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TESTING ORES FOR FLOTATION

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By
A. W. Fahrenwald

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Small Scale Testing

By small scale testing the writer refers to laboratory testing as practiced by the U. S. Bureau of Mines and by private or company laboratories in which 1000 grams of ore is the standard size of sample treated. In a few cases 500 grams is the size of sample used.

Preparation of the Ore Sample

There are two general methods of preparing ore samples for flotation: namely, wet crushing and dry crushing. It is more convenient and admits of a larger number of tests being made in a given period of time to use dry-crushed samples, and such a procedure is permissible for the preliminary work. However, after the most satisfactory conditions for the flotation treatment of the ore have been determined on this basis, several tests should be made on wet-prepared samples duplicating these conditions. It will be found, usually, that the recoveries and grade of product resulting from the test on the wet samples are quite noticeably better, frequently from 5 to 10 per cent better. Another point which should be kept in mind is that, if a satisfactory treatment scheme can not be worked out by testing the dry-prepared samples, no conclusions as to the adaptability of flotation to the ore should be drawn before testing wet-ground samples.

Wet grinding insures complete wetting of all mineral (gangue and sulphide) particles by water and when the flotation agent

(usually an oil) is added, it appears to be more readily adsorbed at these wetted mineral surfaces than if the mineral surfaces were covered with a film of air.

It can be anticipated that a large number of tests will have to be made on an ore before satisfactory conditions for its treatment are determined, and for this reason from 75 to 100 pounds

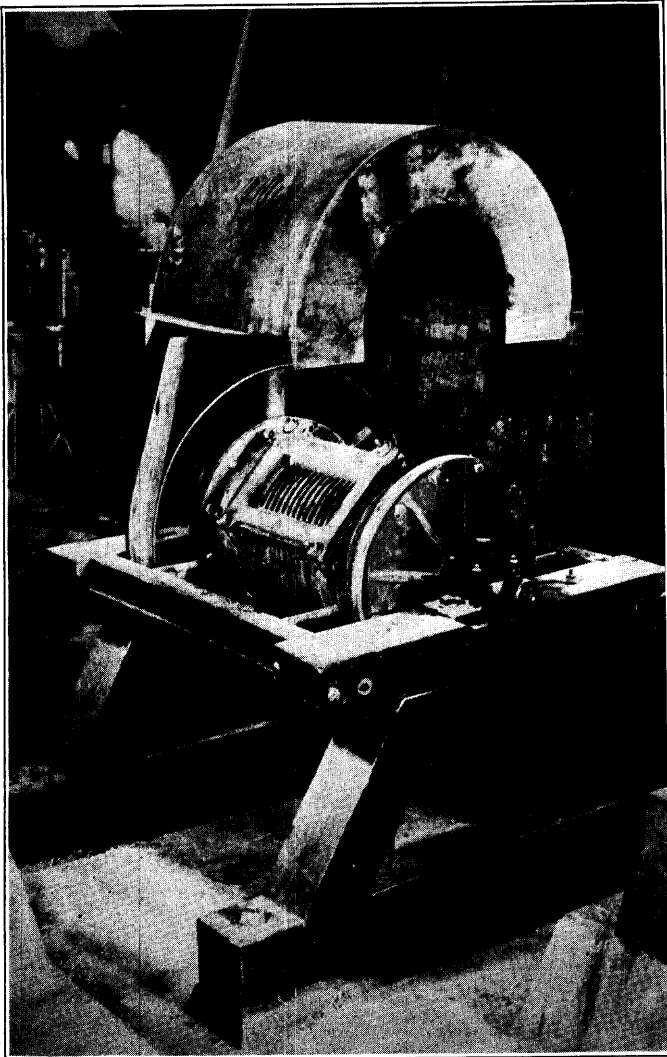


FIG. 1. THOMSON BALL MILL

The grated door shown is used only for discharging after dry crushing. This door is replaced by a solid one while crushing is being done.

of the ore should be prepared in advance of the actual testing work. This will give enough material for from 30 to 40 tests. The material should be ground either wet or dry to pass a certain specified screen, 65-mesh (0.208 mm. opening), being the usual size. A suitable ball mill for the preparation of these large batches is shown in Fig. 1.

After the best conditions for the treatment of the ore have been worked out for a sample prepared as above, the factor of fineness of crushing should next receive attention (whether the results are on dry- or on wet-crushed ore). Samples ground to pass 48-mesh, 100-mesh, and 200-mesh should be tested under the conditions¹ determined for the 65-mesh sample. It is possible that results on the 48-mesh material may be better than those on the 65-mesh or that 100-mesh material on the other hand may give the best results.

Degree of Crushing

This is a factor too often neglected in testing work, and consequently in milling practice. For a discussion of this factor see "Size of Mineral Particle in Relation to Flotation Concentration," Pamphlet No. 2, Idaho State Bureau of Mines and Geology.

A suitable and convenient ball mill for this phase of the work, designed by the writer, is shown in Fig. 2. It can grind either wet or dry, and little manual labor is required for either charging or discharging. It is charged through a funnel inserted in a tap hole; a complete discharge of the pulp is effected by revolving the mill for two or three minutes after removing the encircling rubber band which closes the peripheral slot between the two cones.

Testing Machines

Flotation testing machines are as numerous in type as are commercial machines and there is no one type which is generally adopted as a standard for laboratory testing by flotation engineers. Accurate and consistent results are impossible with improper apparatus of which there is much in use, and in visiting testing laboratories one is often impressed with the lack of correlation between the conditions under which the ore is being tested and those under which it will have to be milled.

A machine suitable for testing purposes should meet the following requirements:

¹It should be borne in mind that more oil will be required for the more finely ground samples, as the quantity of oil required will be in relation to the total amount of floatable mineral surface exposed to the pulp.

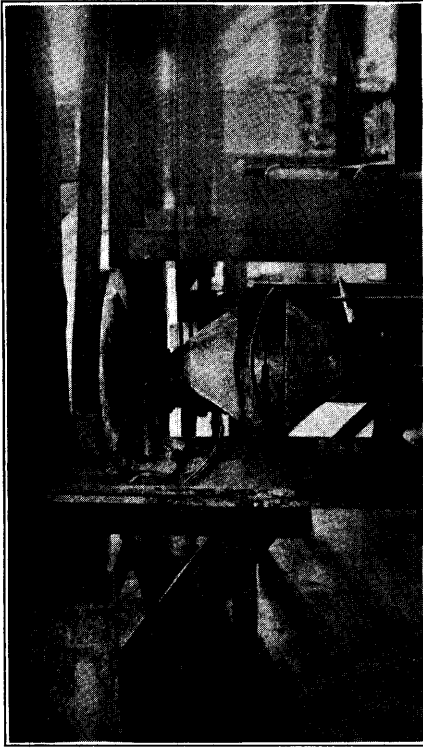


FIG. 2. FAHRENWALD BALL MILL

- (1) It should test not less than 500 grams, preferably 1000.
- (2) It should be easily charged and easily discharged and washed out in order that no material of the test shall be lost. This allows of checking total mineral contents of the sample tested.
- (3) It should be preferably of the centrifugal impeller type, which is convenient in that it allows the aeration to be controlled, and provides an easy and efficient means of using gases, such as SO_2 or H_2S if desired.
- (4) It should have glass sides to allow of close observation of conditions resulting from the use of the reagents added.
- (5) It should have no circulation pipes.
- (6) It should provide for the entrance of the impeller shaft to the flotation chamber from the top; shafts entering from the bottom give trouble and make discharging and washing out of the pulp inconvenient.

Laboratory machines may be classified as follows:

- I. Vertical shaft machines, producing aeration
- (a) through violent agitation of the pulp, exemplified in
 1. some form of Minerals Separation (M.S.) machine
 2. the Janney machine
 - (b) through violent agitation followed by subaeration of the pulp, exemplified in the Jones-Belmont machine
 - (c) through the medium of a centrifugal device operating in the pulp without producing agitation, exemplified in
 1. the Groch and Ruth machines
 2. the Fahrenwald machine
- II. Horizontal shaft machines, producing aeration
- (a) through moderately violent agitation on thin sheets of the pulp, exemplified in the Kohlberg and Kraut (K. & K.) machine
 - (b) through jetting action of the sheet of pulp, exemplified in the Fahrenwald drum machine
 - (c) through the action of spiral pumps (similar to the Frenier), exemplified in the Akins machine.
- III. Machines with no shafts or moving parts, producing aeration
- (a) through the medium of porous bottoms, exemplified in the Callow machine
 - (b) through the medium of air lifts and liquid jets, exemplified in the Arzinger machine.

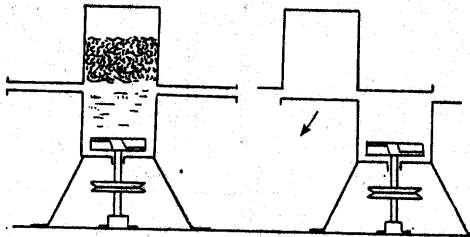


FIG. 3. SLIDE MACHINE

Class I (a). Machines of this type were perhaps the first used to any extent for testing purposes. The slide machine, described by T. J. Hoover¹ and in several subsequent books on flotation, Fig. 3, was among the first used, but it has served its purpose and is now a relic of early flotation methods. It consisted of a rectangular agitation and frothing chamber, the upper portion of the chamber being so constructed as to enable the operator to move it laterally, cutting off the froth and moving it bodily out of the machine. It was of necessity of the type of machine in which the

¹ "Concentrating Ores for Flotation," published by the Mining Magazine, Salisbury House, London.

impeller shaft entered the flotation chamber through the bottom, a construction which was a source of constant trouble. The impeller blades were of various shapes and usually were four in number set in a horizontal plane at right angles to each other and each at a 45-degree angle with the vertical.

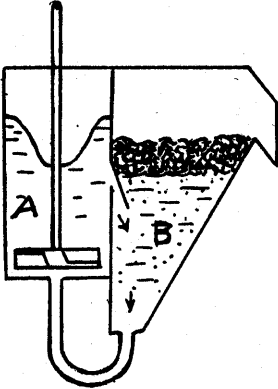


FIG. 4
Undesirable Type Hoover Machine

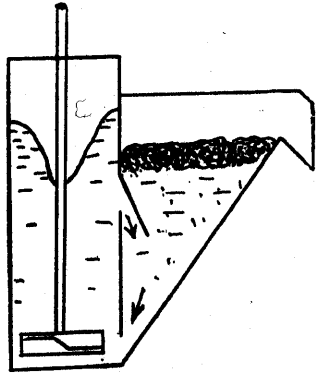


FIG. 5
Desirable Type Hoover Machine

The Minerals Separation or Hoover machine was no doubt the first of any consequence. Fig. 4 shows the early model and Fig. 5 a later form. They are both of the "cell and spitz" class, i. e., the agitation or mixing and aeration of the pulp is effected in a rectangular compartment, from which the pulp is caused to circulate to a V-shaped compartment, or spitz, designed to effect a separation of the floatable particles and the gangue. In the V-shaped compartment the relative quiet of the pulp allows minerals to float and gangue to settle; the latter, with any mineral not floating at once, drops to the apex of the V and is drawn into the agitation chamber by the action of the 45-degree impellers, and forced through the cycle of treatment a second time. The testing machine of this type now generally used, Fig. 6, has the impeller shaft entering the agitation chamber from above, which is an advantage. The pulp flows into the frothing compartment through a rectangular slit 6 to 8 inches above the bottom of the cell and under a baffle slightly below the pulp level. This baffle directs the pulp downward, and causes the bubbles to pass up through a greater depth of pulp, thereby bringing about a cleaning action. The pulp, in the course of its circulation, enters the agitation chamber through a narrow slit at the bottom of the partition between the agitation chamber and the "spitz," the bottom of the

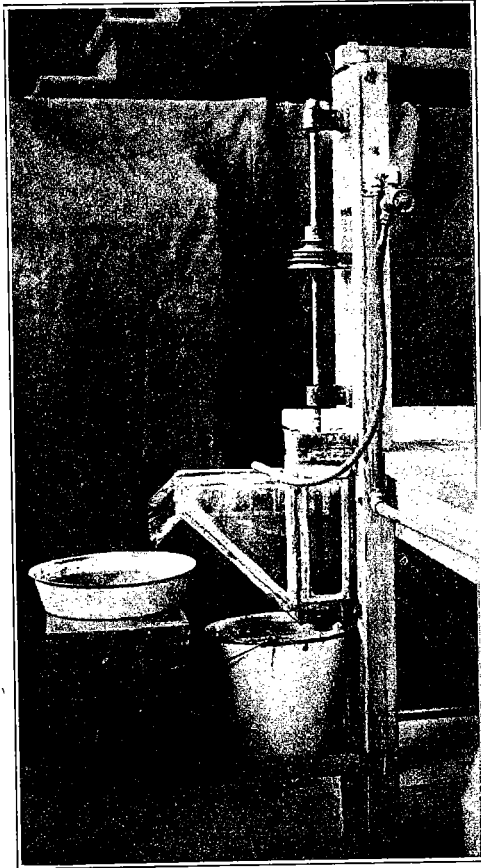


FIG. 6
*Desirable Type Hoover Machine
 (The Varley-Federal Machine)*

agitation chamber being a horizontal continuation of the inclined bottom of the "spitz." The first machines employed small pipes or rubber tubes for connecting the two compartments; these are always a source of trouble. The Janney machine, a neatly designed piece of apparatus, is still used to some extent, and treats a 500 gram charge. In this machine the impeller shaft enters the cell from below. A later design, while obviating the shaft trouble by arranging for the entry of the shaft to the cell from above, is decidedly inconvenient to charge. It has two impellers, each with four blades at right angles to each other; the blades of the upper impeller are set vertically, while those of the lower one are at 45 degrees from the vertical. Baffles, four in number, run vertically up the sides of the agitation barrel, and terminate just below the

upper impeller; the lower impeller revolves inside of these. Their purpose is to prevent undue swirl of the pulp. The aerated pulp is discharged over the top of the agitation barrel around the outside of which is a sloping annular launder that directs the pulp to the frothing chamber or "spitz." Mineral not floated is again drawn into the agitation chamber for further treatment.

Class I (b). While there have been several machines on this principle invented and used, one developed within the past two years by A. H. Jones and called the Jones-Belmont (J.B.) machine, is perhaps the most suitable for testing purposes. The mechanical agitation, mixing, and circulation are effected by the usual impellers (each with four blades at right angles to each other, the lower one having its blades at 45 degrees) operated by a vertical shaft which enters the barrel-like agitation chamber from the bottom. The agitation chamber is provided with vertical baffles. The action of the lower impeller causes the pulp to be drawn from the pneumatic chamber up and over the top of the barrel, whence it

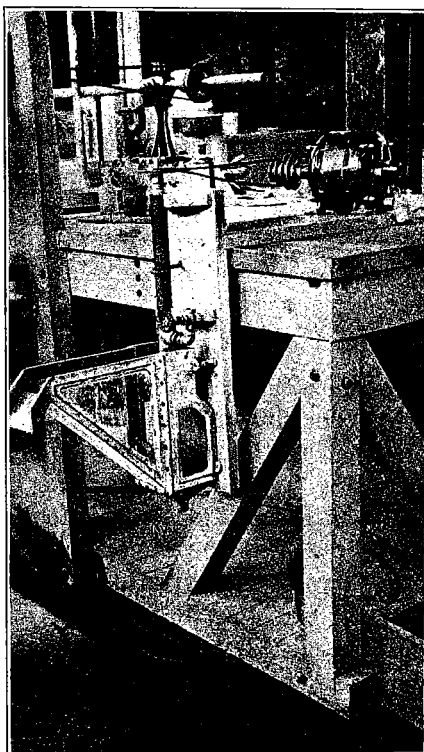


FIG. 7. FAHRENWALD FLOTATION MACHINE

passes into a sloping annular chamber with porous bottom. It is during the passage of the pulp over this porous medium that the minerals are recovered in the usual froth. The froth overflows into an annular launder which slopes to a common spout serving as a froth discharge for the machine.

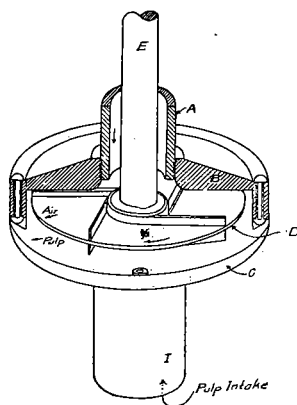


FIG. 8
Showing principle of Aeration

Class I (c). Testing machines effecting mixing, aeration, and circulation of the pulp by the employment of a centrifugal mechanism are the most recent development. The most important of this type for testing are the Ruth, Groch and Fahrenwald machines.

The Ruth machine is of the compartment and impeller type. The impeller is similar in principle to the enclosed runner of the centrifugal pump. The lower part of the impeller lifts the pulp through an axial opening and discharges it through openings in the periphery. The upper part of the impeller connects through four passages with a hollow shaft, through which air is drawn down and discharged through openings in the periphery of the impeller, each opening being midway between neighboring pulp-discharge openings. The air-discharge openings are provided with small hoods that assist in the free discharge of the air into the pulp. The discharged pulp mixed with air rises in a cylindrical chamber and overflows into the spitzkasten compartment. This compartment is V-shaped and connects by a lower passage with the inlet opening of the impeller. A curved deflecting plate is placed at the back of the impeller compartment and throws a steady surface stream of pulp toward the spitzkasten compartment and the discharge lip.

The Fahrenwald machine¹ is shown in Figs. 7 and 8. The essential features of the machine are a stationary hollow tube A, upper and lower housings B and C, suitably secured to A, and an impeller D enclosed by B and C. The impeller is a revolving disc with vanes above and below, these vanes being set tangent to a circle one-third the diameter of the disc and at 90 degree intervals. There is a suitable hub on the upper side of the impeller by means of which it is secured to the solid impeller shaft E, the other end of the impeller shaft projects from the upper end of the tube A and carries a cone pulley through which power is applied to it. This impeller shaft revolves inside the hollow tube in suitable ball bearings secured within it. There is a tee connection just above the frothing level through which air, oil, gas, or other substances may be admitted. Admission of air or other gas through this opening is under complete control of the operator through manipulation of the valve. Additional openings for any purpose may easily be provided. The lower impeller housing C carries the suction pipe J.

There is a real difference in the above two machines. In the latter the impeller, comprising a metal disc and vanes, revolves in a housing as described, and discharges air and pulp at all points around its periphery, giving large pulp circulating capacity and a strong air suction. The Ruth impeller sucks air from the atmosphere through the hollow impeller shaft, and ejects the pulp through four radial orifices. Aeration is the result of centrifugal force and displacement resulting from the action of the air intake hoods. In the Fahrenwald impeller, air is drawn to the periphery through centrifugal action and is then carried into the pulp by the liquid jet action of the sheet of pulp ejected by the lower vanes of the impeller; the air supply is under control of the operator by the simple manipulation of a valve.

The Groch machine is similar in principle to the Ruth, there being some difference in the design of the impeller.

Class II. Flotation machines of this type are as a general rule less convenient as laboratory units, but on the contrary are favored by some mill operators for commercial work.

The K. & K. (Kohlberg and Kraut) machine was the first of this type to make its appearance. Horizontal drum machines are not as easily cleaned as is desirable in laboratory work, and for this reason the K. & K. machine has found but limited application for flotation testing.

¹ Thomson, Francis A., Min. and Sci. Press, Vol. 120, June 12, 1920. Fahrenwald, A. W., Pahasapa Quarterly, April, 1920.

The Akins machine embodies the Frenier pump principle. It consists of a rotor with horizontal axis operating in an elongated tank having one side "spitz" shaped. The tank in a commercial machine is divided by partitions into a number of cells, each cell being so constructed that it provides an air chamber to which the pulp acts as a seal. Each air chamber is fitted with an air regulating valve which controls the quantity of atmospheric air admitted to the cell. The rotor consists of two integral members; one, called the "aeration member," traps and forces air into the pulp; the other, called the "diffusion member," diffuses or disseminates air throughout the pulp. The diffusion member occupies only a part of the cell and is made up of three concentric perforated cylinders surrounding the shaft. The innermost cylinder alone extends the full length of the cell and supports the inside ends in a series of vanes or scoops which extend outward to the periphery and make up the aeration member. This aeration member occupies the balance of the cell. The rotor operates only partially submerged, and as it revolves, the spirals trap air and force it into the pulp. The air bubbles are broken up by passing through the perforations into the central cylinder, and disseminated throughout the pulp by passing quickly through the perforations of the three cylinders of the diffusion member.

The froth rises directly up in the "spitz" and overflows the weir, the rate of aeration and overflow being accurately regulated by the air regulating valve on the air chamber.

Class III. Machines of the latter class (best exemplified by the Callow pneumatic cell) are little used for testing purposes, not being sufficiently flexible for all around work.

Bearing of Type of Machine on Testing Work.

The shape and mechanism of the machine used have important bearing on the results of small scale tests and upon the ability to duplicate them in the mill. Moreover, the machine should not be constructed of brass, copper or other materials that are soluble in the acid and alkaline solutions of some testing work. Wood, particularly in a new machine, is not suitable as certain of its oily and resinous constituents are dissolved in the water and greatly affect its surface tension. Aluminum and lead are suitable materials. The machines should have glass sides so that depth and character of froth may be closely observed.

A machine suitable for good testing work should not disturb the pulp unduly, but at the same time it should aerate it with con-

trollable amounts of finely dispersed bubbles, and should keep it in continuous circulation. In meeting the above requirements it is not important that the machine should operate on any one principle in preference to another. The amount of total frothing surface is important and should be in proportion to the ability of the machine to aerate and circulate the pulp.

General Equipment for Testing

Delicate equipment is not required in flotation testing. Plenty of enamelled buckets for taking care of the tailings are essential, galvanized tubs for holding pulp sample, and 12-inch enamelled pans for catching the concentrates should be provided. In tests on 1000 grams of pulp the tailing discharged plus the water required to wash it all out of the machine will fill an ordinary enamelled water bucket over half full. The quickest way to dry the tailing is to add a little sulphuric acid to promote settling, decant, and dry the thickened pulp on a hot plate; eighty per cent or more of the water can be quickly removed by the decantation. The pans in which the concentrate has been collected are placed on a suitable hot plate and a few hours are required to drive off all the moisture.

If more rapid results are required, the tailing and concentrate can be stirred well, and small samples taken therefrom; these can be dried in much less time than the entire product. The small samples thus taken are weighed and assayed, and the weights are added to those of the corresponding products, which will be dry at about the time returns are forthcoming from the assayer. A day's delay between experiment and assay returns can be saved by this procedure. Scales weighing to the nearest gram are sufficiently accurate for close work.

Procedure in Making the Test.

The methods for preparing the ore sample for testing have been described.

1000-gram charges are the most convenient for general flotation testing work. With ores carrying small amounts of floatable mineral, sufficient concentrate for close work cannot be obtained from a 500-gram sample. One thousand grams is also a good amount on which to base calculations, in that every gram or fraction of a gram of any agent used multiplied by two gives the number of pounds per ton of ore.

If dry ore is being tested it is usually agitated with an equal weight of water, and the addition agents to be used are mixed and

disseminated through the pulp at this dilution. The time of mixing depends upon the type of machine, the temperature, the amount of air beaten into the pulp, and the chemical nature of the agents to be used. Pine oils, for example, are easily broken up and mixed homogenously through the pulp, while coal tars require longer mixing. If controlling agents are used, as for differential flotation, they are agitated and mixed with the pulp, usually in advance of the flotation agent. The time of pre-treatment with such agents can be determined only by experiment. The rate of solution and diffusion, and amount of aeration during agitation are important.

After the flotation agents (usually oil) have been thoroughly incorporated in the ore pulp, the pulp level is raised to within a couple of inches of the overflow lip, and removal of the floatable minerals is effected by frothing. This operations requires from three to twenty minutes, depending entirely upon the mineral content and other factors peculiar to the ore. As the mineral is removed the froth clears and in some cases, after the mineral has been wholly removed, it has the appearance of foam. In most machines the froth is removed by hand with a paddle. Machines provided with air control valves can be manipulated so as to cause the free overflow of the froth.

Ore ground wet for testing is usually of a dilution not greater than 1 to 1 and it is added to the machine at this consistency. Pre-agitation with chemicals and oils is carried out as for a dry sample diluted to this ratio. Testing work is usually done on a pulp dilution of 4 to 1 (water to dry solids). However, before drawing final conclusions, various dilutions should be tested carefully, particularly when testing controlling agents for their effect on flotation. The amount of reagent producing good results will generally be in proportion to the amount of water in the pulp. Low pulp dilution, 2.5 or 3 to 1, is usually best for differential flotation. Pulp dilution is one of the important factors in flotation.

Assays and Recording of Tests.

From the head assay the metal content is known and the approximate mineral content may be calculated, if a 1000-gram sample is to be tested it will contain in units of each metal an amount equal to the percentages in the heads, times the weight of sample, which is say 1000 grams. The number of units of a given metal in a concentrate and tailing will then of course be equal to the sum of the products of the weights multiplied by the respective

percentages. The percentage recovery of the metal is then a simple question of division.

The following example of a *bona fide* test brings out the point more clearly:

	Wt.	%Pb	%Zn	Units Pb	Units Zn	Recoveries	
						Pb	Zn
Head	1400	4.0	3.5	5600	4900		
Concentrate	70	52.6	11.0	3655	770	65.7	15.7
Tailing	1330	1.5	3.2	1993	4156	35.5	84.7

Complete notes should be taken on every test, setting down what was done and what observations were made. When a series of tests is made in which one or more factors and chemicals are involved, a convenient method of setting down the results in a manner to be best scrutinized is in some form of graph. Conditions giving best results can be pointed out at once from such a diagram.

Some Important Factors in Flotation

A recent paper by Ralph D. Nevett¹ discusses at some length several of the important factors in flotation. The writer, however, does not find himself in absolute accord with some of Mr. Nevett's statements. Some of the factors having an important bearing on the success of flotation are discussed in what follows:

(1) *Size of Floatable Particles.* This factor is discussed in another paper, "Size of Mineral Particle, in Relation to Flotation Concentration," devoted entirely to this phase of flotation.²

(2) *Nature of Water Used in Milling.* The nature of the water used in milling often spells the difference between failure and success. There are many contaminants that can be picked up by water and adsorbed at the surface to such an extent that its surface tension and spreading properties are destroyed or lowered. When laboratory tests can not be duplicated in the mill, the difference in water should be one of the first things investigated. Further consideration is given this factor elsewhere.³

(3) *Pulp Ratio.* The amount of water per unit of solids for best flotation is a question of greater importance than is often thought. For ordinary collective flotation, where nothing but oil in any reasonable quantity is used, it is not of first importance. In flotation where controlling agents and definite amounts of oil are used, however, the pulp ratio will be found to be a factor worth regulating very carefully.

¹ "Some Controlling Factors in Flotation," Min. & Sci. Press, Vol. 121, p. 349, Sept. 4, 1920.

² Pamphlet No. 2, Idaho State Bureau of Mines and Geology.

³ Pamphlet No. 4, Idaho State Bureau of Mines and Geology.

When controlling agents are used in flotation, it appears that the molecular concentration of these agents accounts largely for their beneficial action. It is found that there is a particular concentration or quantity of reagent that gives best results. If this amount has been carefully determined and then another ton of water be added per ton of dry solids treated, the molecular concentration of the agent is thereby lowered. The action of most controlling agents is probably physical, i. e., they alter the interfacial tensions through surface concentration or adsorption; the amount of contaminant molecules adsorbed is more or less proportional to the amount of such molecules present.

The specific gravity of the pulp may have a bearing on flotation, for the density increases and decreases with the percentage of solids suspended therein. The viscosity is also a factor varying with the percentage of solids and could easily affect flotation. The fact remains that pulp consistency is a factor of importance, even though it is somewhat difficult to give a specific reason.

(4) *Flotation Agents.* The writer has in mind agents that actually cause the floating, and while in some cases agents other than oils have served in this capacity, oils are generally used. There are, with many ores, a variety of oils that will do almost equally good work and in such cases the determining factor in the final choice of any oil may be the cost. In other cases it is the nature of the froth produced that decides between two or more oils which give equally good recoveries and grade of product. All of the pine oils are good, steam distilled being among the best. Pine tar creosote and wood turpentine are used a good deal. Hardwood creosotes, both Cleveland Cliffs and General Naval Stores brands are used a good deal. Coal tars are used in conjunction with pine or other frothing oils. Coal tar oils lower the surface tension of water less than the more soluble pine oils, and therefore require more agitation and mixing when used. Oils possess different spreading powers and can be classified accordingly. Oils that spread readily on water are easily mixed if plenty of air is used in the agitation; the more air in the pulp, of course, the more spreading surface available and consequently the quicker a dissemination of the oil results. Oils that form globules when dropped on water mix with greater difficulty and more agitation will be required to get them thoroughly mixed through the pulp.¹ Hardwood oils have a very low oil-water interfacial tension, and

¹ In fact oils that do not spread on water will alone be of no value in flotation. They serve as mineral oilers if they spread on them, but not as bubble oilers. The paraffin oils are of this class.—A. W. F.

spread rapidly on water and will replace practically all other oil films on water; they are exceptionally good flotation agents for this reason.

(5) *Controlling Agents.* Such agents, commonly called addition agents, are used in flotation for one or more reasons. They are added in many cases to keep down the percentage of gangue material or "insoluble" in the concentrate. Sulphuric acid, salts or alkalis, may be found suitable—whether they are of benefit or not can be determined by experiment only. Small amounts of sulphuric acid are usually very beneficial and often used for "dropping" the gangue. Controlling agents are added to effect a separation of one floatable mineral from a pulp containing one or more other floatable minerals.

There are as yet no rules governing the use of chemicals as controlling agents, experience being the only guide. The quantity used is usually expressed in grams of the reagent in a liter of water.

The action of these agents is no doubt physical, bringing about selective spreading of both the flotation agent and the water on the minerals. While it is true in a few cases that the agent may promote or take part in a chemical reaction, the fact still remains that spreading is due to physical properties of the phases composing the system. The subject is discussed more fully elsewhere.²

Colloids, as controlling agents, are often encountered, although the effect of true colloids in a flotation pulp is not yet clearly understood. In a few cases the portion of a flotation pulp called slimes has proven beneficial, acting to a certain degree as a flotation agent and diminishing the quantity of oil required. In not a few other cases slimes or fine suspensions, call them colloids or what you choose, have proven detrimental to the point of entirely preventing flotation of the minerals.

A fact which is often lost sight of is that two ores may, on fine grinding, yield equal amounts of fine particles that will remain suspended in solution with equal permanence, and in both cases the particles may be called colloids, but they may have entirely different physical properties (surface energies) which will determine definitely their effects upon flotation. Their respective adsorptive powers and powers of being adsorbed are the controlling factors.

(6) *Time of Pre-agitation and Treatment.* It is understood by all those acquainted with flotation that thorough and complete

² "Differential Flotation," Pamphlet No. 4, Idaho State Bureau of Mines and Geology.

mixing and dissemination of the flotation agent (oil) is essential to satisfactory work. It is often difficult, however, to get mill operators and others less familiar with flotation principles to understand why it is necessary to mix controlling agents before flotation agents are pre-agitated. It is generally, though not always, true that differential flotation is impossible after oil has once been added and mixed with the pulp. This is only natural, for, as soon as the oil is added it proceeds to spread on all floatable minerals. For any agent to effect differential flotation subsequently it would have to replace the oil; and experience has shown that such a replacement is difficult of accomplishment. In a few cases successful differential flotation of lead and zinc concentrate obtained from collective flotation has been obtained by the Bradford SO₂ process.

In differential flotation the time of pre-treatment with the controlling agent is an important factor and must be determined from a series of tests in which time is made the variable.

(7) *Removal of Froth.* Determining the time actually required to remove all of the mineral gives one an idea as to the length and number of cells necessary for good recovery in large scale work. The time required for complete removal of a mineral is a measure also of the intensity of the flotation conditions for that mineral. Three to ten minutes should be sufficient, though this will, of course, vary with the amount of mineral to be floated and with the manner in which it is drawn from the machine.

(8) *Time of Test.* The total time for making a test should be recorded as follows:

Time of pre-agitation with controlling agent	say	5 minutes
Time of pre-agitation with flotation agent (oil)	"	3 minutes
Time of frothing	"	10 minutes
		18 minutes
Total time		18 minutes

The time of pre-agitating flotation agent and of frothing should be kept constant while the time of pre-agitating with the controlling agent is being varied.

(9) *Temperature.* The factor of temperature is discussed elsewhere.¹

Reliability of Small Scale Tests.

It is the writer's belief, based on his experience, that if testing be done with care and a knowledge of the influence of all the little

¹ See "See Surface Energy and Adsorption in Flotation" by A. W. Fahrenwald, to appear shortly in Min. and Sci. Press.

details and factors, that in ninety-five cases out of one hundred the small scale tests can be duplicated in the mill. Many failures to duplicate laboratory work in the mill can be attributed entirely to lack of understanding by the testing engineer of the actual conditions prevailing in his laboratory tests. Quantities of reagents, time of treatment, and results can not be determined by guess. A true record of all factors tested and assays of products should be made. The eye, while a splendid medium for conveying information to the brain, is often deceived, and the grade of product cannot be dependably determined by the eye.