large part have graduated out of machine shops, and even the least of them are first-class 'monkey-wrench' machinists, but only a small part are metallurgists. The methods of many of them are those that were taught them, and these methods they apply to all conditions with but little variation. This lack of ability to initiate experiment, to test, to devise new methods, and to progress, has hampered the advancement of the stamp-mill process. It is seen in the tenacity with which they cling to the old-time idea of saving the maximum amount of gold in the mortar, when the same, and in some cases higher, saving could be obtained by giving the stamp-battery a chance to perform its proper function —to prepare the ore for amalgamation, rather than to amalgamate it. Wherever the millmen have forsaken the well-beaten path of trying to save all the gold possible in the mortar, the tonnage has increased and ease of operation has been promoted. To "catch the gold as soon as you can catch it inside the mortar," is a good old maxim, but the slogan of the millman should be, "down with the tailing and up with the tonnage," and not, "increase the inside catchment—keep it up to 60 or 80 or 95%." The millman should understand adjusting the mill to the peculiar requirements of the ore, that he may be able intelligently to put his slogan into actual practice. He should also be able to determine the point where a higher tonnage ceases to be desirable by reason of resulting in too high a tailing, the economic limit having been reached.

The millman should have, in addition to training in large and small mills in various localities, and in mechanical work dealing in a general way with the setting up, operating, and repairing of machinery, with carpentering, pipe fitting, and construction work, a short training in assaying and ore-testing, and some study—home study if nothing more—in chemistry and mechanical and constructive drawing. In view of the wide application of electricity as the motive power for mills, the millman should understand the use and care of alternating-current machinery. While it is not expected that he should be able to set up transformers or connect the coils of motors, he should understand more than to merely start the motor according to the printed directions.

Much has been written and said about the honesty of mill employees. One of the principal arguments advanced for dispensing with amalgamation and centralizing the recovery of gold in the cyanide plant, is that it will prevent loss of amalgam by theft. It has been the fortune of the writer to have worked and associated with many millmen in various parts of the country, and to have come in contact with them on an equal footing and under conditions whereby their character could be best studied, and he has not known of a case of amalgam theft or a suspicion of such, except by report.

There are two reasons why so little thieving occurs, despite the fact that amalgam stealing appears easy and safe. The first is the *esprit de corps*, or loyalty to the profession, which is as strong in the millman as in any other calling. The second is that the amalgam or bullion is viewed by the millman as so much merchandise which he is accumulating for his employer, just as he is saving the sulphide in the concentrating department. It is an actual fact that millmen who may 'high grade' when working in the mine, or on the rock-breaker, will take no amalgam from the mill and nothing more than a specimen from the feeders.

The danger of amalgam theft lies in putting a green man of unknown character in a mill as helper, or temporarily on clean-up day. Also in the employment of a so-called millman who is only following milling until he can find an easier way for getting the living that 'the world owes him.' Outside of the above two, the danger does not lie mainly with the professional mill employee, but with the dishonest manager, superintendent, or confidential man who does the melting, and who may have a private ingot mold of his own to fill.

In late years a new class of stamp-mill superintendents has arisen, these are the cyanide metallurgists, who as milling and cyaniding operations are becoming more closely linked together, are taking both operations in charge. Where the work is carried out in conjunction this is a step in the right direction, but one in advance of the supply, for it is difficult to find men who have a thorough experience in stamp-milling, amalgamation, and cyanidation, mechanically as well as metallurgically. In the extended acquaintanceship of the writer there is only one past master of stamp-milling, amalgamation, and cyanidation, who is able to direct and instruct his subordinates in every detail.

The tendency of these new mill superintendents who have little or no training in stamp-milling and amalgamation, is to put too much stress on the cyanide branch. These are the men who would grind all the ore so that the value would be extracted by cyanide solution, disregarding the fact that if a grain of gold is caught on the plates, practically 100% of it is recovered; whereas, if it goes to the cyanide plant, a little of it is lost through the various wastes of solution, the cleaning up, and through the imperfect washings of the filters used.

The stamp-battery, to do good work, requires to be in the hands of a man who is in immediate charge of it, one who is a good millman and a strict disciplinarian, a crank on having everything done right and kept in condition, stopping just short of the point where the details to be carried out become idealistic rather than practical and beneficial. The average competent mill employee prefers to work under these conditions, rather than where no system prevails and everything is racked to pieces so that he must constantly keep a sharp outlook for trouble and be continually repairing. The placing of a stamp-battery in charge of a master mechanic who is not an experienced millman and whose attention is elsewhere most of the time, is just as serious a mistake as to consign it to the mercy of the different shifts of employees, all of whom are equally responsible and acting without a directing head. A man may be a first-class millwright and machinist and still be unsuited by lack of experience to take charge of a mill. A mistake is made in placing a man in charge of a stamp-battery whose experience has been superficial, no matter how competent he may appear; the result of such error is that the mill gradually wrecks itself until it becomes so badly racked and worn and generally broken down that it is a nightmare for a millman of long experience to work in it. The stamp-battery is such a simple machine that an observing man can learn to operate it under instruction in a short time, but being ponderous machinery subjected constantly to jar, tremendous vibration, and high tension, that to insure long life and good health it must have a man in charge who can promptly recognize its symptoms of trouble and at once apply the proper remedies.

The crew of a 10-stamp mill having concentrators will be composed of one man per shift. The man on the day shift will be in charge, and is assisted by the man who tends the rock-breaker. A 20-stamp mill has been run by the same sized crew, but the work is so strenuous that men will not long remain and the company suffers a direct loss during their stay from poor work, especially in the concentration. One man per shift with a head millman can run 40 stamps and do the amalgamating; and for this reason this is an economical size of mill to build. One man per shift has run up to 60 stamps and done the amalgamating, but the work is entirely too arduous for one. The crew of a 100-stamp mill will consist of an amalgamator in charge of the shift, one batteryman who attends to the feeding, and one helper. On the day shift there may be a repair man in addition to the head millman. Should the ore be low grade, requiring only one or two dressings of the plates in 24 hours, and the mill be in first-class condition, the helper on each shift may be dispensed with. The mill wood work, such as making screen-frames, chuck-blocks, and other small matters of this kind, are made in the mine carpenter shop.

Each 5-stamp battery is commonly designated by a number, but it is better to use letters for the batteries, reserving the numbers for the stamps of each battery. Thus

B4 is a short way of designating in writing, or orally, the fourth stamp of the second battery.

To record mill work various report systems and blanks are in use. These should be simple and cover the details desired without requiring questions from the management. At some mills a tin holder carrying a small sheet of paper is nailed to the post of each battery, upon which all hang-ups, breakages, and other causes of stoppage occurring to the battery are noted. These papers are collected each morning by the mill foreman and turned into the superintendent's office. An excellent method, especially in a small or medium-sized mill, is to post a form covering a month near the change room of the mill. This form is on heavy detail paper and has a line for each shift, with large space under the caption, 'remarks.' Just before going off duty, the millman whose shift is ending fills out his line, and under 'remarks' notes down what stems have broken, where new steel has been put in, what boxes are running hot, and any other details, so that the oncoming millman, by glancing over the sheet, will note at once what has been done on the other shift and knows what parts of the mill require special watching. At the end of the month the columns are totalled for the monthly report of operations and the sheet filed away as a summary of the work for the month. Where there is irregularity in the hours worked, or the crew is large, the time-slip method, whereby each man turns in his own time, should be used. A ruled form in a book, or posted on the wall, should be provided in which to record supplies received, used, and remaining on hand at the end of the month.

For recording the loss of running time the 'stamp-hour'

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system is the simplest and best. In this system the length of time any number of stamps is hung up is multiplied by the number of these stamps, the result being called 'stamp-hours.' The idea is to show the time lost as measured on one stamp only, and to simplify the recording of lost time. Thus, on one shift a single battery is shut down for 20 minutes, which is equivalent to one stamp being shut down for 100 minutes or 1⅔ stamp hours; later on 10 stamps may be shut down for 30 minutes, making a loss of 5 stamp-hours, or a total of 6⅔ for the shift. At the end of the day, or month, the millman divides the total number of stamp-hours lost by the number of stamps in the mill, and the result is equivalent to the number of hours of running time lost by the entire mill.

The mill-foreman should also be provided with a blank form in which he should enter daily the following data: Number of tons crushed; ounces of mercury fed inside the batteries, on outside plates, and ounces amalgam collected from outside plates. These data relating to feeding of silver and collection of amalgam should be entered for each unit of 5 stamps, if accurate information is desired; also number of pounds (wet weight) of sulphides collected from concentrators each 24 hours. To this sheet may properly be added the various stoppages and their cause, such as dressing plates, broken belts, babbitting shafts, changing screens, broken stems, replacing shoes or dies, power off, and the numerous other affairs that interfere with the steady operation of the mill. This sheet is not posted for general inspection, but goes promptly each morning to the office of the superintendent, where it is entered on a book kept for the purpose, and the mill-sheet placed on file.

Another sheet should show the supplies consumed, including shoes, dies, screens, quicksilver, lubricants, light, belting, chemicals, lumber, water, power (read by meter), concentrator belts, and all other items going to make up the cost of milling, including labor.

Whether a daily mill report is made or not for the superintendent at the property, or the manager at the general office, a monthly summary of operations should always be required of the mill superintendent, which should include a cost-sheet, and also a description of all tests and experiments made. This summary should be exhaustive, giving all the data of any practical value it is possible to obtain, and these should become a part of the permanent records at the property, with a duplicate at the general office. In the preparation of this report the millman will observe many things of interest and value that may result in further study and increased efficiency. It would require too great a length to speak of the invaluable uses these reports are put to. A concrete illustration will suffice. A small mill having a somewhat complicated treatment system was operated for an extended period by different metallurgists of repute. The mill finally shut down pending negotiations for equipping the property with a larger plant, and the blocking out of ore. When it was decided to begin metallurgical operations on an increased scale, the company in attempting to decide whether to increase the small plant, build a larger mill, or use some other system for treating the ore, found itself with only a lot of scattered incomplete information of the most vague nature much of which was hearsay. In this extremity they were obliged to send out a metallurgist to start up the small plant and by a series of experiments determine what could be done—in short, to get the data that a proper report system should have given.

The general superintendent, or manager, can materially assist milling operations by impressing on the mine foreman the necessity for keeping the mill bins full; by keeping the mine foreman, the mill foreman, the cyanide man, and the assayer in harmonious relation instead of antagonistic to each other, as is too often the case; and by urging the mill foreman to take advantage of the help of the assayer in his testing.

Directly in front of the middle of the batteries a floor should be erected overhanging the concentrator floor. A good stove should be placed here, that the batteryman on the night shift may be able to warm himself at a point where he has everything in plain sight, instead of going out to the boilers, or down to the cyanide plant. In a cold climate these floors have been boarded up to form a clean and cozy change-room with a glass front. The clean-up room can be situated to advantage at this point. It is preferable, where not too cold, to surround it with wire netting instead of boarding it up, that there may be more light. It is a wise expenditure to build a commodious and well-equipped clean-up room. Floors should be built tight and drain into a launder running the length of the mill to a box from which the amalgam, sulphide, and sand that has been flushed into it can be recovered to go into the clean-up barrel or through the mortars. Concrete floors make a neat looking mill, but are cordially detested by mill employees as they produce leg-weariness, calloused feet, and 'draw the cold and dampness.' A millman experiences a great relief in changing from a mill having concrete floors to one having wood. The use of rubber heels, overshoes, or thickly soled shoes affords some relief. Where concrete floors are put down, a walk of plank or grating should be run between the concentrators and along in front of the plates for the benefit of the employees.

A work-bench should be provided together with a full set of the tools such as are required in a stamp-mill, including the more common carpenter and machinist tools. These tools should be stamped but not kept under lock and key, with the exception of the extras. Each tool should have a place and the name of the tool should be printed at that place. During shut-downs on account of lack of power, or other external causes, the belts should be gone over and those parts of the mill repaired and cleaned that cannot be conveniently gotten at while in operation.

The millman who wishes to make a name for himself will keep his mill scrupulously clean and neat in appearance. He will first stop the running out and splattering about of oil and grease, likewise of the water and pulp, then of the ore that falls out of the chutes and about the feeders. Finally he will remove the rust, grease, and mud from the stems and shafts, and the mortars. Once the mill is burnished up and the splattering about and leakage stopped the mill can easily be kept in this condition. A clean mill and a good millman go together. There is a great difference in millmen, some are so careless and inexpert in making repairs and so unsystematic in the daily routine work that the duties become trying to the employees. Other millmen are able to keep their mills in such good condition and to plan the routine of daily work so well that the mill work is no longer odious but is accompanied with a considerable degree of gratification. Besides an able millman, a well constructed and properly designed mill is necessary. With these factors the stamp-mill becomes the most satisfactory metallurgical machine in use, to those both directly and indirectly interested. There are 40-stamp mills operating without a machine-shop or even a lathe, all repairs necessary being made by the millman sometimes assisted by the blacksmith. There are 10-stamp mills that, figuratively speaking, are in the machine-shop all the time, due to the absence of one of these factors, usually to defects in the installation.

No whistling or shouting should be allowed in a mill, except as a danger signal. To call attention a hissing noise should be made; as such a noise is keyed in a different pitch from that of the stamps, it can be heard across a large mill. Similarly, in talking, no attempt should be made to talk above the roar, but in a moderate tone keyed in a different pitch, which can only be learned by experimenting. Sign language should be developed as far as possible. Where it is desired to call a man at a distance, as at the rock-breaker or the cyanide plant, a triangle, such as is in common use at mine boarding-houses, should be used. In some mills the foreman carries a police whistle for the purpose of calling men. Colored signal lights are used for telephones.

There is a serious part of stamp-milling—the loss of hearing. A 10 or 20-stamp mill is not hard on the hearing, but the larger mills cause the majority of men to become deaf in time. To save the ear drums as much as possible and reduce the distress of the continuous noise, wads of cotton, wool, or waste are worn in the ears. These should be softened with clean oil such as olive oil or vaseline, that they may not inflame the ears. Further relief can be obtained by sealing the ears up, after the cotton, with a soft pliable wax or stiff salve that can be moulded into place.

For elevating pulp where necessary the tailing wheel is used at large installations. As these wheels are costly to install and the cost of operating remains practically the same whether a large or small quantity of pulp is to be elevated, some other machine is used in small plants. The centrifugal pump is too costly and troublesome from the shell, liners, and stuffing-box of the pump becoming rapidly worn by the grit. The Fernier sand-pump has been found very satisfactory. Its maximum lift is about 20 ft. in a practical way, and for a higher lift two or more of them should be placed tandem. The wear on these pumps is mainly in the bearings, the grit of the pulp giving no trouble. They have to be stopped for a period of 10 minutes every 2 to 4 weeks to allow replacing the gland with one that has been re-packed. Experiments have been made with an air-lift pump. These cost little to install and to keep in repair, but their efficiency is low. The air-displacement pump is now being used in pumping slimy and gritty liquids and slush, and is being introduced for pumping thickened pulp into filter-presses against a high head. This pump would appear to solve the problem of a cheap and efficient installation for elevating wet pulp as they cost but slightly more than a centrifugal pump, require little attention, are compact, have high efficiency, and the cost for wearing parts or repairs is nominal. The hydraulic lift, or elevator, is being used for elevating pulp where the extra amount of water necessary to their operation is not considered undesirable, as in a canvas-plant.

Stamp-mill launders within the mill should be set with a grade of one foot in twelve. Discharge launders or flumes leading away from the mill should have a grade of not less than one foot in sixteen. A grade of one foot in twenty will work under favorable conditions without giving trouble, but is generally too small, particularly in a cold country. In one case the finely crushed tailing of a 40-stamp mill was transported in a flume having a grade of one foot in thirty-two, but considerable trouble was experienced.

Where it is necessary to impound the tailing, it is usually done to prevent it from reaching sites, or water courses, where it is not wanted, or for the purpose of subsequent treatment, such as by the cyanide process. A hillside can usually be had to form a wall on from one to three sides, while the pond is laid out in two or more sections that the walls of one section may be raised by shoveling or scraping while the other is filling. Where the tailing is not being banked for future treatment, the tailing flume is carried over the pond just inside of the wall that has to be raised by shoveling. The tailing is discharged along this wall through several small gates. The coarser sand of the tailing settles at this point, damming the slime back against the hillside where a box flume laid on the ground and passing underneath the pond, carries off the clearer water. The depth of the slime is increased by extending the bedrock flume as needed. The mill flume can run along the contour of the hill and small V-shaped troughs can be lightly trestled up to carry the tailing to the outer bank of the pond. This method of filling results in the slime being separated from the sand, and should not be used where the tailing is to be eventually cyanided, as it is impossible to treat this caked slime without a highly expensive equipment. Four sets of inlets and outlets should be spaced about each section of the pond and a change made from one set to another daily or semi-daily. This will result in throwing a layer of sand upon a stratum of slime through which it will sink to some extent, and will enable the cyanide man to put a homogeneous and leachable charge into his tanks, without leaving any material behind as unleachable.

These ponds have been used to return some of the water to the mill for re-use, but a settling plant is much better. This may be of the well known cone settlers purchased outright or home-made of wood at a small plant. A simple and efficient water-saving plant consists of deep pulp-thickening tanks ending in cones with 60° sides and large gate-valve discharges. The pulp is introduced into the center of the tank some distance below the surface of the overflowing water that its introduction may not be violent and that the settling effect of a slowly ascending column of water may be obtained. The valves are opened at intervals of a few hours to withdraw a part of the thickened pulp, which comes out as a thick and solid sludge requiring a launder set at heavy grade. The wooden box settlers so common around small mills on the desert and so unsatisfactory in operation, should be divided into compartments fitted with these cone bottoms and gate valves.

Novel instances of mill-tailing put to agricultural purposes are found in California. Some 30 years ago, the tailing from a large mill crushing a quartz ore containing much of the slate in which the orebody lay, after running in a creek for three miles, was diverted by an earth dam and impounded to form a fill. The flat bottom of the creek had been cleaned bare years before by placer miners. A stone wall, 6 by 15 ft. high, was roughly laid at the side of the creek, to raise the proposed surface above high water. This wall was about 2200 ft. long, and inclosed a strip of ground of that length and from 125 to 250 ft. wide, to be filled by the tailing. This filling was done in sections and required several years to complete. The surface was well manured, and the tailing was found to make an excellent soil for growing vegetables and fruits, being preferred to the natural soil. It is still actively worked and is considered the best garden in the county. There are many gardens of this character along the Mother Lode of California.

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