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Laboratory Model Shaking Table; An Investigation of Defects and Suggested Improvements

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LABORATORY MODEL SHAKING TABLE

AN INVESTIGATION OF DEFECTS AND SUGGESTED IMPROVEMENTS

by

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A Thesis

Submitted to the Department of Mineral Dressing
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Metallurgical Engineering
(Mineral Dressing Option)

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INTRODUCTION

In view of the interest in gravity concentrating methods in the last few years and particularly the Dense Media (sink-float) processes and the Humphrey spiral, a re-examination of table concentration is relevant. Thus in this thesis an examination of the laboratory shaking table and its efficacy as a means of mineral separation is appropriate. The objectives of this study are: 1) greater ease of machine control, and 2) the ability of attaining higher efficiency of separating the ore minerals from the gangue minerals.

The laboratory model is considered in this thesis. Information gained from this investigation has not been transferred to the larger industrial machines. Some of the factors noted concerning the efficiency of the laboratory shaking table are inherent in this small scale model only.

The relative importance of ore concentration by shaking tables may be thought by some to be on the decline, but this method of mineral separation is used extensively. R. S. Dean[1] in 1938 stated that tables in many plants are doing the main sand and slime concentration, roughing work, separating of sulfides, and are used as pilot machines following flotation cells. He further predicted at that time that the table will never be completely discarded. A. M. Gaudin[2] as late as 1941 stated that the use of shaking tables in the field of agglo-

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1 R. S. Dean, "Recent Trends In Ore Dressing," The Mining Congress Journal, pp. 37-39, April, 1938.

2 A. M. Gaudin, "Mineral Dressing," Engineering and Mining Journal, pp. 80-81, February, 1941.

merated feeds is expanding and in plain feeds is holding its own. In preliminary mineral testing it is therefore important that tabling be considered. It is essential that the laboratory model table duplicate as closely as possible the results of the larger industrial machines.

Because laboratory concentration tables are only used for short periods of time and that their application is not directly commercial little thought is given to their improvement. Coghill[3] gave this problem his attention and improved the models within his own laboratory. With Mr. Coghill's investigations as a guide the laboratory model concentration table at the Montana School of Mines was investigated for any defects tha could be feasibly corrected.

Defects noted by Mr. Coghill are listed as follows: 1) asymmetrical position of the water launder, 2) dry bank of ore on the lower concentrate corner, 3) jammed draw bar when deck is tilted, 4) flimsy substructure (backbone), 5) stroke too short for correlation with plant work, and 6) poor tilting mechanism. Other objectionable features found on inspection were: 1) variation in tilt due to looseness causing rocking on the longitudinal axis, 2) "salting", and 3) poor drain system of pulp from deck surface.

Complete accord was not obtained with Mr. Coghill's criticisms and suggestions for improvement. An attempt was

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3 W. H. Coghill, G. T. Adams, and H. S. Hardman, "Improved Laboratory Concentration Table," U. S. Bureau of Mines Report of Investigations 3831, October, 1945.

made to improve further on Mr. Coghill's suggestions though much will have to remain a matter of opinion until a more detailed study is made along these lines.

After studying the table for the previously mentioned defects, a set-up with all the recommended improvements was made and comparative tests were run on both the original and modified tables. Comparisons were made as to ease of operation and efficiency of mineral separation.

With due credit to the designers and manufacturers of this table, it is doubtful whether the efficiency was or can be improved. An appropriate statement was made by Hersam[4] referring to tables, "Their proper operation rests not entirely upon the design, but depends upon delicate adjustment to bring out the possible effects". The basic principles of the shaking table have not been altered, and likewise the efficiency of mineral separation shows no marked change.

The adjustment of tables in plant operation sometimes takes weeks with skilled operators before maximum efficiency is attained. In a laboratory test the table is usually in operation only half an hour or thereabout. It is hoped that this investigation will aid in attaining a nearly maximum efficiency in the relatively short time involved, so that closer correlation with plant work is possible. It is not the intention to increase the maximum efficiency of a shaking table but rather to improve the control of the table so that

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4 E. A. Hersam, "The Status of Research in Ore Dressing," U. S. Bureau of Mines Report of Investigations 2669, pp. 31-33, January, 1925.

an investigator in this short time can obtain conclusive results as to the amenability of an ore to tabling.

ACKNOWLEDGEMENTS

The author is indebted to Professor Donald McGlashan, Head of the Department of Mineral Dressing at the Montana School of Mines, and his predecessor, Doctor S. R. B. Cooke, former Head of this Department, for their invaluable assistance, guidance, and advice.

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Also gratitude goes to my fellow students who helped me with this problem: Mr. Paavo P. Puumala, Mr. John C. Richards, and Mr. George D. Gale.

REVIEW OF LITERATURE

On reviewing the literature of Mineral Dressing over the last several years the lack of study with regard to table concentration becomes apparent. Even annual reviews of the progress in Mineral Dressing usually omit reference to table concentration. The utilization of the shaking table in coal preparation has had more consideration than application to ore minerals.

United States Bureau of Mines publications proved exceptionally helpful though some articles were somewhat dated. Pertinent papers dated from 1910 to the present were reviewed. The most important was Coghill's "Improved Laboratory Concentration Table," U. S. Bureau of Mines Report of Investigations No. 3831, October, 1945. Other helpful articles were "The Relation of Table Feed Preparation to Table Efficiency," by A. W. Fahrenwald and W. F. Meckel, U. S. Bureau of Mines Report of Investigations No. 2949, July, 1945; "The Status of Research in Ore Dressing," by Ernest A. Hersam, U. S. Bureau of Mines Report of Investigations No. 2669, January, 1925; and "Classification and Tabling of Difficult Ores with Particular attention to Fluorspar," by W. H. Coghill, U. S. Bureau of Mines Technical Paper 456, 1929.

A specific search was made for suggestive ideas in the "Operating Ideas" department of the Engineering and Mining Journal but negative results were obtained. Articles in periodicals pertaining to mineral dressing and tabling were reviewed and technical bibliographies of the past three decades investigated for such subject matter. The articles thus read and sometimes quoted do not warrant mention here.

Mineral dressing books and texts were read to build up a knowledge of the theory of table concentration and operation. Among those most helpful were: "Handbook of Milling Details," by the editorial staff of Engineering and Mining Journal, McGraw-Hill Book Company, New York, 1914; "Ore Dressing Principles and Practice," by Theodore Simons, Mc Graw-Hill Book Company, New York, 1924; and "Handbook of Mineral Dressing," by A. F. Taggart, John Wiley and Sons Inc., New York, 1945.

INVESTIGATIONS AND IMPROVEMENTS

In general the defects noted were improved in the following manner:

1. The asymmetrical position of the water launder is entirely remedied by removing the water launder and bringing the water to the deck through a self-supported pipe fitted with adjustable stop cocks (see Figures 1 and 3).

2. The "dry bank of ore" is kept from forming by truncating the deck so that wash water will reach the lower concentrate corner where the bank previously formed (see Figure 4).

3. Jamming of the draw bar is prevented by a spindle arrangement which transmits the head motion but allows free tilting (see Figures 5 and 6).

4. A flimsy sub structure is not evident in that the deck is well constructed. Support of the deck is changed so that it rides upon stationary parallel slipper rods (see Figures 9 and 10).

5. No attempt was made to change the stroke nor did the investigations warrant that such a change be made. Perhaps more investigation should be given to this phase.

6. The tilting mechanism was retained but shims were fitted to remove all looseness. This mechanism tilts the support rather than the deck. Tilting is positive and secure.

7. Looseness and variation in tilt were overcome by the parallel slipper rods and tightening the former tilt mechanism (see Figure 10).

8. "Salting", due to openings under the riffles, could have been best eliminated by using a composite deck surface and riffles made of one piece of rubber.

9. Drainage of pulp from the deck was aided by placing a sheet of copper at the concentrate end in order that the pulp would drain from pointed fingers rather than a continuous edge (see Figure 12).

Asymmetrical Position of Water Launder The asymmetrical position refers to the fact that the axis of the water launder is not parallel to the axis upon which the deck rotates and therefore when rotating the launder about this axis with the deck the slope of the launder is changed. This changes the flow of the water and necessitates readjustment of the water launder knobs after a change in tilt. This is overcome by suspending a horizontal pipe with adjustable drain cocks over the upper side of the table (see Figures 1 and 3). The water launder as attached to the table is also objectionable in that it offers an unnecessary load for the motor. All efforts were made to keep the moving parts of the table mechanism as light as possible for any superfluous weight will dampen the asymmetric head motion imparted to the table.

Figure 1. THE MODIFIED DESIGN

The table as in operation. Note the suspended pipe fitted with adjustable drain cocks.

Figure 2. THE ORIGINAL DESIGN

The water launder is attached to the deck. Note the lack of a water launder on the modified deck in the background.

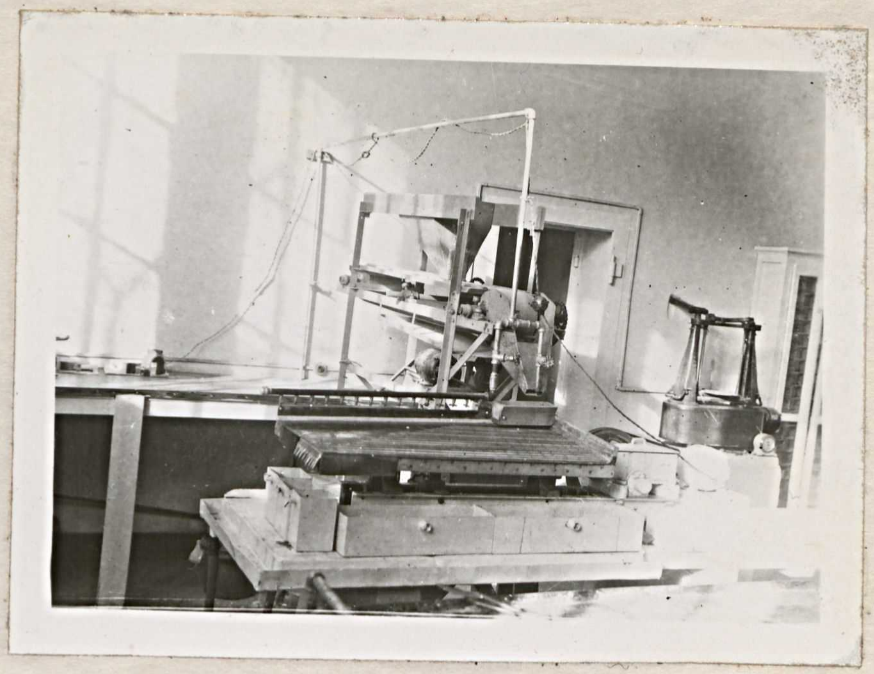

Figure 1

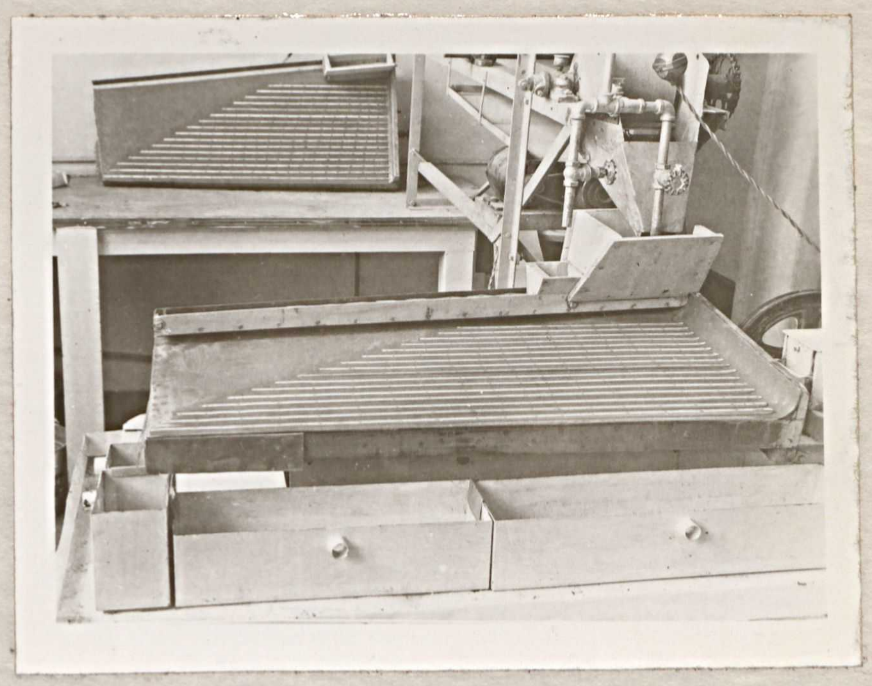

Figure 2

The pipe used was ordinary $\frac{1}{2}$-inch black water-pipe 32 inches in length. The pipe was drilled and tapped at 2 inch intervals and fitted with adjustable drain cocks of the wing-nut type. The threads were sealed with a mixture of litharge and glycerine. This pipe suspended over the table is very similar to the manner which Coghill[5] describes but is thought to be a considerable improvement in that adjustable cocks are employed.

It is realized that this type of a set-up is only applicable in the laboratory for debris in the mill water of a plant would cause clogging of the cocks.

The main difficulty was in getting a drain cock that would deliver a very slight quantity of water in a continuous stream. The ones finally selected were very satisfactory.

Dry Bank of Ore on the Lower Concentrate Corner The remedy of this difficulty of banking on the corner was essentially taken from Coghill's report[6] though only a minimum truncation was effected. As shown in Figure 4, a cut was made 2 inches back from the concentrate end on the lower side and angled to the upper corner of the concentrate end. This amount was effective in removing the cause of the trouble. Drastic truncation would only shorten the path of the pulp and thus offer less opportunity for separation of minerals. The wash water now strikes the corner.

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5 W. H. Coghill, G. T. Adams, and H. S. Hardman, "Improved Laboratory Concentration Table," U. S. Bureau of Mines Report of Investigations 3831, October, 1945.

6 ibid.

Figure 3. SPRAY PIPE

A close up of the spray pipe that was substituted for the wooden water launder.

Figure 4. TRUNCATED END

The original corner was square. The space between the steel square and the deck shows the area removed. The minerals on the table are quartz and pyrite.

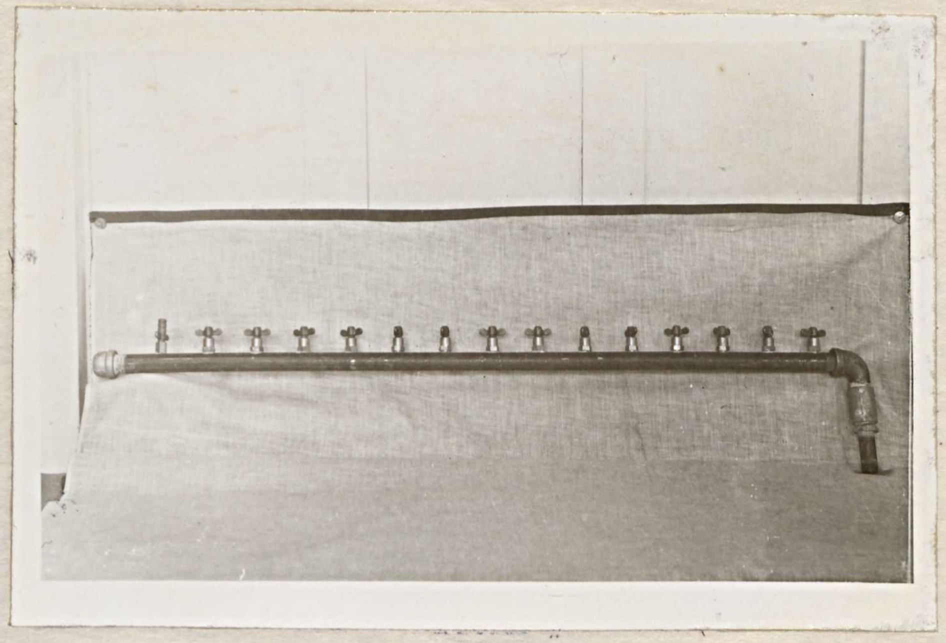

Figure 3

Figure 4

Jammed Draw Bar When Deck Is Tilted No allowance was made for free tilting in the original design. The shaft supporting the deck is rigidly attached and must rotate with the deck. This shaft is also the draw bar and must not transmit its rotation strain to the head motion mechanism. The draw bar is fastened to the head motion yoke by two jam nuts that when loose allow the shaft to rotate but in this loose condition the table will not operate correctly and the looseness causes knocking. In other words the nuts must be tight and therefore the deck can not be tilted when in operation.

In operation fine adjustment to achieve maximum efficiency in mineral separation is necessary. However fine adjustment can not be made when the deck is not in motion and if it is impossible to make an adjustment when the deck is in motion the operator is seriously handicapped.

Mr. Coghill[7] overcame this with a ball and socket joint. A spindle arrangement is thought to be better (see Figures 5 and 6). This method is believed to be much stronger than a ball and socket. The draw bar in this case is only about 7 inches long and fastens to the yoke as the original did but one end was turned down on a lathe to fit into a pillow block. Shoulders were left on the machined portion of the fitting in order that head-motion could be transmitted to the deck.

The block and the spindle are of such dimensions that end-play is prevented. A 5/8-inch diameter babbit-lined block

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7 ibid., p. 10.

Figure 5. THE SPINDLE MECHANISM ASSEMBLED

This mechanism is bolted to the table and the jam nuts attach it to the head motion yoke.

Figure 6. THE SPINDLE MECHANISM DISASSEMBLED

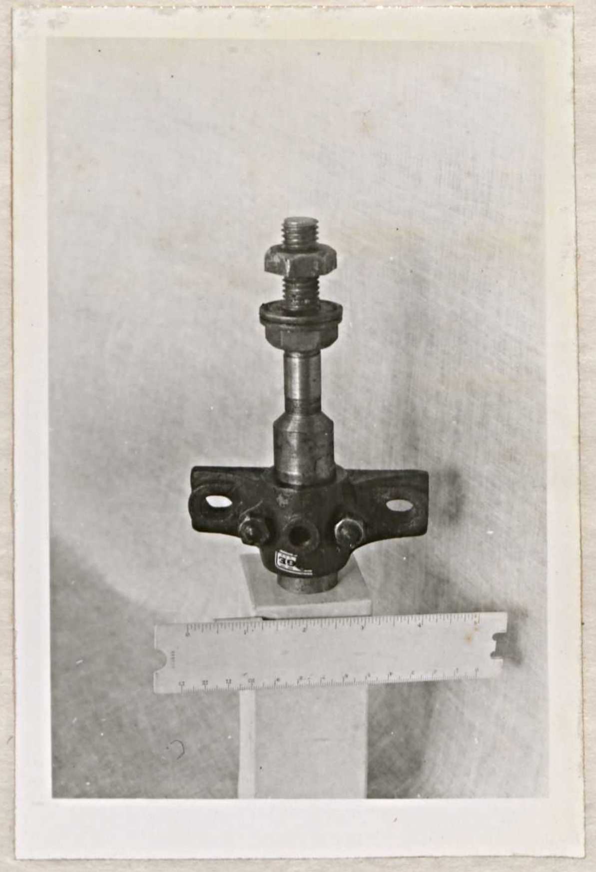

Figure 5

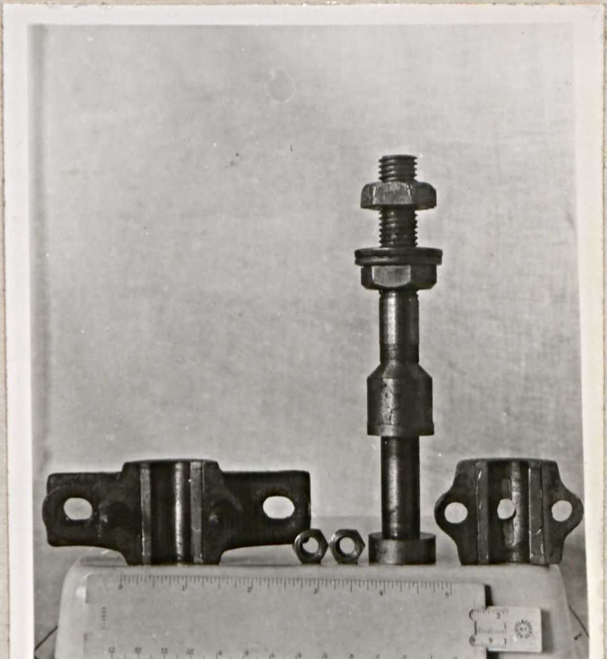

Figure 6

was employed and the spindle was formed from 1 inch cold rolled shafting. The block is bolted to the table (see Figure 7). This arrangement gives no resistance to tilting motion and delivers the head motion without knocking.

Flimsy Sub Structure (Backbone) The deck itself is sturdy and does not warrant strengthening. Strengthening of the deck would increase its weight offering more inertia for the head motion to overcome.

The supporting structure was entirely changed. The parallel slipper rods idea was taken directly from Coghill[8] but the slipper rods were made stationary rather than being fastened to the deck. Instead, in order to keep the deck light, guide shoes were attached to the underside of deck to ride on the slipper rods (see Figure 7). These shoes, which are made of half drilled steel blocks held in place by screws, are parallel to and equidistant from the longitudinal centroidal axis of the table. The spindle arrangement also was aligned on this axis. In placing the blocks on the underside of the deck, the original iron braces were removed and replaced by thin iron straps. These straps were fastened snugly on each side of the shoes to prevent any tendency for the shoes to work loose. A small cup was drilled at the top of each shoe for the retention of grease.

The slipper rods are bolted to the iron braces which were removed from the underside of the deck. A one inch cold

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8 ibid., p. 10.

Figure 7. THE MODIFIED UNDERSIDE OF THE DECK

Attention is called to the slipper guide shoes and the metal straps on either side of the shoes for added stability. The spindle on the right end prevents jamming of the draw bar.

Figure 8. THE ORIGINAL UNDERSIDE OF THE DECK

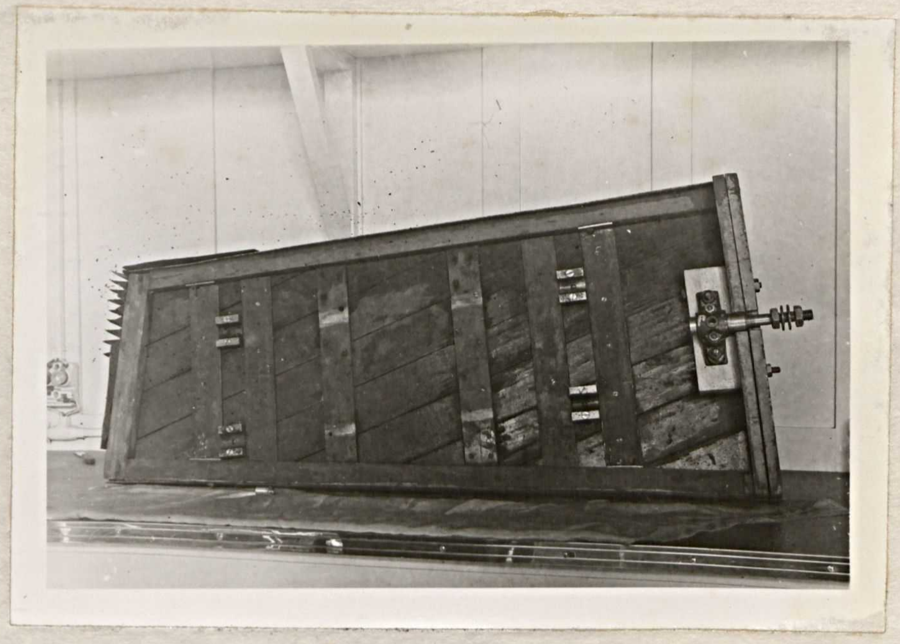

Figure 7

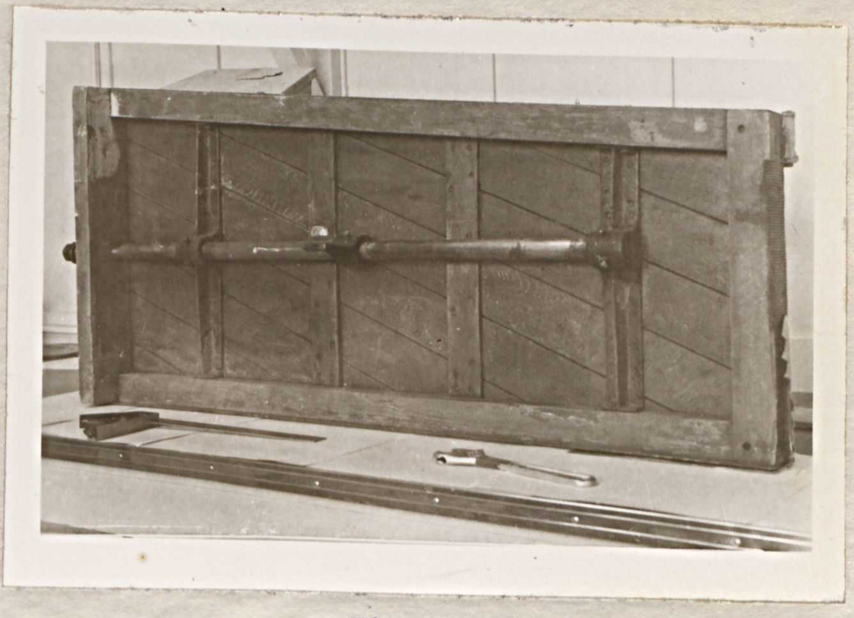

Figure 8

Figure 9. THE MODIFIED SUPPORTING SUB STRUCTURE

These are the parallel slipper rods upon which the deck rides. The rods are bolted to the former braces of the original deck. Also notice the fully encasing radial bearings on the center shaft in comparison to the open guide bearings seen in Figure 11. The tilting lever is the object on the center shaft between the bearings.

Figure 10. THE MODIFIED SUPPORTING SUB STRUCTURE MOUNTED

The deck is easily removed by lifting it off after loosening the jam nuts attaching the deck to the head motion yoke at the right. Attention is called to the original tilting mechanism as it is applied to the modified structure.

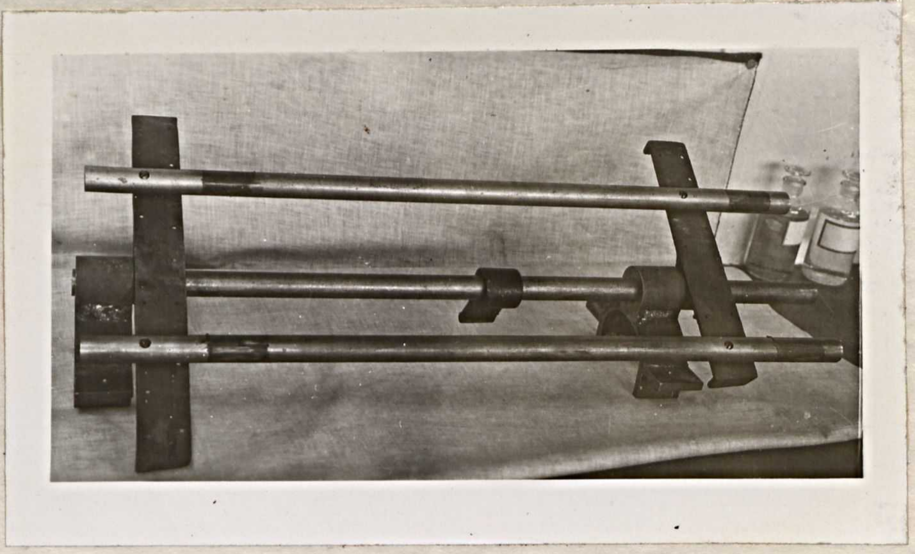

Figure 9

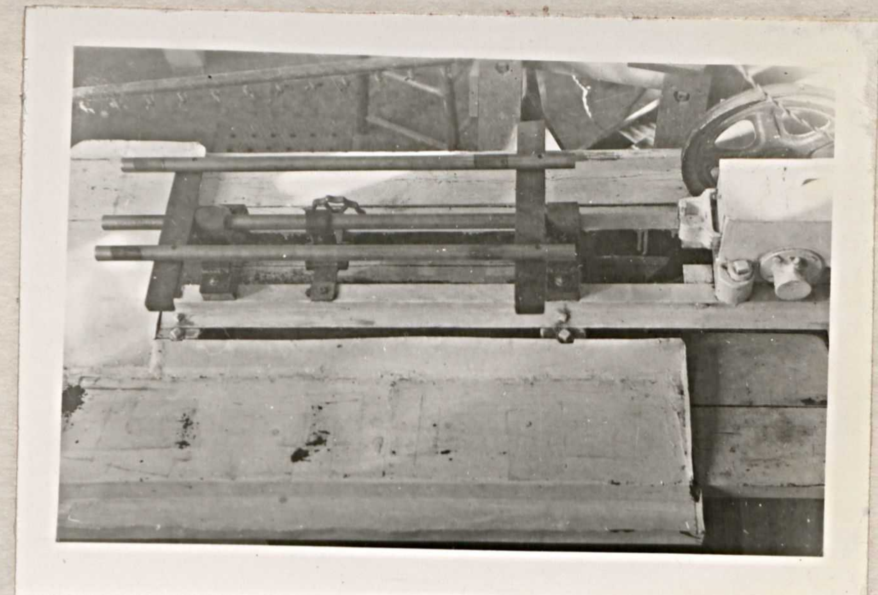

Figure 10

rolled shaft was substituted for the original shaft that previously fitted into the braces (see Figure 7). The slipper rods were also made of 1 inch cold rolled shafting. To have the plane of the slipper rods in the same plane with the guide shoes the bolted rods were laid into the shoes while the center supporting rod was free in the iron braces. The rods naturally conformed to the plane of the shoes and the set screws were tightened on the loose center rod making the entire supporting structure rigid. The center supporting rod is free to turn and thus effect the tilt of the table. This center rod is the axis about which the table rotates, and is supported by radial bearings fully housing the shaft. The supporting structure will now rotate to give tilt to the table but is stationary in relation to the head motion. This arrangement gives more positive positioning of the deck, lightens the deck, and prevents the rocking found in the original set-up.

<u>Stroke Too Short for Correlation With Plant Work</u> No attempt was made to lengthen the stroke beyond its former limits. Efficiency tests were run using the variation of the stroke within its limits (5 to 10 millimeters). No conclusive evidence resulted from these tests (see Figure 14). Before making a definite statement as to whether longer strokes are more effective a more complete study would have to be made of this problem. Visual observation tends toward leaving the stroke the same. The longer strokes increased the force moving the particles along the length of the table. This is evident by the particles traveling higher on the table. This calls for

an increase of the lateral forces on the particles from the flowing film of water and must be brought about by more deck tilt giving the water more velocity. Narrow fans of minerals result and with narrow fans mineral separation is more difficult.

This is in discord with Mr. Coghill's views[9] for he recommends lengthening the stroke. Correlation between laboratory and plant tests would furnish the necessary data to answer this problem.

Poor Tilting Mechanism Much of the difficulty occurring from the inadequate tilting mechanism was overcome by the change in the supporting structure of the deck. While the original mechanism is retained, the tilting lever or tongue from the original shaft was put on the central shaft of the now modified set-up. The table is tilted in precisely the same manner as before, i.e. by the traveling block which moves the end of this tongue in an arc and thus tilts the supporting structure of the deck. Play in the groove in which the tongue fits is removed by shimming. Wear has been eliminated due to the fact that the tongue no longer moves back and forth with the head motion of the table. Though the adjusting handle for tilting is considered by many to be in an inconvenient place it has not been moved for the lack of a better place to put it.

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9 ibid., p. 10.

Rocking on the Longitudinal Axis The original table deck could be freely rotated on its lengthwise axis to give a displacement in elevation of the lower (tailings side) of more than ½ inch. It is doubtful that a new table would be in such condition. Nevertheless, a table in use develops this condition and it can be prevented.

Housing the central shaft of the supporting structure in radial bearings rather than the previous guide bearings (see Figure 11), giving wider support to the deck with parallel slipper rods, and shimming the tilt mechanism to snugness completely removed the objectionable feature of rocking.

"Salting" An ore test is certainly nullified if "salting" has occurred. This is an unforgivable defect. Though no preventive measures were taken to eliminate "salting" the solution of this problem is very evident. Cracks and crevices under the wooden riffles and in the feed box are literal gold traps in the testing of a gold ore. With meticulous cleaning after each test, minerals from three to four tests previous have reappeared in a later test. These openings wherever they occur must be removed from the table deck and the feed hopper. A one piece deck surface of molded rubber mat with the desired style of riffling would prevent "salting" from the deck. Such construction is entirely feasible. It is realized that the fabrication of such a surface is easily possible when one observes the intricate design of automobile tire treads. Rubber is known to be wear resistant under the abrasive action of the pulp. This is shown by its application in the riffling of sluice boxes and its use as a lining in pipes and pumps to minimize abrasion.

The feed box should have rounded corners to facilitate cleaning. Rather than making it of wood that will invariably form cracks at the joints soldered or welded sheet metal could be used. Light construction is emphasized to minimize the weight of the table. Linings are not recommended for there is too much chance for material to get under the lining.

Of course this is not applicable to plant operation where the same ore flows continuously over the table. In ore testing "salting" should be avoided for reliable results.

Poor Drain System of Pulp From the Deck It is observed that water draining from a continuous edge will run along that edge and carry mineral particles with it. On the concentrate end where the separation is usually made this is extremely undesirable.

The practice in the Mineral Dressing Laboratories of the Montana School of Mines was to place a sheet of thin metal with a large saw tooth edge at the concentrate end from which the pulp will drain (see Figure 12). This is not an original idea but is presented here because it is not often seen. Joplin, Missouri, mills[10] used such notched lips in 1914 but the ease it gives to the draining of the separate mineral products warrants its mention herein.

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10 Claude T. Rice, "Wilfley Table Kinks," Handbook of Milling Details, by the Editorial Staff of Engineering and Mining Journal, (New York: McGraw-Hill Book Company, 1914) pp. 174-176.

Figure 11. THE ORIGINAL DESIGN WITH DECK REMOVED

Notice the half open guide bearings for the single slipper rod. The sliding block which engages the tilting lever shows well here.

Figure 12. THE NOTCHED DISCHARGE LIP

The pulp drains from each individual finger (numbered from left to right 1 through 9) and thus is easily separated into its various components. A quartz and pyrite mixture is on the deck.

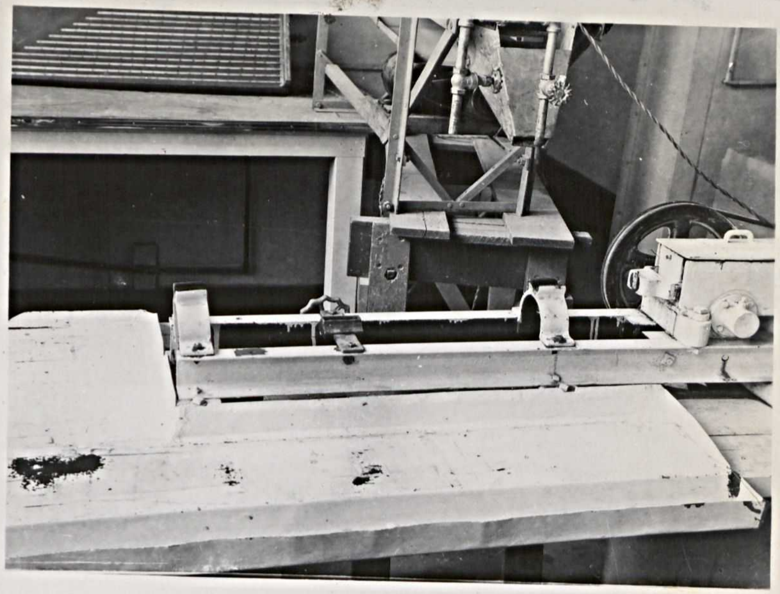

Figure 11

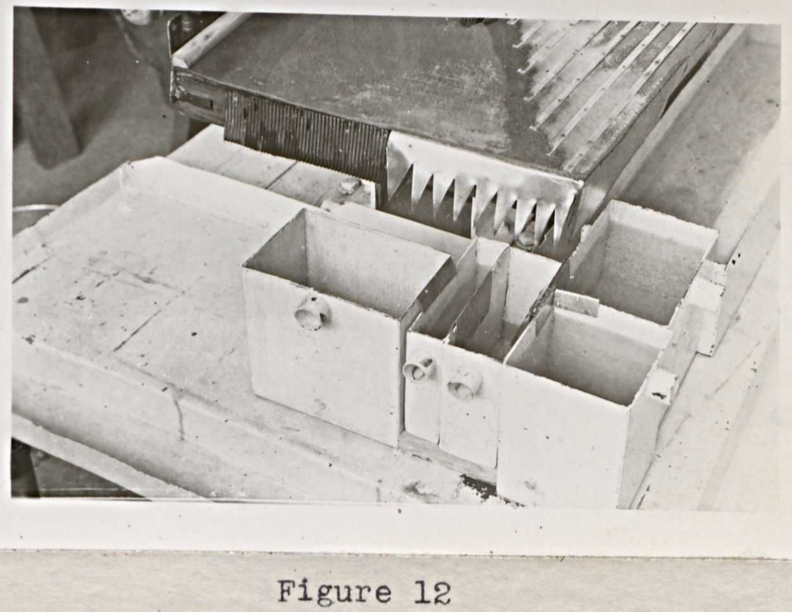

Figure 12

COMPARISON TESTING

Tests were made for comparison of the original design to the modified design. A synthetic ore of garnet and limestone was used as test material. Operating tests were made changing only one variable at a time keeping the other variables as constant as possible. After the table was in operation for sufficient time for the line (ore-gangue line of demarcation) to become stabilized under each changed condition, samples were taken from the table products (concentrate and tailing). The samples were assayed to determine the amounts of garnet in each product and the separation efficiency computed. The formula for calculation of efficiency[11] is $C + T - 100 = E$, in which C is the percentage of concentrate material in the concentrate product, T is the percentage of tailings material in the tailings product, and E is the efficiency of mineral separation. Comparison of efficiencies should indicate whether the modifications aided the operator in control and adjustment of the table.

Selection and Preparation of Test Ore In the selection of a proper test ore the requisites were that it had to be amenable to tabling yet not give perfect separation, it should lend itself to quick easy assaying, middling products such as locked particles should be absent, and it should be

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11 A. W. Fahrenwald and W. F. Meckel, "The Relation of Table Feed Preparation To Table Efficiency," U. S. Bureau of Mines Report of Investigations 2949, July, 1929.

composed only of two minerals of different color for maximum visual control of the table. Obviously a synthetic ore fulfilled these requirements.

Crushed pure white quartz and magnetite sand were thought to be good and sized products of each were mixed together. The ore was to be easily assayed by magnetic separation. It was found though that the phenomenon known as magnetic flocculation occurred with the only available type magnetite. The ore was definitely not amenable to tabling. A quartz-pyrite mixture was then tried and it worked very well except the assaying procedure proved more involved than was to be desired.

After several other attempts a garnet-limestone ore was selected. The limestone is of a dark variety used for flux at the Anaconda Copper Mining Company's smelter and the garnet is a very pure garnet concentrate from a local dredging operation.

Specifically, the limestone was judged to be slightly dolomitic containing carbonaceous matter and about 5.3 per cent insoluble under the assaying conditions used. The percentage of insoluble material is known to be higher but the method of assaying used gave this value and it will be shown later that this discrepancy has no effect on the results obtained. The specific gravity of the limestone is 2.73.

The garnet was thought to be Rhodolite because of its specific gravity of 4.1 and its pale violet tint.

Both the garnet and the limestone were crushed and sized, the garnet to minus 48 mesh plus 65 mesh and the limestone to minus 35 mesh plus 65 mesh. Each of the constituents was classified using a constriction-plate hydraulic classifier to remove odd-shaped and foreign particles. The relative sizes were kept rather close together so that complete separation on the table would not occur. Near perfect separation was not wanted for then a variation in efficiencies would not be distinguishable. The two were mixed to give a test material that contained 25 per cent garnet.

Test Procedure Special launders were attached to the tables to aid in cutting samples for the test (see Figure 13). The launder on the concentrate end was devised to slide on a simple runner in order that the built-in splitter would cut the products in any position.

Three variable factors were considered: the angle of tilt, length of stroke, and the pulp consistency (the percentage of dry feed to wash water). The dry feed was measured as it came off the feeder, the amount of wash water was measured as it drained into the sump, the angle of tilt (the dihedral angle between the plane of the deck and the horizontal plane) was measured with a Brunton pocket transit, and the length of stroke was measured directly. In the three tests given each design, two of the variables were maintained constant while the third was varied. The mineral fans formed on the deck by the ore were observed to be constant in position

Figure 13. SPECIAL LAUNDERS FOR CUTTING SAMPLES

The launder on the concentrate end is moveable back and forth so that the splitter can make a cut between any of the fingers. Fingers are referred to by number. The splitter is between fingers 4 and 5.

Figure 13

and action before a sample was cut. The line of separation of the two minerals was not allowed to shift during the cutting of the samples. If this happened the sample was discarded and a new one taken.

Assaying Method Assaying was very simple amounting to merely dissolving the limestone away from the garnet. All samples were dried in a drying oven and then thoroughly mixed so as to be homogeneous throughout. Ten grams of each sample were weighed to the nearest hundredth gram. A ten gram sample of only limestone was run with each set of assays as a control.

The weighed products were placed in beakers and the material covered with distilled water. Hydrochloric acid was added in small amounts to dissolve the limestone. After the effervescence ceased surplus acid was added and the assays allowed to stand for 20 minutes. Then the beakers were filled with water and allowed to stand so that particles could settle to the bottom of the beakers. The solution was then decanted off to about 5 cubic centimeters and refilled. Each sample had water added and decanted three times in this manner not counting the first decantation of acid. Each assay was treated exactly the same. The limestone sample served as a control to indicate whether consistent results were being obtained. Limestone assays varied from 5.0 to 5.5 per cent insoluble material and averaged 5.3 per cent insoluble material.

After the last decantation the remaining water was evaporated and the sample dried and weighed. Percentages were computed from the weights with a correction factor applied for the 5.3 per cent insoluble material. Some of the insoluble material from the limestone formed slimes and was lost in decantation. The formation of slimes was due to the acid dissolving major portions of the already sized particles which contained small amounts of silica. None of the insoluble garnet was decanted away for it was previously classified for removal of odd shaped particles and deslimed. It was assumed that proportional percentages of undissolved limestone slimes were washed from each assay and thus consistent results could be obtained. This assumption is acceptable as is indicated by the consistent results of the limestone control samples taken with each batch of assays. A higher degree of accuracy is not justifiable due to the human element involved by the judgment of the operator in splitting the tailings product from the concentrate product. Efficiencies were computed to the nearest tenth of a per cent and rounded off to the nearest unit.

Tests and Test Results Attention is called to the fact that the resulting efficiencies herein obtained are not to be interpreted as actual efficiencies of the two machines but really indicate a measure of ability of the operator to run the tables. In reiteration: "It is not the intention to increase the maximum efficiency of a shaking table but rather to improve the control of the table so that an investigator in a relatively short time can obtain conclusive results as to the amenability of an ore to tabling." The human factor is very important in these tests because of the sensitivity of the table to adjustment by the operator. The tests were conducted as impartially as was physically possible.

The following comparisons of efficiencies indicate that more effective separation can be obtained by an operator with the modified design of the laboratory table. This is directly attributable to more effective control and ease of adjustment of the table.

Test 1-a. <u>Variation of the stroke - the Modified design</u> (see Figure 14).

Pulp consistency - 3.5 per cent dry ore.

Angle of tilt - 3° 04'.

Stroke varied from 5 to 10 millimeters.

10 mm.	84 per cent efficient
9 mm.	87 per cent efficient
8 mm.	84 per cent efficient
7 mm.	86 per cent efficient
6 mm.	84 per cent efficient
5 mm.	85 per cent efficient (tilt steepened somewhat)

Notes: Wide fans of minerals resulted with short stroke. Long stroke gave narrower fans carried high on the deck.

Test 1-b. <u>Variation of the stroke: - Original design</u> (see Figure 14).

Pulp consistency - 3.5 per cent dry ore

Angle of tilt - 4° 45'

COMPARATIVE EFFICIENCY TEST NO. 1
MODIFIED AND ORIGINAL DESIGN
Per Cent Efficiency vs. Stroke Length

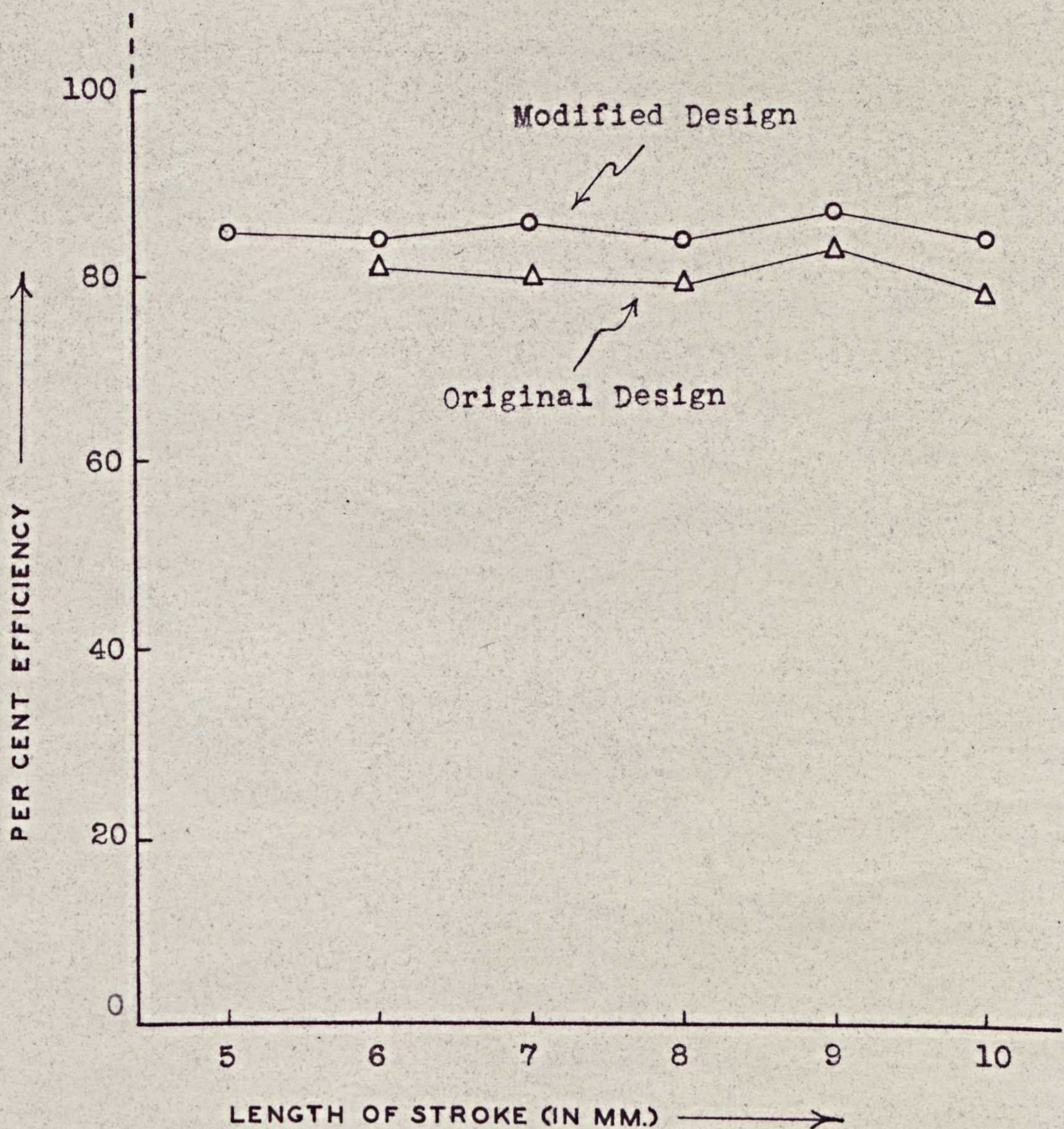

Figure 14

Stroke varied from 5 to 10 millimeters

10 mm.	78 per cent efficient
9 mm.	83 per cent efficient
8 mm.	79 per cent efficient
7 mm.	80 per cent efficient
6 mm.	81 per cent efficient
5 mm.	(thrown out - banking occurred on the lower concentrate corner)

Notes: The table would not retain its original tilt setting. The mineral fans were much narrower due to an increase in tilt. Tilt had to be increased to make the mineral separation occur in the same corresponding location as the previous test.

Test 2-a. Variation of tilt: - Modified design (see Figure 15).

Pulp consistency - 5.1 per cent dry ore

Length of stroke - 7 millimeters

Angle of tilt varied from 6^{o} 05' to 2^{o} 40'

6^{o} 05'	87 per cent efficient
4^{o} 30'	86 per cent efficient
4^{o} 25'	87 per cent efficient
3^{o} 05'	90 per cent efficient
2^{o} 40'	87 per cent efficient

Notes: Variations of the deck tilt were made so that the line of separation was between finger 1 (see Figure 13) and the tailings side, then between fingers 1 and 2 and successively up to between fingers 4 and 5. The steeper tilts gave narrower mineral fans.

Test 2-b. Variation of the tilt - Original design (see Figure 15).

Pulp consistency - 4.8 per cent dry ore

Length of stroke - 7 millimeters

Angle of tilt varied from 9° 45' to 4° 05'

9° 45'	81 per cent efficient
8° 20'	83 per cent efficient
5° 15'	81 per cent efficient
4° 50'	79 per cent efficient
4° 05'	78 per cent efficient

Notes: The same manner was held to in adjusting the variation of tilt as was in test 2-a. Banking was impending on the lower concentrate corner but the pulp kept moving enough to accept the test. All fans of mineral were narrow.

Test 3-a. Variation of pulp consistency: - Modified design (see Figure 16).

Angle of tilt - 4° 25' (varied slightly at times to keep the line of separation between fingers 2 and 3)

Length of stroke - 7 millimeters

Pulp consistency was varied by keeping the flow of wash water constant at 4,000 grams per minute and

COMPARATIVE EFFICIENCY TEST NO. 2
MODIFIED DESIGN AND ORIGINAL DESIGN
Per Cent Efficiency vs. Angle of Tilt

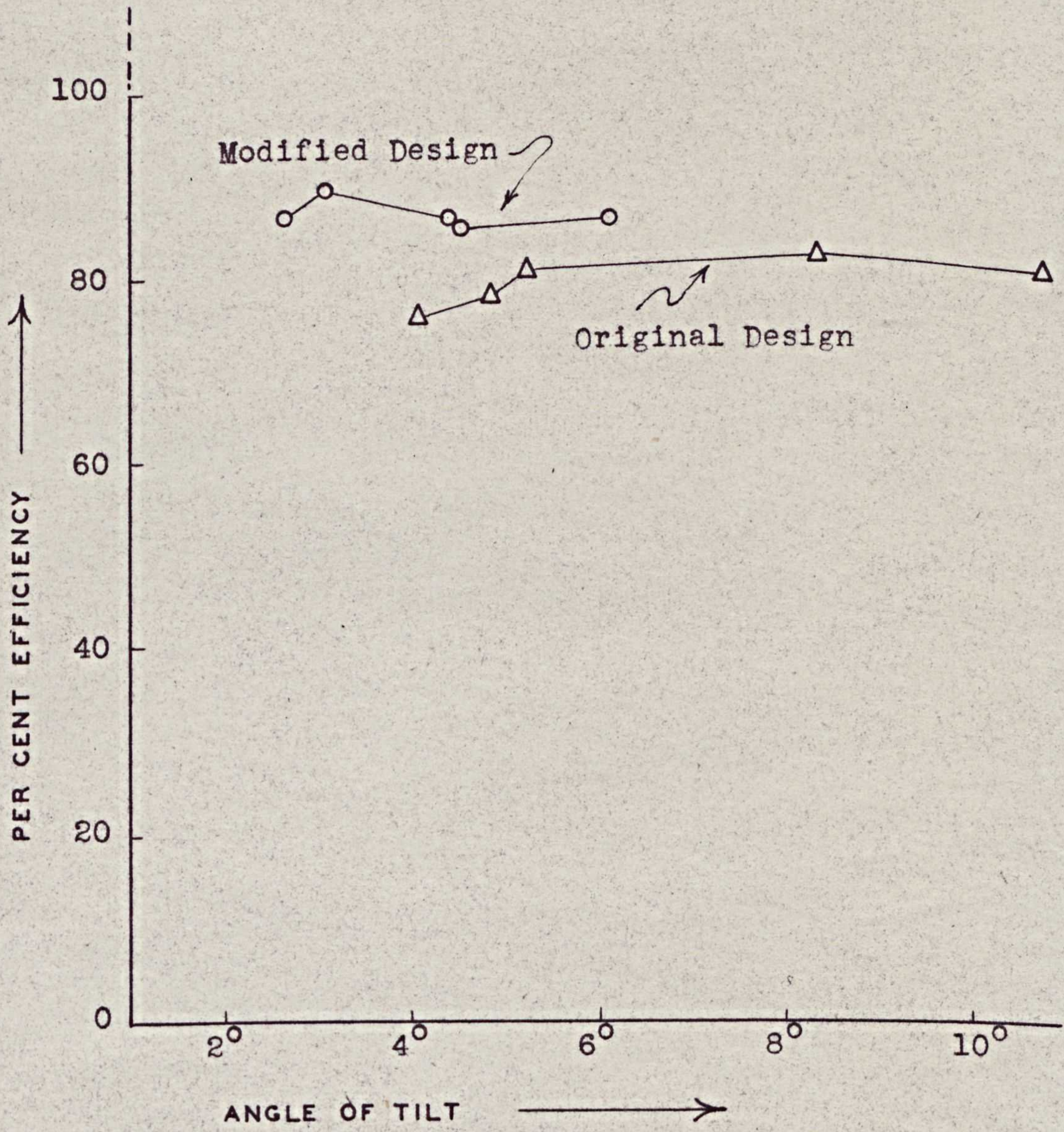

Figure 15

varying the flow of dry ore from 178 to 440 grams per minute.

4.3 per cent dry ore	85 per cent efficient
5.5 per cent dry ore	84 per cent efficient
6.6 per cent dry ore	85 per cent efficient
7.9 per cent dry ore	86 per cent efficient
9.9 per cent dry ore	85 per cent efficient

Notes: 4,000 grams of water per minute was the minimum. The heavier feeds gave wider fans of minerals.

Test 3-b. Variation of pulp consistency - Original design (see Figure 16).

Angle of tilt 5° 25' (varied as mentioned in Test 3-a)

Length of stroke - 7 millimeters

Pulp consistency was varied in the same manner as Test 3-a with the wash water constant at 3,750 grams per minute and varying the flow of dry ore from 243 to 526 grams per minute.

6.1 per cent dry ore	74 per cent efficient
7.7 per cent dry ore	76 per cent efficient
10.0 per cent dry ore	81 per cent efficient
12.3 per cent dry ore	87 per cent efficient

Notes: The original deck seems to operate with less water. The water has a greater tendency to come over the concentrate end. Narrow mineral fans due to steeper tilt were encountered. The fans became wider with heavier loading of the deck.

COMPARATIVE EFFICIENCY TEST NO. 3
MODIFIED DESIGN AND ORIGINAL DESIGN
Per Cent Efficiency vs. Pulp Consistency

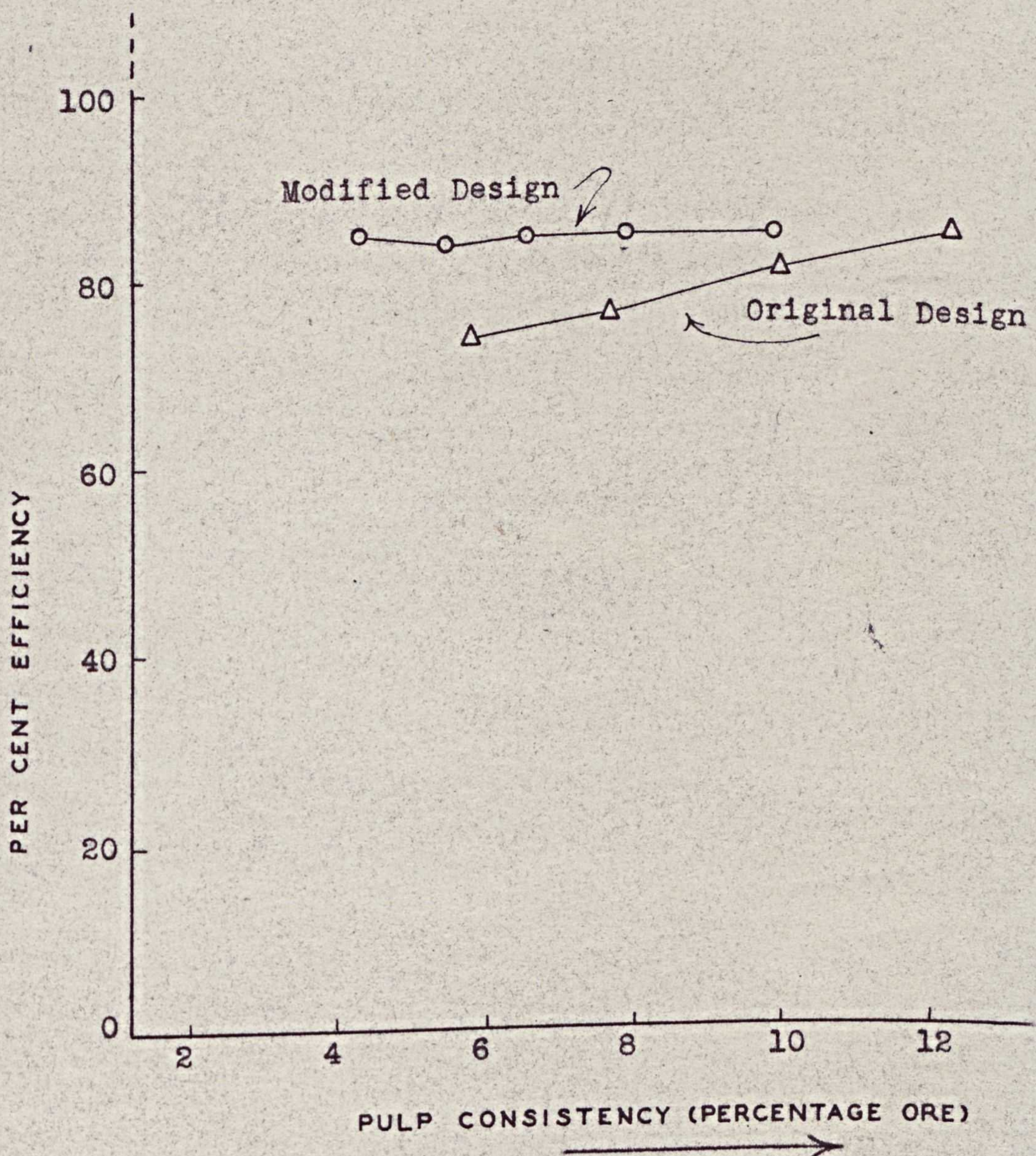

Figure 16

Discussion of Test Results In all tests a higher range of efficiencies was obtained using the modified design. It is not known which modification had the greatest efficacy in raising the efficiency level since the tests were conducted after all modifications were applied. Some modifications could have had no effect at all though it is doubtful that any one modification could have been responsible for the efficiencies obtained.

Most of the results obtained from the tests on the original design were relatively erratic and would indicate that it is easier for the operator to get consistent results with the modified design. This statement before being fully accepted should be sustained with more data.

The ease of operation which does not show in the tests was improved. Smoother operation was noticeable.

Conditions producing wider fans of minerals seemed to give better results and closer control. The fact that the water on the original deck did not flow as readily to the tailings side required an increased tilt and by narrowing the mineral fans may have been a large factor in the reduction of efficiencies. Why the water acted thusly is not known. A possibility is that a longitudinal velocity was imparted to the water when leaving the water launder and its inertia tended to carry it toward the concentrate end. More investigation should be given this phase.

The modified design called for more water to cover the deck. This may be due to the wetability of the deck in that different types of linoleum were used for deck surfaces. This too should be given more investigation.

RECOMMENDATIONS AND SUGGESTIONS

If these modifications are accepted the following minor changes are recommended, that:

1. The ends are sawed off the braces supporting the slipper rods to give a trimmer appearance.

2. Holes are bored through the slipper rods where the guide shoes ride upon them and grease cups fitted to give more effective lubrication.

3. The wearing surfaces of the shoes be babbitted.

4. The guide shoes are bolted to the deck rather than held in place by screws in the soft wood. This involves resurfacing the deck for the bolt heads will have to be under the linoleum and counter-sunk.

5. A non-babbitt lined pillow block is used for the spindle arrangement. Babbitt is not necessary here and may cause end-play after a long period of use.

Suggestions for future investigations are:

1. A thorough investigation with other ores both natural and synthetic should be tried for more sustaining data.

2. Correlation tests between large plant tables and the laboratory model could be made for comparable efficiencies and determination of the optimum lengths of stroke. This is not difficult. Briefly outlined: Nearby operating plants could be visited, samples taken of their heads, concentrates, and tailings products. The con-

centrates and tailings products could be assayed for computation of efficiency and the heads could be treated on the laboratory table for comparable tests.

3. The suggested improvements to prevent "salting" should be tried.

4. Testing in the Mineral Dressing Laboratories of the Montana School of Mines is usually carried on at a low feed rate and a low ore to water ratio. Experiments should be tried with the objective of increasing both. Answer the question, "Why excessive water is necessary for operation of both designs?".

SUMMARY AND CONCLUSIONS

In summation, this investigation has successfully located and remedied several obvious faults and defects of the laboratory model Wilfley concentration table. A test method for computing mineral separation efficiency indicated that the modifications applied enabled the operator to get better results from the table.

Enumerating again the improvements or changes made:

1. Wash water is brought to the table through a spray pipe with adjustable jets rather than the wooden launder.

2. The deck was truncated to prevent the formation of a dry bank of ore on the lower concentrate corner.

3. Jamming of the draw bar was remedied with a spindle arrangement.

4. The deck was designed to ride on stationary parallel slipper rods which gave positive positioning and better tilting control.

5. The original tilting mechanism was tightened with shimming and the design of the support system eliminated wear of the tilt mechanism.

6. Enclosed radial bearings around the main support shaft, tightening of the tilt mechanism, and wider support of the deck eliminated rocking on the longitudinal axis.

7. "Salting" could be prevented by employing decking and riffles molded of one piece of rubber.

8. Separation of the concentrates and tailings products is greatly aided when a notched thin metal strip is placed on the concentrate end of the table.

These modifications are not applicable to large plant installations but are specifically for the laboratory ore testing model.

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APPENDIX

Original Data

<u>Test 1-a</u> Varying stroke with the modified design.

Feed - 189.6 grs. per minute of solids

Water - 5,560 grs. per minute

Angle of Tilt - 3^{o} 4'

Weights:

Stroke	Cons.	Tails.	Ratio
10 mm.	88 grs.	220 grs.	1 to 2.6
9 "	98 "	279 "	" " 2.9
8 "	125 "	349 "	" " 2.8
7 "	124 "	333 "	" " 2.7
6 "	105 "	297 "	" " 2.8
5 "	155 "	384 "	" " 2.5

Assays: 10 gr. sample

Stroke	Cons.	(-10)	Tails.	(-10)
10 mm.	8.59 grs.	1.41	0.63 grs.	9.37
9 "	8.96 "	1.04	0.70 "	9.30
8 "	8.79 "	1.21	0.85 "	9.15
7 "	9.00 "	1.10	0.73 "	9.27
6 "	8.81 "	1.19	0.90 "	9.10
5 "	8.67 "	1.33	0.66 "	9.34
Ls.	-		0.50 "	9.47

Correcting for Limestone 94.7 (average) per cent insoluble

Stroke	Cons. (Wt. of Garnet)	Tails. (Wt. Ls.)
10	10 - 1.41/.947 = 8.51	9.37/.947 = 9.90
9	10 - 1.04/.947 = 8.90	9.30/.947 = 9.83
8	10 - 1.21/.947 = 8.72	9. 15/.947= 9.69
7	10 - 1.10/.947 = 8.83	9.27/.947 = 9.80
6	10 - 1.19/.947 = 8.74	9.10/.947 = 9.62
5	10 - 1.33/.947 = 8.59	9.34/.947 = 9.89

Calculation of Efficiency C + T - 100 = Eff.

Stroke	
10	85.1 + 99.0 - 100 = 84.1
9	89.0 + 98.3 - 100 = 87.3
8	87.2 + 96.9 - 100 = 84.1
7	88.3 + 98.0 - 100 = 86.3
6	87.4 + 96.2 - 100 = 83.6
5	85.9 + 98.9 - 100 = 84.8

Test 1-b Varying stroke using the original design

Feed - 190.0 grs. of solids per minute

Water - 5,560 grs. per minute

Angle of Tilt - 4^{o} 45'

Weights:

Stroke	Cons.	Tails.	Ratio
10 mm.	31	84	1 to 2.7
9 "	30	75	" " 2.5
8 "	27	71	" " 2.5
7 "	29	76	" " 2.6
6 "	20	53	" " 2.6
5 " Formed bank on concentrate corner - no results			

Assays: 10 gr. sample

Stroke	Cons.	(-10)	Tails.	(-10)
10 mm.	8.55	1.45	0.86 grs.	9.14
9 mm.	8.39	1.61	0.81 "	9.19
8 mm.	8.20	1.70	0.79 "	9.21
7 mm.	8.70	1.30	0.82 "	9.18
6 mm.	8.47	1.53	0.81 "	9.19
Ls.			0.53 "	9.47

Correcting for Limestone 94.7 (average) per cent soluble

Stroke	Cons. (Wt. of Garnet)	Tails
10 mm.	10 - 1.45/.947 = 8.38	9.14/.947 = 9.39
9 "	10 - 1.61/.947 = 8.63	9.19/.947 = 9.69
8 "	10 - 1.70/.947 = 8.21	9.21/.947 = 9.72
7 "	10.- 1.30/.947 = 8.30	9.18/.947 = 9.71
6 "	10 - 1.53/.947 = 8.47	9.19/.947 = 9.60

Calculation of Efficiency C + T - 100 = Eff.

Stroke	
10	83.8 + 93.9 - 100 = 77.7
9	86.3 + 96.9 - 100 = 83.2
8	82.1 + 97.2 - 100 = 79.3
7	83.0 + 97.1 - 100 = 80.1
6	84.7 + 96.0 - 100 = 80.7

<u>Test 2-a</u> Varying Angle of Tilt using the Modified Design.

Feed - 190.0 grs. of solids per minute

Water - 3,530 grs. per minute

Stroke - 7 mm.

No. 1	All concentrate material off end of deck	(6° 05')
2	Tailings off finger 1	(4° 30')
3	Tailings off fingers 1 & 2	(4° 25')
4	Tailings off fingers 1, 2, & 3	(3° 05')
5	Tailings off fingers 1, 2, 3, & 4	(2° 40')

Weights:

	Cons.	Tails.	Ratio
1	42	115	1 to 2.7
2	45	142	" " 3.2
3	46	132	" " 2.9
4	37	121	" " 3.3
5	80	244	" " 3.1

Assays: 10 gr. sample

	Cons.	(-10)	Tails.	(-10)
1	9.01 grs.	0.99	0.76	9.24
2	9.12 "	0.88	1.01	8.99
3	8.95 "	1.05	0.71	9.29
4	~~8.45~~ 9.51 "	~~0.55~~ 0.49	1.00	9.00
5	9.12 "	0.88	0.91	9.09
Ls.	-		0.55	9.45

Correcting for Limestone 94.7 (average) per cent soluble.

	Cons. (Wt. of Garnet)	Tails. (Wt. Ls.)
1	10 - 0.99/.947 = 8.95	9.24/.947 = 9.75
2	10 - 0.88/.947 = 9.07	8.99/.947 = 9.49
3	10 - 1.05/.947 = 8.89	9.29/.947 = 9.81
4	10 - 0.49/.947 = 9.48	9.00/.947 = 9.51
5	10 - 0.88/.947 = 9.07	9.09/.947 = 9.59

Calculation of Efficiency   C + T - 100 = Eff.

1	89.5 + 97.5 - 100 = 87.0
2	90.7 + 94.9 - 100 = 85.6
3	88.9 + 98.1 - 100 = 87.0
4	94.8 + 95.1 - 100 = 89.9
5	90.7 + 95.9 - 100 = 86.6

Test 2-b Varying Angle of Tilt using the Original Design.

Feed - 190.0 grs. of solids per minute.

Water - 3,750 grs, per minute

Stroke - 7 mm.

No. 1 All concentrate material off end of deck (9° 45')

2 Tailings off finger 1 (8° 20')

3 Tailings off finger 1 & 2 (5° 15')

4 Tailings off fingers 1, 2, & 3 (4° 50')

5 Tailings off fingers 1, 2, 3, & 4 (4° 05')

Weights:

Due to fact that containers could not be simultaneously removed from under the table the ratio of concentration has not been considered here.

Assays

	Cons.	(-10)	Tails.	(-10)
1	8.51	1.49	0.83	9.17
2	9.22	0.78	1.38	8.62
3	8.77	1.23	1.11	8.89
4	8.81	1.19	1.32	8.68
5	8.86	1.14	1.45	8.55
Ls.	-		0.51	9.49

Correcting for Limestone 94.7 (average) per cent soluble

	Cons. (Wt. of Garnet)	Tails. (Wt. Ls.)
1	10 - 1.49/.947 = 8.43	9.17/.947 = 9.69
2	10 - 0.78/.947 = 9.18	8.62/.947 = 9.10
3	10 - 1.23/.947 = 8.70	8.89/.947 = 9.38
4	10 - 1.19/.947 = 8.74	8.68/.947 = 9.18
5	10 - 1.14/.947 = 8.80	8.55/.947 = 9.04

Calculation of Efficiency C + T - 100 = Eff.

1	84.3 + 96.9 - 100 = 81.2
2	91.8 + 91.0 - 100 = 82.8
3	87.0 + 93.8 - 100 = 80.8
4	87.4 + 91.8 - 100 = 79.2
5	88.0 + 90.4 - 100 = 78.4

Test 3-a Varying Pulp Consistency using the modified design.

Water 4,000 grs. per minute

Stroke 7 mm.

Angle of Tilt 4^{o} 25' (varied in order to keep line of separation between fingers 2 and 3)

Dry feed varied

No. 1 178 grs. per minute

2 235 grs. per minute

3 284 grs. per minute

4 344 grs. per minute

5 440 grs. per minute

Weights:

	Cons.	Tails.	Ratio
1	41	113	1 to 2.8
2	44	124	" " 2.8
3	48	136	" " 2.8
4	63	184	" " 3.0
5	47	147	" " 3.1

Assays: 10 gr. sample

	Cons.	(-10)	Tails.	(-10)
1	8.79	1.21	0.75	9.25
2	8.83	1.17	0.78	9.22
3	8.98	1.02	0.87	9.13
4	9.06	0.94	0.96	9.04
5	9.00	1.00	0.96	9.04
Ls.	-		0.53	9.47

Correcting for Limestone 94.7 (average) per cent soluble

	Cons. (Wt. of Garnet)	Tails. (Wt. Ls.)
1	10 - 1.21/.947 - 8.72	9.25/.947 - 9.77
2	10 - 1.17/.947 - 8.76	9.22/.947 - 9.73
3	10 - 1.02/.947 - 8.92	9.13/.947 - 9.64
4	10 - 0.94/.947 - 9.01	9.04/.947 - 9.54
5	10 - 1.00/.947 - 8.94	9.04/.947 - 9.54

Calculation of Efficiency C + T - 100 = Eff.

1	87.2 + 97.7 - 100 = 84.9
2	87.6 + 97.3 - 100 = 83.9
3	89.2 + 96.4 - 100 = 84.6
4	90.1 + 95.4 - 100 = 85.5
5	89.4 + 95.4 - 100 = 84.8

Test 3-b Varying Pulp Consistency using the original design.

Water 3,750 grs. per minute

Stroke 7 mm.

Angle of Tilt $5^{\circ}\ 25'$ (varied in order to keep line of separation between fingers 2 and 3)

Dry feed varied

No. 1 526 grs per minute

2 416 grs. per minute

3 314 grs. per minute

4 243 grs. per minute

Weights:

	Cons.	Tails.	Ratio
1	43	135	1 to 3.1
2	53	145	" " 2.7
3	41	91	" " 2.22
4	33	75	" " 2.3

Assays: 10 gr. sample

	Cons.	(-10)	Tails.	(-10)
1	8.99	1.07	0.98	9.02
2	8.64	1.36	0.95	9.05
3	7.91	2.09	0.72	9.28
4	7.69	2.31	0.70	9.30
Ls.	-		0.52	9.48

Correcting for Limestone 94.7 (average) per cent soluble.

	Cons. (Wt. of Garnet)	Tails. (Wt. Ls.)
1	10 - 1.01/.947 - 8.93	9.02/.947 - 9.53
2	10 - 1.36/.947 - 8.56	9.05/.947 - 9.56
3	10 - 2.09/.947 - 7.79	9.28/.947 - 9.78
4	10 - 2.31/.947 - 7.56	9.30/.947 - 9.82

Calculation of Efficiency $C + T - 100 = Eff.$

1	89.3 + 95.3 - 100 = 84.6
2	85.6 + 95.6 - 100 = 81.2
3	77.9 + 97.8 - 100 = 75.7
4	75.6 + 98.2 - 100 = 73.8