AN INVESTIGATION OF A BALL MILL

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Being the M. Sc. Thesis

presented by

G. Vibert Douglas

\- 1921 -

The investigations described in this paper were undertaken for the purpose of obtaining definite information regarding the efficiency of a small Ball Mill fitted with Trunion discharge.

The paper consists of a general discussion of ball milling and a description of experimental work carried on by the writer in cooperation with Mr. E. G. Harding. Much of the information is set forth graphically and some conclusions are drawn from the data obtained.

PART I
HISTORY:

The discovery by MacArthur and Forrest in 1890 of the Cyanide process for the extraction of gold, created a great demand for fine crushing. This demand had been realized when amalgamation was still the main process of extraction. Drury in South Africa shewed that the gold recovered on plates was from the finer particles only. Particles crushed no finer than 60 mesh yielded no gold on the plates, whereas particles finer than 150 mesh yielded to amalgamation 83% of the total gold.

The demand for a fine crushing machine was met by various types such as the grinding pan and modifications of the Chilean Mill. However mining men were quick to notice that the cement manufacturers were able to grind their materials to a very fine powder in tube mills, and began to experiment in ore crushing by using hard pebbles in such mills. The results obtained very soon showed large increases in the recovery of gold from the ore. Tube milling soon became an indispensable part of gold milling equipment.

This progress had been made in America and Australia and in 1904 was introduced on the Rand. Today all the important mills in South Africa and generally elsewhere have adopted the Tube Mill. In Australia, however, opinion is divided between tube mills and grinding pans.

The original tube mills on the Rand used Danish flints, which were costly. The first step towards reducing operating expense was in the substitution of selected pieces of the banket, in place of the imported pebbles. The next step was to reduce the length and increase the diameter of the mill. This step produced the so-called Ball Mill in which the diameter is generally equal to, or greater than the length. The crushing is done in these mills by balls, which are made of steel or cast iron. At the present time the tendency is towards a mill of medium length (about 8 feet) with a diameter less than the length.

A brief discussion of the theory underlying Ball Mills.

A cylinder half filled with balls and revolved may have three possibilities - (a) If it be revolved slowly the balls will be dragged up one side until their angle of repose is exceeded, when those on top will roll down. (b) When the speed is increased the centrifugal force of the balls carries them up above the point where their angle of repose is exceeded and on to a point where the downward pull of gravity equals or slightly exceeds the centrifugal force. At this point the ball leaves the wall of the mill and follows a path governed by its initial velocity and gravity. This path will be a parabola and it has been shown that for most efficient crushing the envelope of the parabolas should come again in contact with the mill just a little to the down-coming side of the lowest point of the mill. (c) When the speed is increased still further the balls remain on the periphery of the Mill throughout the revolution. Such a condition prevents crushing.

Davidson's experiments have shown that the most efficient speed is given by the formula -

$$\text{R.P.M.} = \frac{200}{\sqrt{\text{Diam. (in inches) of Mill.}}}$$

Ball and Pebble Load:

Data accumulated in many experiments shew that the greatest amount of crushing is effected by a load of pebbles equivalent to 3/5 of the volume of the mill. However, the power consumption for such a load is excessive, and striking a balance between power consumption and effectual crushing, it is found that the most efficient charge is one whose volume is 7/16ths that of the mill.

Another way of arriving at the charge of pebbles is:-

$$\text{Weight of pebbles} = 44 \times N$$

when N = volume of the mill expressed in cubic feet. This number should be increased by 50% for wet grinding.

<u>Size of Balls</u>:

In an ideal mill the weight of a ball would be just great enough to crack up the largest particle. Such a condition would demand large balls for mills of small diameter and small balls for mills of large diameter, as obviously to produce an equal amount of work the greater mass will require a shorter fall than a smaller mass. The above is true when crushing only by impact is considered, but according to many (all) authorities some of the grinding is done by attrition as opposed to impact.

The attrition effect of balls is a function of their size, hence the attrition of the large balls offsets to some extent the excessive work done by them in impact.

In practice balls up to 5 inches diameter are in use. Mill men endeavour to use balls of uniform size but as the method of replacement is the gradual addition of new balls of the original size, the variety of sizes is constantly increasing.

The wear of the balls is proportional to the weight and the length of time required for a ball to wear a given amount may be calculated from the formula:-

$$\text{Time} = \frac{6.9}{K} \log_{10} \frac{Da}{Db}$$

Where K = a constant for any ball charge - and Da and Db the original and final diameters. (Ref. Trans. Am. Inst. M.M.E. Vol. LV).

The material of which balls are made is generally cast iron or steel but occasionally very high quality chrome or manganese steel is used.

The material with which ball mills are lined is high grade steel. For tube mills, however, the lining may be made of silex bricks or cement with flint reinforcement. Such a lining as the El Oro may also be used, in which the pebbles themselves actually form the lining.

The absolute determination of the power required for a mill involves much intricate calculation. In practice the Davidson Empirical formula is generally used for this purpose. The formula is as follows:-

Horse power = 0.15 (volume of the tube mill in cu. ft.)

(Reference - Trans. Am. Inst. M.M.E. Vol. LXI, page 275).

Practice:

In practice both single stage and double stage crushing are advocated but the evidence seems to show that double stage crushing is more efficient. On the Rand the tendency has been in favour of single stage crushing, using a closed circuit. In other words, the product from the tube mill is classified and the coarser material is returned to the same mill for further crushing.

The chief advantage of double stage crushing lies in the more perfect adaption of crushing machinery to the required size.

In most gold milling plants the tube mills follow the stamps. The arrangement varies considerably but generally there is one tube mill to 10 (2000 lbs.) stamps or to 7 Nissen stamps. At Kalgoorli the ball mills are fed directly from the Gates or Blake rock crushers.

PART II. The following is the description of the experimental work carried out by Mr. E. G. Harding and the writer:

The Preparation of the Material:

The material used in these following tests was tinguaite obtained from the quarry near the Angus Shops, Montreal. The reason for the choice of this rock was that it has been used in previous tests carried on at McGill University. It was initially chosen because of its uniformity of fine grain.

The material on hand consisted of sizes ranging from + 20 R.P.S.* to + 15 R.P.S. The desired sizes were obtained by comminution in a Rolls crusher. In order to produce the required sizes the rolls were set with the following distances between faces:

5/8 for + 20 mesh (R.P.S.)
3/8 " + 19 "
1/4 " + 18 and + 15 mesh (R.P.S.)

By this method considerable oversize (+15) of a thin flaky nature was produced. The remainder of the material was composed of +13, +10, +8 and -6. Very little +6 was obtained on on first crushing. To overcome this difficulty the set of the Rolls was reduced to 0.095" and the thin +15 product was reduced to +6 with a little +8 oversize, which was rejected.

Of the desired sizes a total of 140 55-lb. bags were put through.

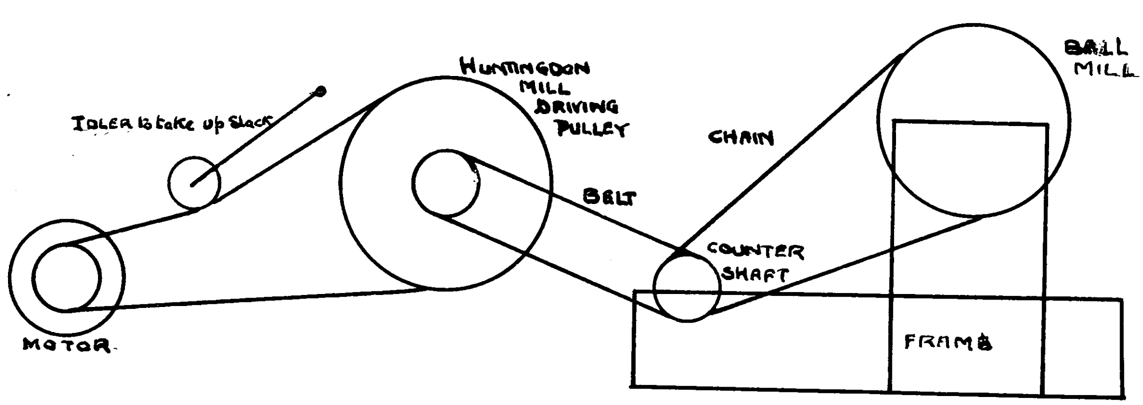
* R.P.S = ROUND PUNCHED SCREENS.

Power:

The power for the mill was supplied by a 5 horse power C.C. motor made by the General Electric and rated at 220 volts with 19 amperes.

A part of the preliminary work consisted in determining the efficiency of this motor at full load. This test, which is appended, shews that the time required for the motor to heat up under full load and become normal ranges from forty minutes to one hour, giving an efficiency of 79.7%.

The empty mill was then connected to the motor and a test run full load being secured by fitting a specially designed brake to the countershaft which shewed an input of 5.58 horse power and a brake horse power of 4.23. Since the efficiency of the motor was 79.7%, therefore the actual power delivered was 4.45, the discrepancy betweenthis figure and the measured brake horse power of 4.23 expresses the loss in horse power due to friction (i.e. 0.22 H.P.)



ELEVATION

The above diagram indicates diagramatically the arrangement used in supplying power to the mill.

The Calibration of the Feeder:

As can be seen from the accompanying photographs the feeding apparatus consists of an inverted pyramid hopper which is connected by a flexible canvass funnel to a pen which is riveted to a pan made of heavy galvanized sheet iron. The pan is actuated by a cam and spring which gives a quick forward movement with slower return. The pan slides on two parallel bars which are fastened firmly to a substantial cast iron plate. The pan and plate have a grade of 1 to 8 horizontal. The length of the cam stroke and therefore the blow to the pan can be adjusted by a capstan head screw.

The calibration of the feeder consisted in measuring the output of the feeder with varying length of cam stroke. The method was to collect and weigh the feed, delivered for five minutes, at each adjustment of the cam stroke. The graduation of the capstan head screw controls the adjustment, a complete revolution being equal to a change of cam stroke of 0.25 inches.

According to the Jamieson theory of bins, the head of feed in the hopper should have little or no effect on the rate of feed. The truth of this theory was fairly well demonstrated in a number of tests. In these tests it was found that the filled hopper delivered its feed at a fairly constant rate.

Such a test as the following exemplifies this assertion:-

Time	Amt. in Weight	Rate lbs.	Total Accumulated	
0 to 5 min.	38.0 lbs.	7.6	38.0 lbs.	
5 " 10 "	40.12 "	8.0	78.12 "	
10 " 15 "	43.37 "	8.7	121.49 "	Average 8.34
15 " 20 "	44.37 "	8.8	165.86 "	
20 " 24 ""	34.14 "	8.5	200.00 "	

Other series while varying little from their respective means were not consistent with each other. The concrodance of readings in any series shews that the changing head has practically no effect on the rate of feed. The discrepancies amongst the different series of tests must be sought for in some other variable. The possible causes of variation seem to be the degree of packing, the rate of withdrawal of the feed, the surging in the hopper, and the vibration.

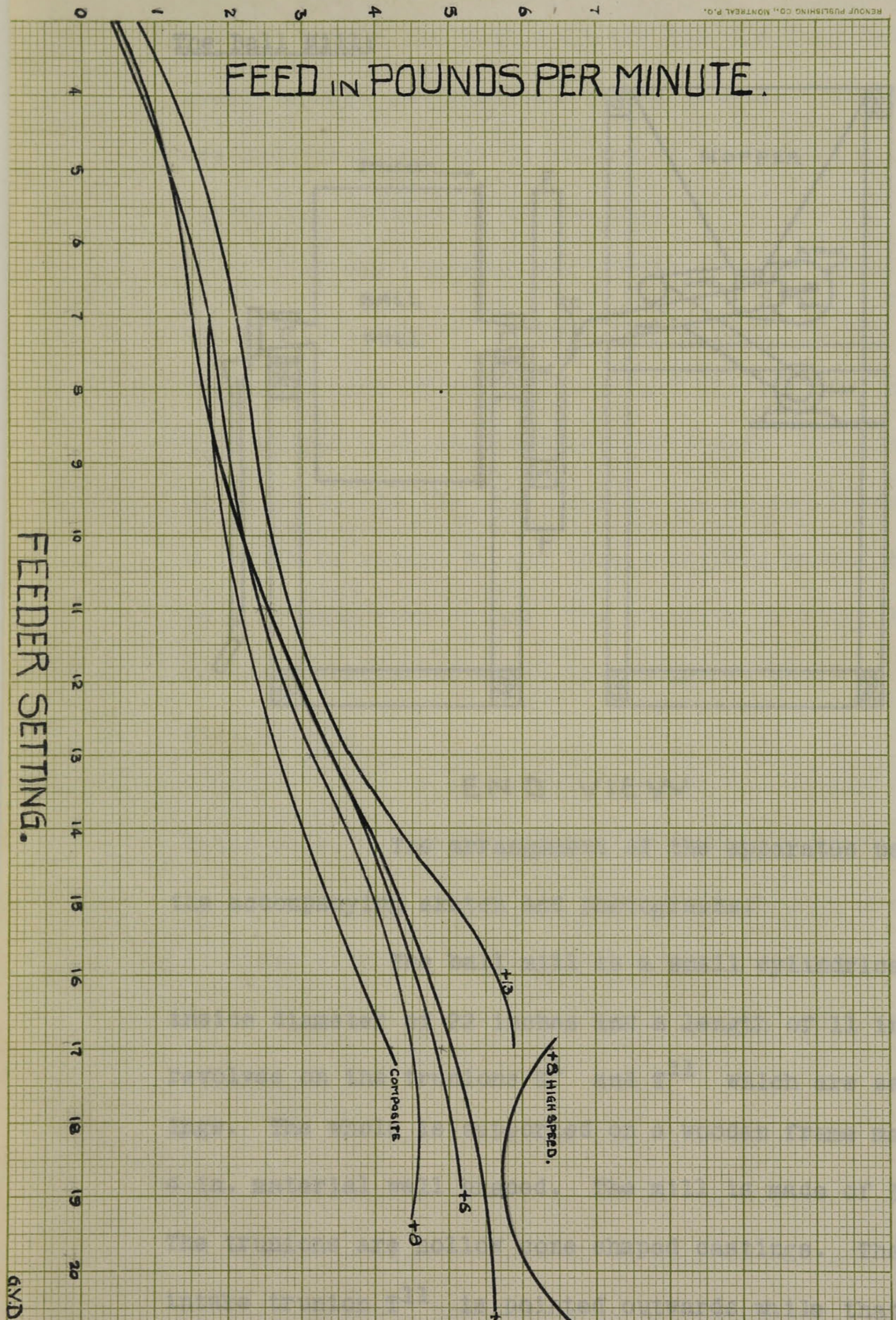
It was suggested that the degree of packing could be controlled by a diaphragm arrangement. The diaphragm first used was a circular disc held by rods in the centre of the rectangular discharge orifice of the feeder. The series of tests with this diaphragm shewed no closer agreement and the irregularity was attributed to the shape of the opening between the disc and the walls of the hopper. A rectanuglar diaphragm was then used of such dimensions that the area of the space on all sides of it were equal. The results shewed irregularities greater than before.

A second pyramidal hopper was then inserted in the first one reaching almost to the bottom and with a space of about two inches between the sides. The reason for this arrangement was that the material passing through the interior hopper would build up on the shaking pan and lie at its natural angle of repose with the apex of its pyramid in the outlet of the inner hopper. It was considered that this method of feed would give a more uniform degree of packing. Experiments made with this modification shewed no improvement. Thus it was seen that other variables must be controlled.

These other variables are the rate of withdrawal of the feed, the surging in the hopper and the vibration. The first was overcome by increasing the grade of the shaking pan from 1 to 8 to 1 to 4. The second and third it was thought could be regulated by using a conical hopper supported on an independent base. The conical hopper is desirable because the surge is due to the unequal slopes of the sides of the hopper and also to the retardation due to the four solid angles.

Curves showing rates of feed at various feeder settings are attached.

The feeder settings correspond to the graduations on the capstan head screw, each single division representing a change of 0.025 inches in the stroke of the cam.


FEED IN POUNDS PER MINUTE.
FEEDER SETTING.
0
1
2
3
4
5
6
7
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
+13
+8 HIGH SPEED.
COMPOSITE
+6
+8
+10
G.V.D.
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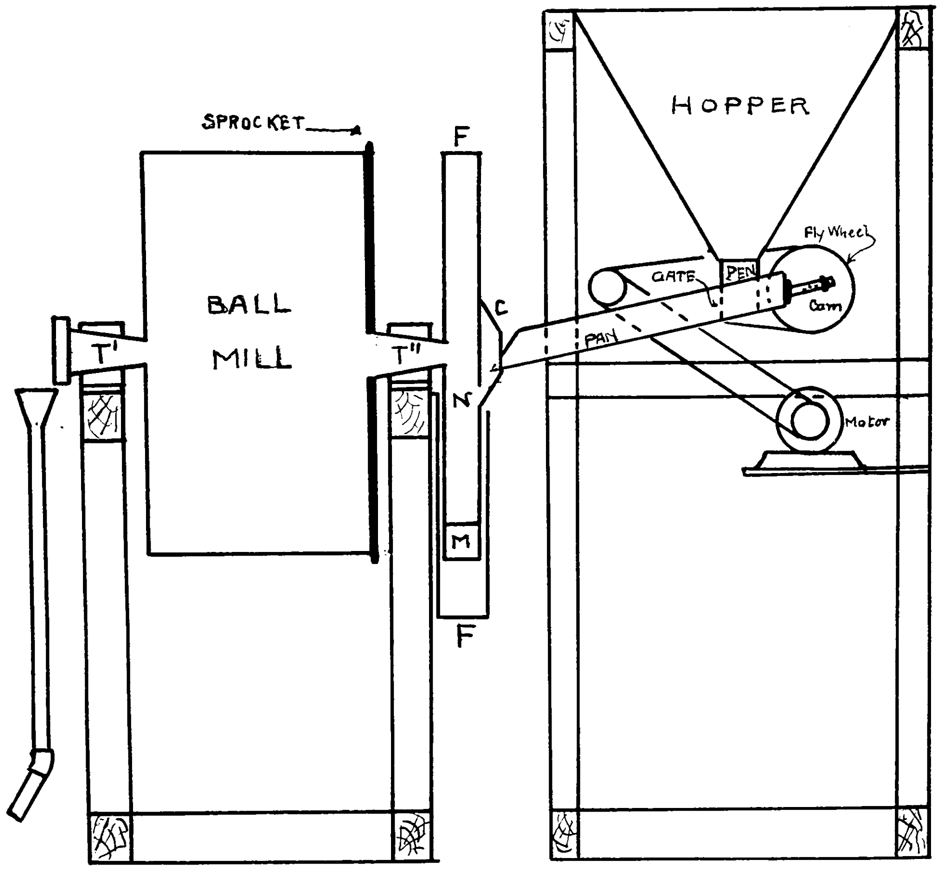
The Ball Mill:



END VIEW

The arrangement of the apparatus used is shewn in the accompanying sketch and photographs.

The ball mill is a small cylindrical mill, with an inside diameter of 22 inches and a length of 11 inches. The mill revolves on the trunions T^1 and T^{11} which are set in simple bearings. The whole is supported on a wooden frame made of 6 in. x 4 in. material well braced. The mill is made of 3/4" cast iron. The trunions are hollow cone shaped castings. The apex of the intake trunion T^{11} is pointed outwards while that of the discharge trunion T^1 is inwards - so as to aid the inflow and outflow.

Within the ball mill are six 3/4 inch half round bars, evenly spaced and parallel to the length. These are called lifters and their purpose is to assist the upward movement of the balls during the revolution of the mill.

At the mouth of the intake trunion there is a feeding arrangement, called a spiral feeder (F.F. on the sketch). This feeder is made of heavy galvanized sheet iron, in the form of a true spiral contained between two discs. One entrance to the spiral is at M. As the mill rotates the spiral feeder passes through a trough of water, W, and thus a uniform amount of water enters by M at each revolution. The quantity of water taken in depends on the amount of water in the trough W, which is controlled by a piezometer.

On the intake side of the spiral feeder is a truncated cone, C. The solid feed is projected into this cone from the shaking pan and enters the spiral through a slot, N, where it mixes with the water. There were originally two such slots but a single slot was later found to be more satisfactory.

Ball Load:

In the tests run the number of balls was not varied. The initial weight of balls was 207 lbs. In all there were 89 balls - 8 with a diameter of 3.35 inches and 81 with a diameter of 2.45 inches. The volume is approximately 7/16 of the mill. The height of a pile of balls N layers high is given by formula.

$$\text{Height} = 2\,r\,(1 + \overline{N-1}\ \sqrt{2/3})$$

Where r = radius of the balls.

The volume may be calculated when the height and the area of the base are known.

The apparatus has now been described up to the point where the feed leaves the shaking pan. From the pan it is projected into the cone of the spiral feeder and enters the spiral through the slot N. There it is mixed with the water and the mixture is forced by the rotation of the spiral through the intake trunion into the ball mill. In the ball mill the action is essentially that described in the general discussion.

When the mixture in the mill has reached the level of the trunions, discharge begins and from this point output is equal to input. While the mill is in rotation there is continual classification, with the result that the finest material is carried out with the water through the discharge trunion.

A short length of pipe is connected to the discharge trunion. The material passes through this to the receptacles provided.

The Description of the Actual Tests.

In order to obtain the greatest efficiency of which the motor was capable, it was decided to run it at full load and to take up the extra power required over and above what was used by the mill in work and friction, by the brake which had been designed for this purpose and is described by Professor Bell in Vol. XIX, Trans. C.M.I. It was also thought that it would be interesting to see what results would be obtained by crushing dry for a few tests. This was found actually to be impossible as the spiral feeder choked in five minutes from the time of start.

The moisture tests were then commenced with a 50% mixture. Even with this amount of water it was evident that the mixture was unsuitable as the feeder threw out about five pounds of feed during the period of the test. However, the mill took one lb./min. of + 13, but when two lbs./min. of the same size were tried with 50% moisture, choking occurred almost at once. The rate was reduced to 1.5 lbs./min. and the test completed. The next test tried was 1 lb. per min. of + 10 material, followed by 2 lbs./min. but this latter one choked and the rate was cut down to 1.5 lbs./min. which proved satisfactory.

It was then determined to experiment with + 8 material and a test was started at 1 lb./min. with moisture the same as before, - 50%. In a little over an hour the feeder choked and it became evident that some radical change was necessary. Professor Bell made two suggestions which really solved the difficulty. The first one was to increase the water to 66% or even 75% and the second to close up one of the slots in the feeder, there originally having been two for the entrance of the rock.

The next two tests were run at 66% moisture nominally and then it was decided to aim at 75% moisture and commence a new series which if it proved successful should show of what the mill was capable.

The procedure briefly was as follows:- The hopper was charged up with the material for that test, the feeder set to give as nearly as possible the required feed and the piezometer arranged likewise to give the 75% moisture. The mill, feeder, water, etc., were started and the time taken. Then when the time had elapsed necessary to have allowed 100 lbs. of material to have passed through the mill the sampling was commenced. It was assumed at the start that after 100 lbs. had passed through conditions would be constant and this assumption was well justified by the closeness with which the A and B samples checked.

Each sample was collected in a tub over a period ranging from 3 mins. to 20 mins. depending on the rate of feed, the aim being to collect about 80 lbs. of the pulp. The A sample was weighed, dried, weighed again to give the amount of moisture and then screened over the No. 6 R.P.S. The oversize was collected, weighed and screened and the undersize cut down in the Jones' Riffle to about 150 grams which was then weighed accurately. The -200 mesh material was washed out, dried, weighed and cut in two parts, one part being held as a reserve sample, the other being screened on the Bell screening machine which is shewn in the accompanying photograph. The B sample was treated in exactly the same way and was taken continuously from the time when the A sample was cut off and over an equal period of time.

When this series of tests was run, it had been intended to run a similar series using rollers instead of balls to do the crushing. A considerable number of these rod mills are used and advertised. As it is claimed that the use of rollers minimizes the amount of slime produced, it was thought that a comparative series of tests would be interesting. Some $2\frac{1}{2}$" steel shafting was procured and 28 rollers were cut 10" long and the ends turned in a lathe to fit the inside of the mill. Each roller weighed about $12\frac{1}{2}$ lbs., the total weight being 350 lbs. The mill was cleaned out and the rollers and some fines were put in, care being taken to lay the rollers [redacted], parallel to the axis of the mill. The mill was started slowly and after a few turns was stopped as the frame began to sway and evidently the rollers were not keeping level. The mill was opened and it was found that the rollers were in general confusion, standing at all angles. Further investigation shewed that the trouble was probably due to one roller as it cascaded over catching in one of the hollow trunions and then as the mill turned it simply threw every other roller across the mill.

It was clear that for a mill whose diameter is greater than its length rollers are impossible and it is apparent that even with an arrangement like a Tustin Mill rollers are useless in a mill of these proportions, unless it is simply the case of exceedingly fine grinding from a very much smaller size than [redacted] had been fed to the mill in question.

The comparison tests between rollers and balls in the same mill was therefore impossible.

It was decided to try a set of composite feeds:- 25% each of + 13, + 10, + 8 and + 6 and then to see if the mill would take higher rates of feed with only + 10 and + 8 material. These tests were carried out successfully and the results appear in the discussion which follows.

Discussion of the Results:

The merits of a number of tests or of the performance of two mills may be compared in various ways. The most scientific way is the calculation of the Relative Mean Efficiencies (R.M.E.). This calculation is made in the following manner:- The results of the sample screening are expressed as a percentage of weight. Each percentage is multiplied by the reciprocal of the average diameter of the grain. This procedure is according to the Rittinger Law of Crushing. The number thus obtained is called the surface unit, and the total number of surface units is found by addition. This total number less the Surface Units of the Feed is multiplied by the number of tons per 24 hours produced by the mill. The product of this multiplication is then divided by the horse power consumed.

Therefore it was decided to take an average power and work out a set of MEAN R.M.E. results and call attention to the above points, leaving the problem of power to future investigators.

The chief effect of working out this mean R.M.E. on the curves is the reduction of the R.M.E's of the + 13 material and the + 6 with less pronounced effects on the + 10 and + 8. The nett R.M.E's are simply the R.M.E's. worked out disregarding the 0.22 H.P. of friction and are a series of curves lying parallel to the ones recorded. The following is a consideration of the R.M.E. curves and the conclusions which may be drawn from them:-

1. - The composite feed is the most efficient. This is to be expected because under conditions of composite feed there is the minimum of interstices, - interstitial space being a maximum when all the particles are of equal size. The maximum efficiency is attained with a feed rate of about 2.25 tons/24 hrs. although there seems to be a range of from 2.0 to 2.5 tons/24 hrs. when good results can be expected.

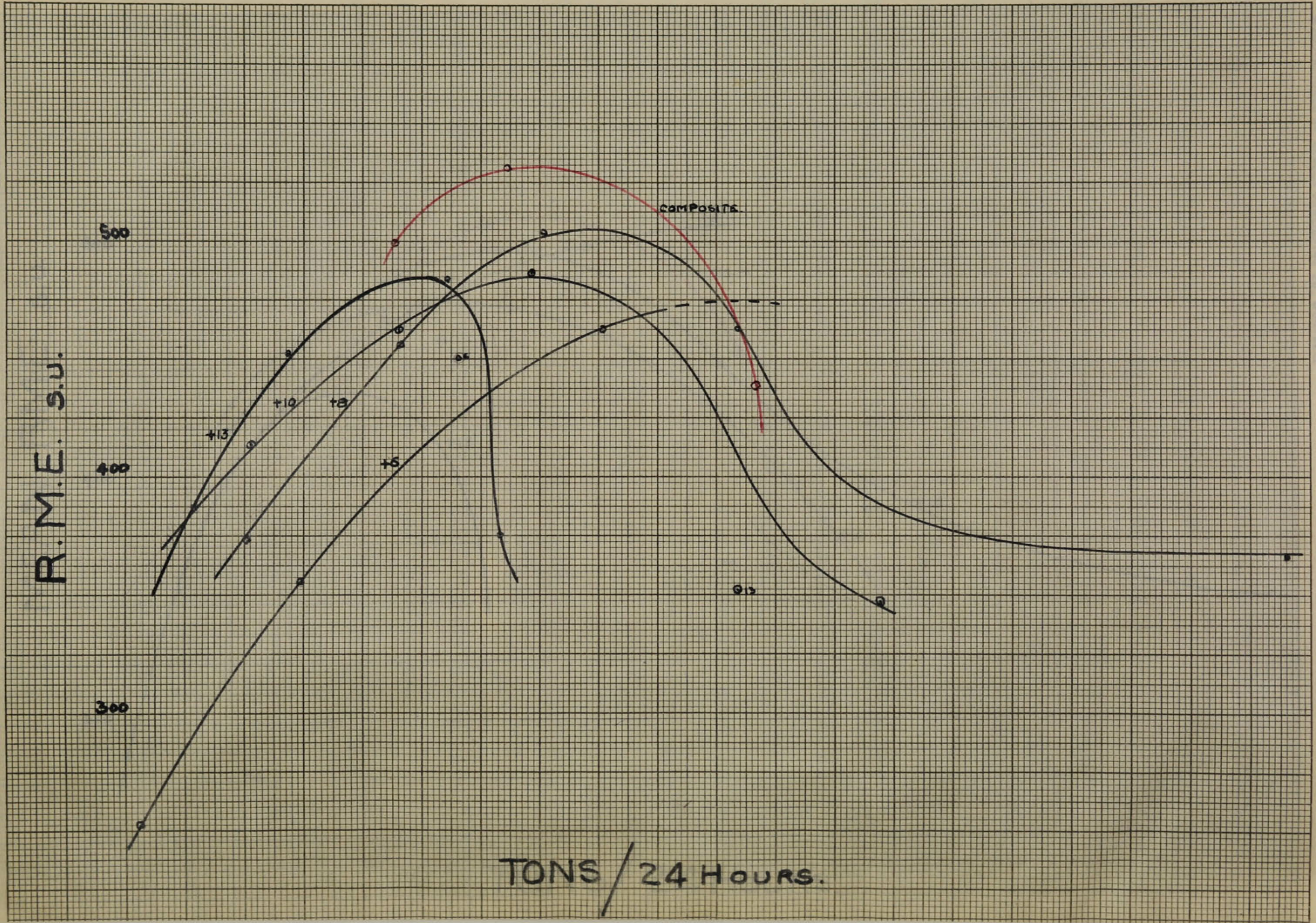
2. - The next most efficient at high tonnages, say in excess of 2.6 tons/24 hrs. is the + 6 feed. It was unfortunate that there was not sufficient time to continue this curve to a point where the curve would, having reached its maximum, begin to fall off. This point would probably be somewhere between 4 and 5 tons/24 hrs.

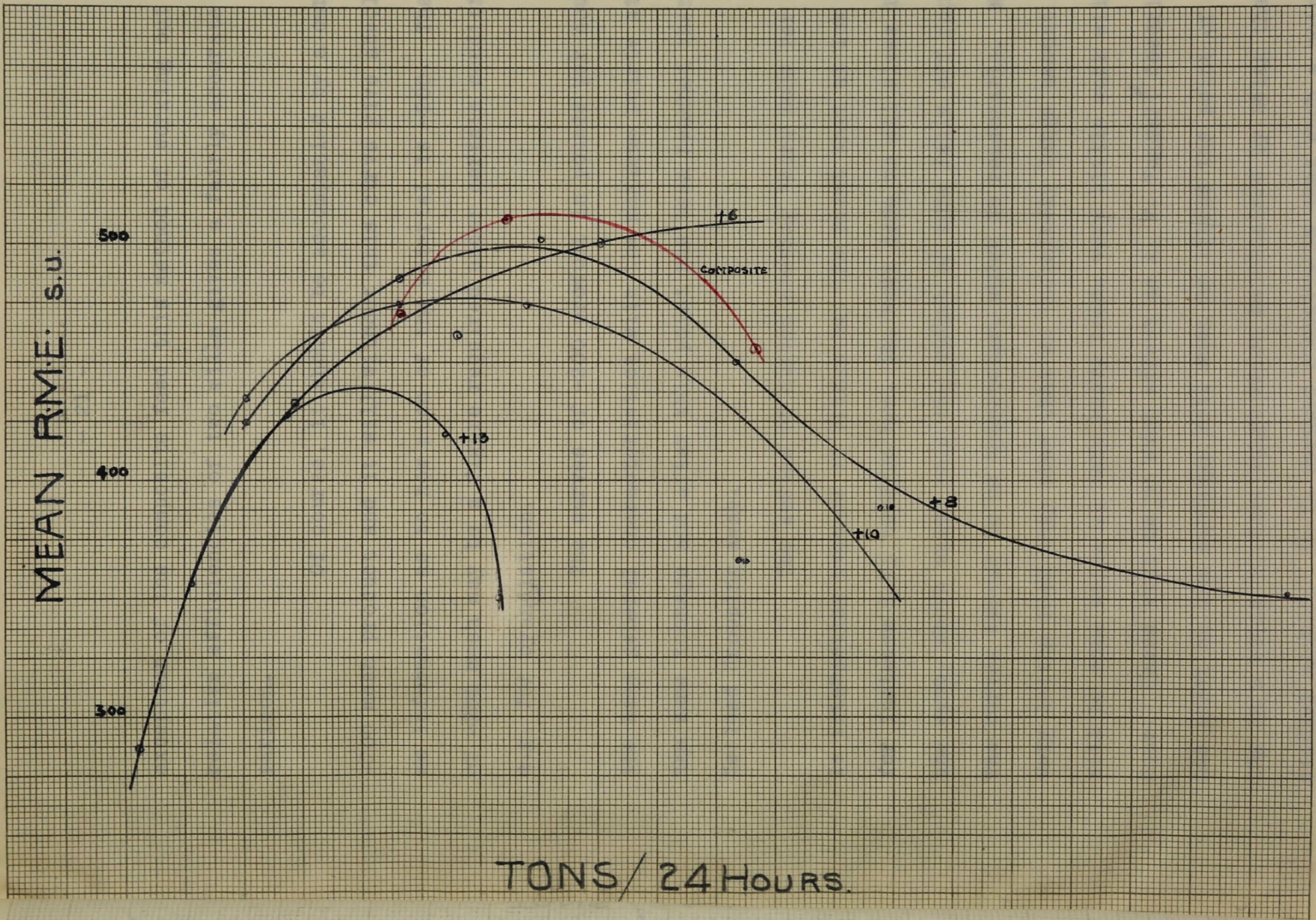
3. - At tonnages up to 2.25 the + 8 feed seems to be most efficient, with the + 13 and + 10, rising to a maximum and falling off off quickly.

The next discussion concerns the curves of the so-called -48 efficiency or the number of pounds per hour which will pass -48 mesh. The most striking thing is the similarity of the curves as regards shape and general relative position. With the

The resulting number is the R.M.E.

Two sets of Relative Mean Efficiency Curves have been drawn because, as may be seen in consulting the sheets of the tests, the power appears to vary considerably for different tests. It seems hard to realize why this should be if the percentage of moisture is kept constant, because the main demand on the power is expended in turning over the mill with its load. The load is made up of rock, water and balls, and these balls were kept at a constant weight. The weight of the rock varies slightly according to size and the composite or uniform nature of the feed. The amount of water should be constant but variations creep in due to the piezometer. However, these variations appear hardly great enough to be definitely detected in the power readings. There is the possibility that the power lost in the journals, chain, etc., might be a variable. In the power test as has been already noted, the total friction was worked out as 0.22 H.P. but there are no means at present of finding out whether such power varied during actual running conditions. In an ideal test the friction of the journals would be reduced to a minimum by means of ball bearings or some like device and there would be a more sensitive means of taking up the excess power. Under such conditions it could be noticed if there were any changes in friction. Also it might be possible to find out if the power necessary for the actual crushing varied with the size, rate and nature of feed.


COMPOSITE.
500
400
300
R.M.E. S.U.
+13
+10
+8
+6
TONS/24 Hours.


MEAN R.M.E. S.U.
500
400
300
+6
COMPOSITE
+13
+8
+10
TONS/24 HOURS.

exception of the composite feed this method of working out the relative efficiencies of two mills gives a fairly accurate comparison.

Of course, it should be accompanied by a curve of -200 mesh product and it will without this curve give absolutely no information as to how much of the material is -200. The amount of -200 mesh may be a figure required under certain conditions, e.g. for cyandiation.

The curves of -200 product in pounds per hour shew the same general characteristics with the maximum points at about the same tonnage and after this point has been reached there is a decided dropping away.

The series of curves shewing "Work Done Per Ton" is interesting because it brings out the point that at low rates, for instance 1.25 tons/24 hrs. the work done on all sizes is about the same, above which rate the amount of work falls off rapidly. The curves appear to be hyperbolas, which is reasonable. With a very little feed they shew that an infinitely large amount of work will be done while at very heavy loads very little work will be done. There will be no such effect as A. F. Taggart# describes in his paper on the Hardinge Mill when he likens the point of stalling in a rolls to some point which he obtained by using the Kick-Stadler method. It is perhaps conceivable that such a point might

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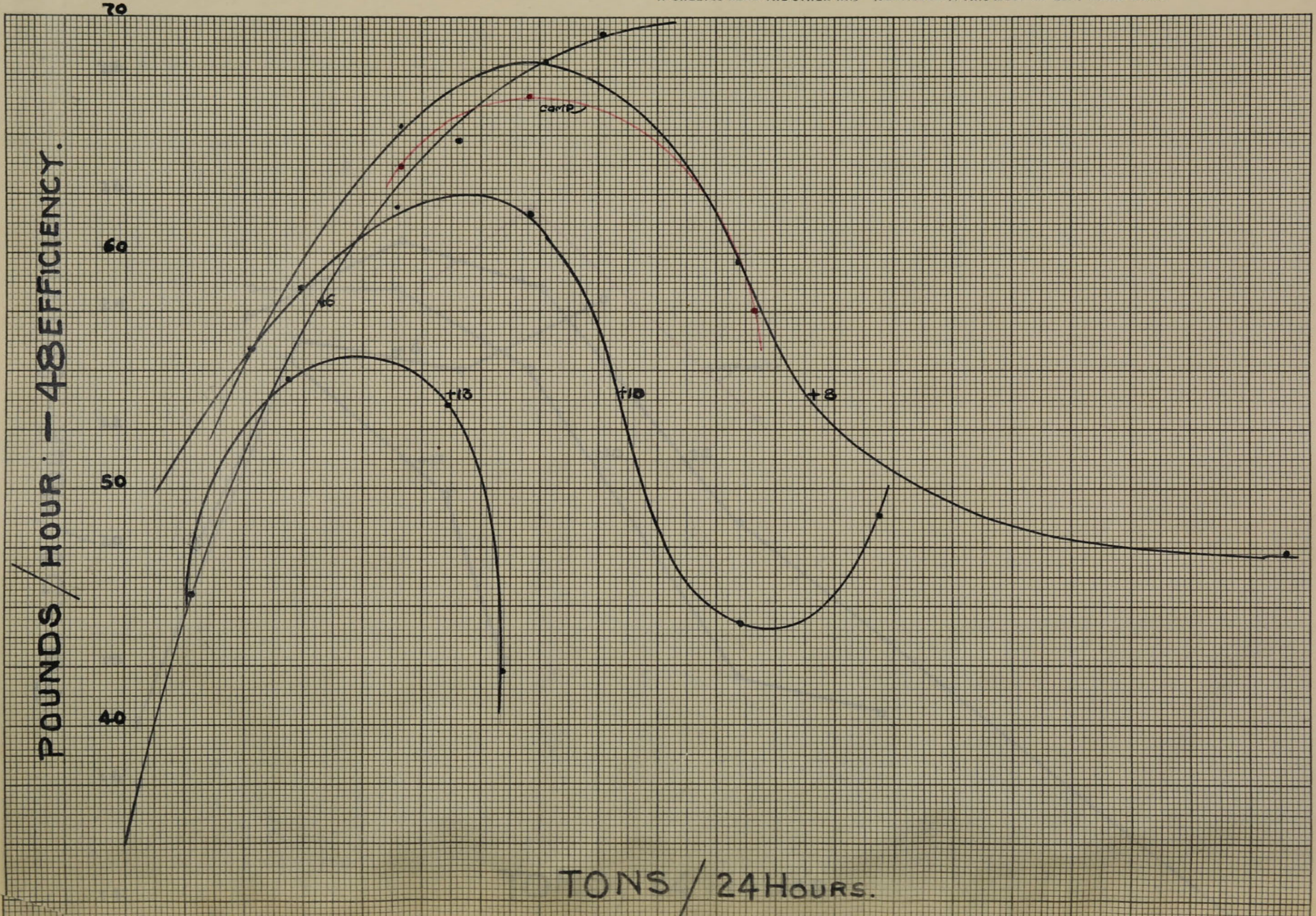

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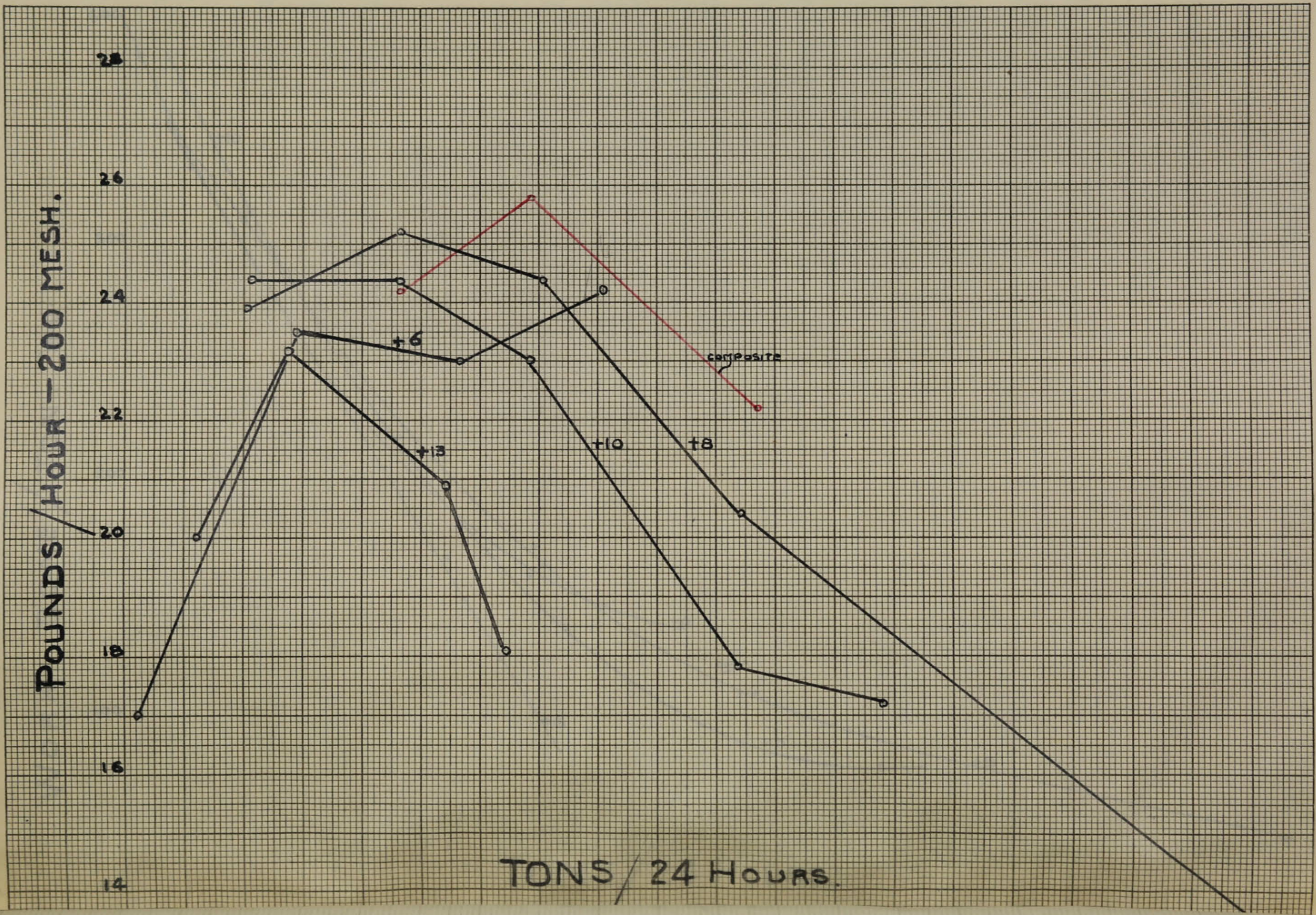
POUNDS / HOUR — 200 MESH.
28
26
24
22
20
18
16
14
+6
+13
+10
+8
composite
TONS / 24 HOURS.

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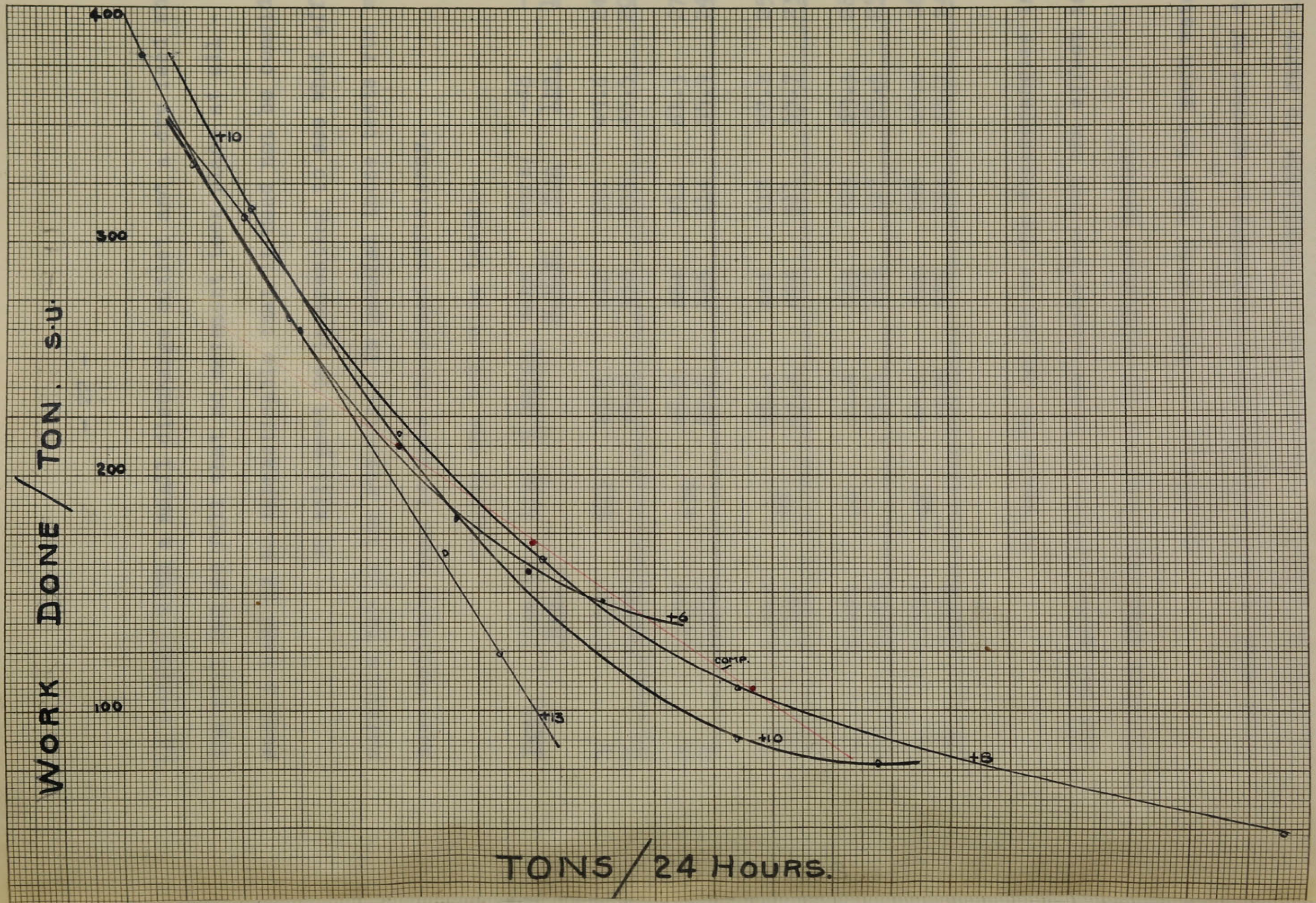

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be reached with a small discharge outlet and a dry feed where the mill was so full that no movement took place at all - but such a case is so impracticable that it need not be considered.

It will next be interesting to see what effect moisture has on the results. In general those tests run with less moisture seem to shew increased efficiency.

Compare the following tests:-

Test	Tons/24 hrs.	Size	% Moist.	Mean R.M.E.	Work/ Ton	-48 lbs.	-200 lbs.
1	0.778	+13	46.5	412	392	49.6	24.6
3	0.792		73.2	356	333	45.5	20.0
8	1.150	+10	48.8	484	311	61.3	27.5
9	1.026		67.8	435	314	55.9	24.4
14	1.032	+8	58.3	444	318	57.2	25.4
17	1.009		67.8	424	311	55.7	23.9
15	1.775	+8	60.6	535	223	69.3	28.7
18	1.656		72.1	486	217	65.4	25.2
16	2.591	+8	62.1	516	148	65.8	26.6
19	2.266		72.8	502	164	68.1	24.4

In tests No. 16 and 19 the discrepancies in feed are too great to make a close comparison but the effect is very obvious when one looks at the -200 mesh output.

In general it would seem that too much water had been used, a precedure rendered necessary on account of difficulties in feeding. As time was not available to carry the experiments to a point where the maximum efficiency for any feed and size was determined by altering the moisture, the above data must suffice.

It would seem that in this question of moisture the main points are:- First, that there should be present enough moisture to keep the rubbing surfaces clean. This works in two ways - it allows the unbroken rock to come in contact with the balls or other surfaces against which it strikes or is ground, and it removes the material that has been ground so that no further work is done upon it. Secondly, more water than that required to do the above is simply acting as a buffer between the balls and the rock to be crushed.

The increasing moisture will, however, not be detrimental to the future operation of a mill used in connection with a flotation plant. With this in view the moisture may possibly be even further increased. This high percentage of moisture may account for the very low percentage of -200.

If time had permitted, the feed rate of the + 6 material would have been increased, and long tests would have been run to see if the mill continued to behave in uniform fashion over a considerable period of time.

It would also be an interesting experiment to put one large roller inside the mill, (the roller to be about 18" diam. by 7" long) and to remove the lifters. A mill something between a Chilean mill and a rolls would result and it would have the advantage of not stalling as does the latter.

In comparison with the efficiencies obtained by other experimenters it is perhaps interesting to point out that A.F. Taggart in his tests with a Hardinge Mill[#] obtained 530 as his highest R.M.E. and in our tests the highest R.M.E. was 510 for the mixed feed at 2.1 tons/24 hrs. and 535 for the + 8 feed at 1.775 tons/24 hrs. with 60.6% moisture.

It would therefore seem probable that the efficiencies of a large and a small ball mill would not be greatly different provided they were crushing feed sizes suited to their respective diameters.

The writer wishes to thank Dr. J.B. Porter and Professor J.W. Bell for their advice and help. It is only fair to say that but for Professor Bell's enthusiasm many difficulties would not have been overcome in time to complete the work.

The thanks of the writer are also due to Messrs. Erlenborn and Edwards for their assistance in turning the rollers.

A. Vibert Douglas.
16th May 1921.

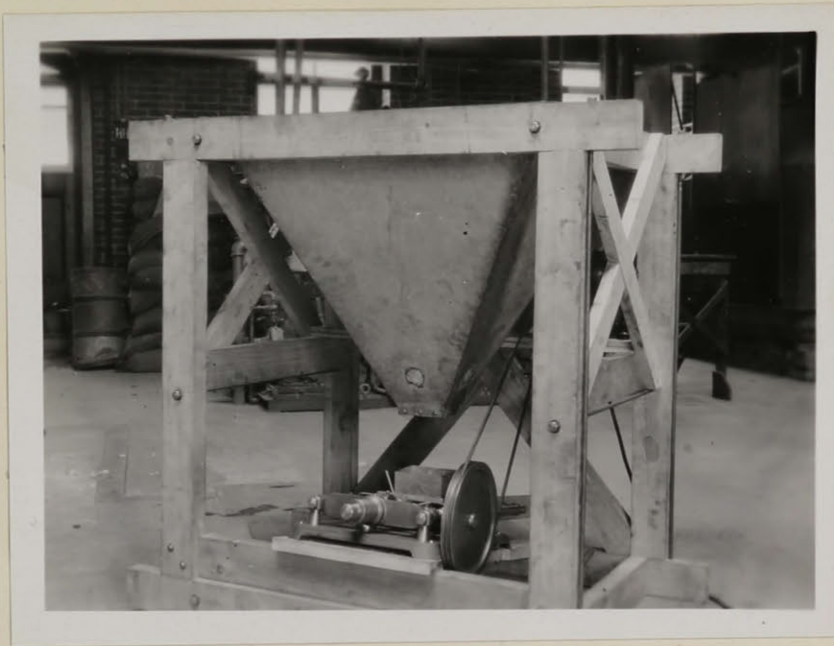
(# Computed from calculations made by Prof. Bell in 1916)

est No.	Size	Lbs./ Min.	Tons/ 24 hrs.	% Moist.	Power	RME.	Mean RME.	Nett RME.	Nett Mean RME.	Work per ton	-48 Output	-200 Output
1	+13	1.08	0.778	46.5	0.90	339	412	448	586	392	49.6	24.6
2	+13	1.20	0.864	55.6	0.63	468	398.1	720	567	341	50.2	22.7
3	+13	1.10	0.792	73.2	0.68	387	356	572	506	333	45.5	20.0
4	+13	1.65	1.188	78.6	0.70	452	427	658	607	266	54.6	23.2
5	+13	2.571	1.852	77.8	0.64	484	419	738	596	167	53.5	20.9
6	+13	2.900	2.085	80.5	0.69	375	350	551	498	124	42.3	18.1
7	+10	1.16	0.835	42.6	0.83	383	430	522	611	380	52.4	25.6
8	+10	1.60	1.150	48.8	1.71	505	484	731	689	311	61.3	27.5
9	+10	1.425	1.026	67.8	0.78	413	435	575	620	314	55.9	24.4
0	-10	2.300	1.655	74.0	0.76	462	474	651	675	212	62.0	24.4
1	+10	3.071	2.210	73.9	0.72	486	474	702	675	159	61.7	23.0
2	+10	4.30	3.095	73.6	0.72	352	366	493	522	88	44.3	17.8
3	+10	5.125	3.690	75.2	0.83	346	388	471	553	78	48.8	17.22
4	-8	1.432	1.032	58.3	0.73	450	444	644	632	318	57.2	25.4
5	-8	2.465	1.775	60.6	0.74	535	535	762	762	223	69.3	28.7
6	-8	3.600	2.591	62.1	0.73	523	516	749	735	148	65.8	26.6
7	+8	1.400	1.009	67.8	0.84	373	424	506	603	311	55.7	23.9
8	-8	2.300	1.656	72.1	0.79	456	486	632	692	217	65.4	25.2
9	+8	3.150	2.266	72.8	0.74	503	502.5	715	715	164	68.1	24.4
0	+8	4.300	3.095	73.5	0.72	462	450	666	640	108	59.6	20.4
1	+8	7.500	5.400	71.7	0.71	365	351	530	499	48	47.3	13.1
2	+6	0.775	0.558	79.3	0.84	252	286	342	408	380	37.2	17.0
3	+6	1.700	1.223	77.9	0.90	355	431	470	614	261	58.3	23.5
4	+6	2.643	1.902	76.9	0.76	450	461	632	656	179	64.8	23.0
5	+6	3.500	2.502	77.6	0.80	462	500	638	711	147	69.3	24.2
6	Comp.	2.300	1.655	64.3	0.70	499	471	727	672	212	63.7	24.2
7	"	3.071	2.212	70.4	0.71	531	510	770	725	171	66.6	25.8
8	"	4.400	3.170	69.0	0.77	438	456	614	650	107	57.5	22.2

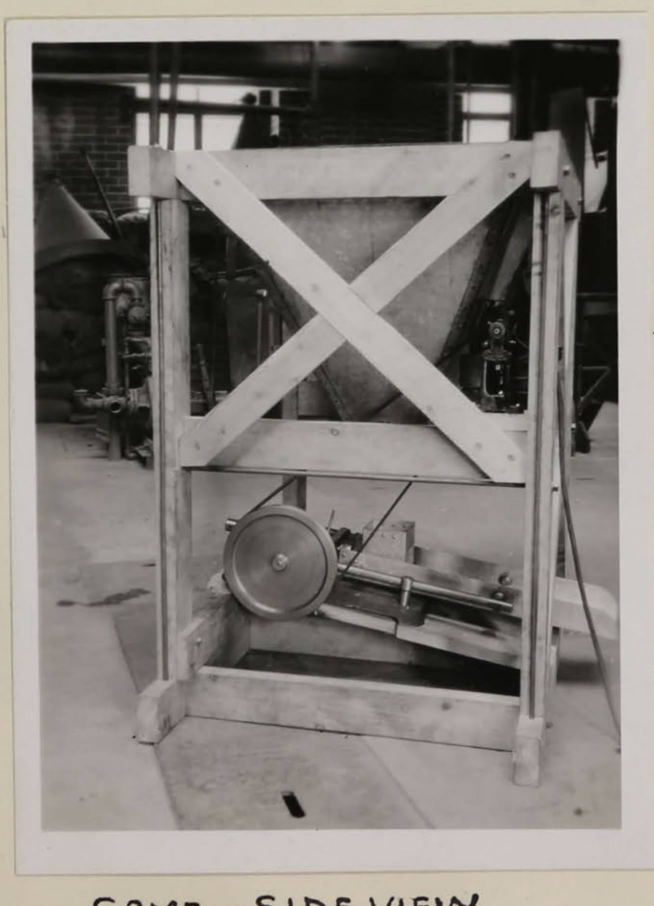
SUMMARY OF TESTS.

Power Sheet

Test No.	Volts	Amps.	E.H.P. Input	B.H.P. Input	R.P.M.	Nett Wt.	H.P.on Brake	H.P. Friction	Nett H.P. to Mill
1	226	18.15	5.50	4.38	1107	8.25	3.48	0.22	0.68
2	226	16.9	5.12	4.07	1094	8.25	3.44	0.22	0.41
3	225	18.0	5.42	4.32	1092	8.75	3.64	0.22	0.46
4	226	18.1	5.48	4.37	1099	8.75	3.67	0.22	0.48
5	226	17.9	5.43	4.32	1103	8.75	3.68	0.22	0.42
6	225	17.75	5.35	4.26	1069	8.75	3.57	0.22	0.47
7	226	18.53	5.62	4.48	1094	8.75	3.65	0.22	0.61
8	226	18.05	5.47	4.36	1094	8.75	3.65	0.22	0.49
9	224	18.4	5.52	4.40	1087	8.75	3.62	0.22	0.56
10	224	18.4	5.52	4.40	1090	8.75	3.64	0.22	0.54
11	224	18.3	5.49	4.37	1094	8.75	3.65	0.22	0.50
12	222	18.45	5.49	4.37	1079	8.75	3.60	0.22	0.55
13	226	18.55	5.62	4.48	1096	8.75	3.65	0.22	0.61
14	226	18.1	5.48	4.37	1091	8.75	3.64	0.22	0.51
15	226	18.15	5.50	4.38	1092	8.75	3.64	0.22	0.52
16	226	18.1	5.48	4.37	1090	8.75	3.64	0.22	0.51
17	227	18.3	5.64	4.50	1098	8.75	3.66	0.22	0.62
18	222	18.6	5.53	4.41	1087	8.75	3.62	0.22	0.57
19	226	18.25	5.52	4.40	1097	8.75	3.66	0.22	0.52
20	226	17.8	5.39	4.30	1072	8.75	3.58	0.22	0.50
21	226	17.95	5.43	4.32	1084	8.75	3.61	0.22	0.49
22	224	18.6	5.58	4.45	1083	8.75	3.61	0.22	0.62
23	224	18.8	5.64	4.50	1080	8.75	3.60	0.22	0.68
24	224	18.25	5.47	4.36	1079	8.75	3.60	0.22	0.54
25	222	18.5	5.50	4.38	1076	8.75	3.58	0.22	0.58
26	225	18.0	5.42	4.32	1087	8.75	3.62	0.22	0.48
27	224	18.2	5.45	4.35	1092	8.75	3.64	0.22	0.49
28	224	18.45	5.54	4.41	1092	8.75	3.64	0.22	0.55

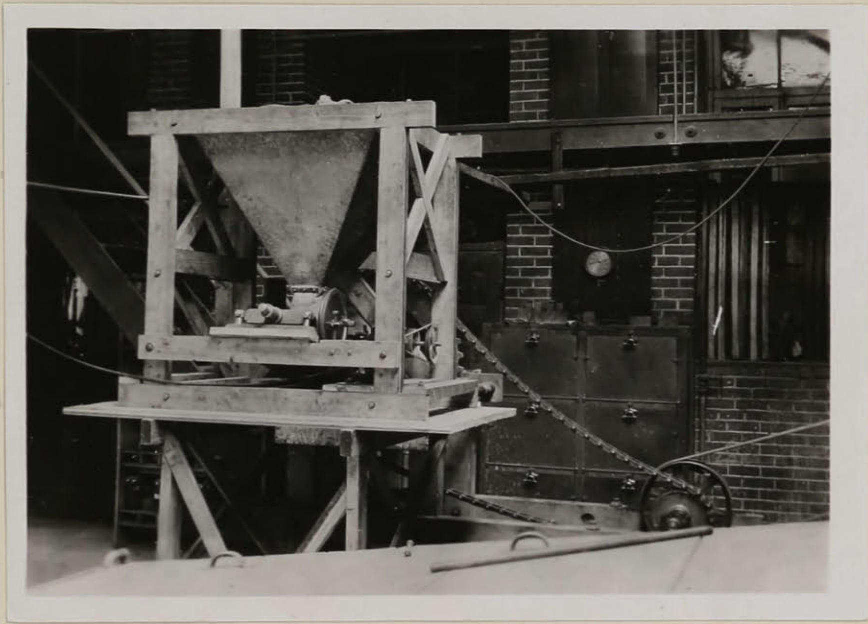


HOPPER + SHAKING FEEDER B.VIEW.



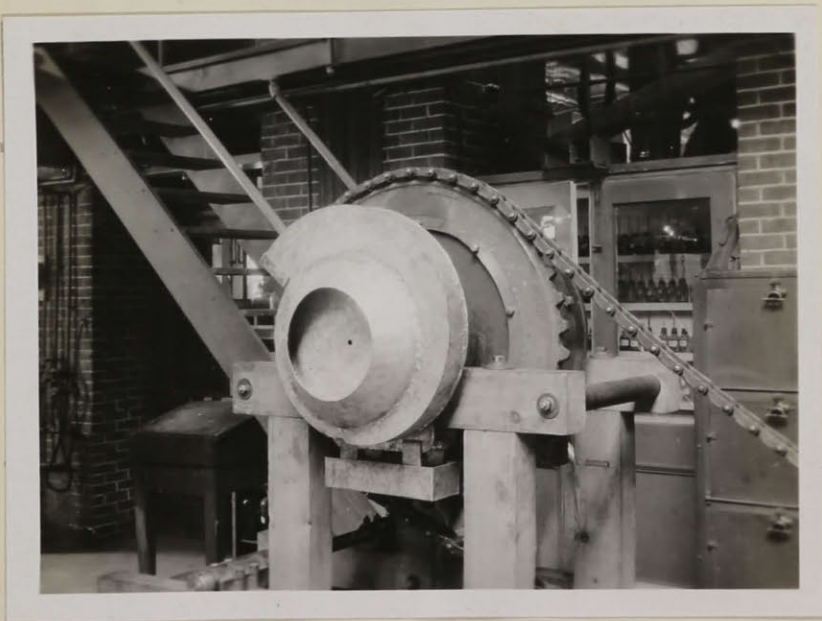
← MOTOR

SAME - SIDE VIEW.



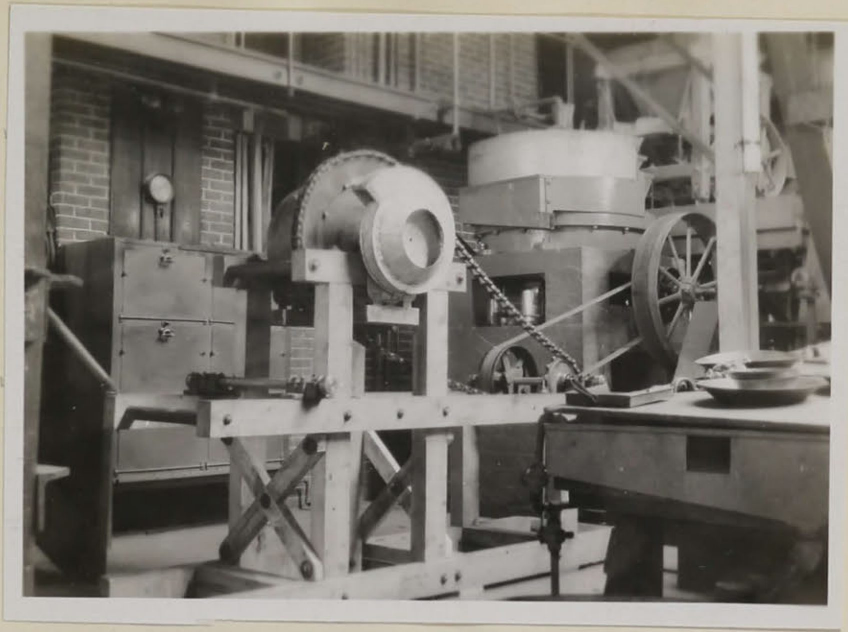
BELT DRIVE

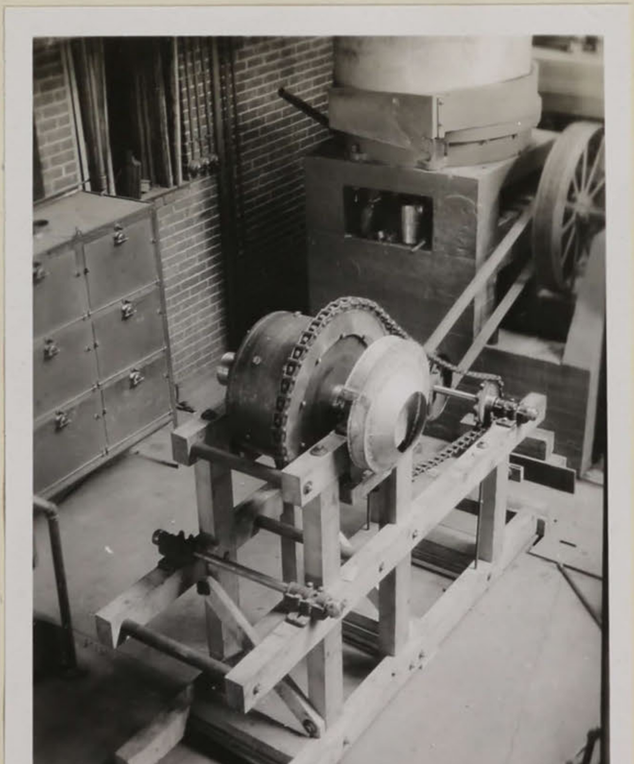
FEEDER IN POSITION



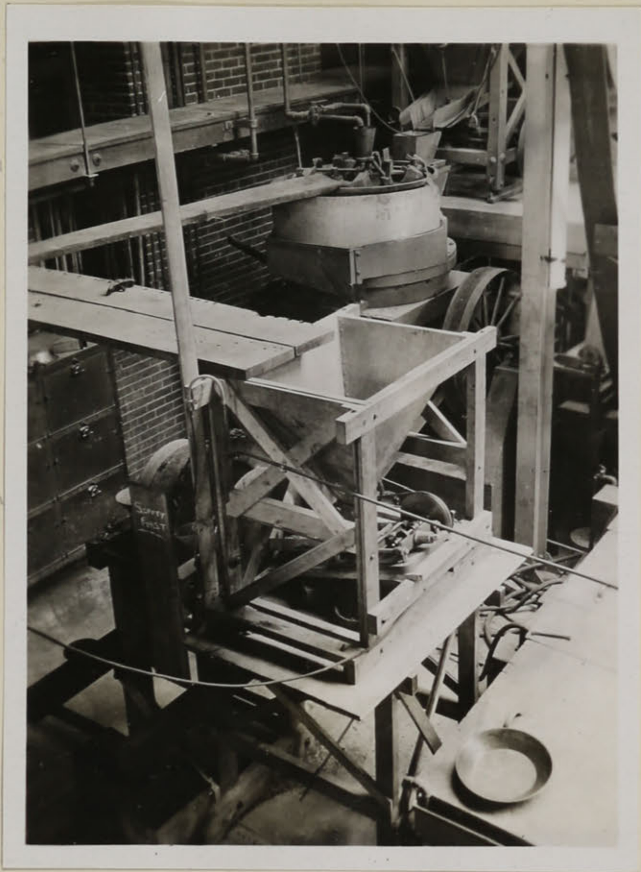
CHAIN DRIVE

SPIRAL FEEDER ON MILL

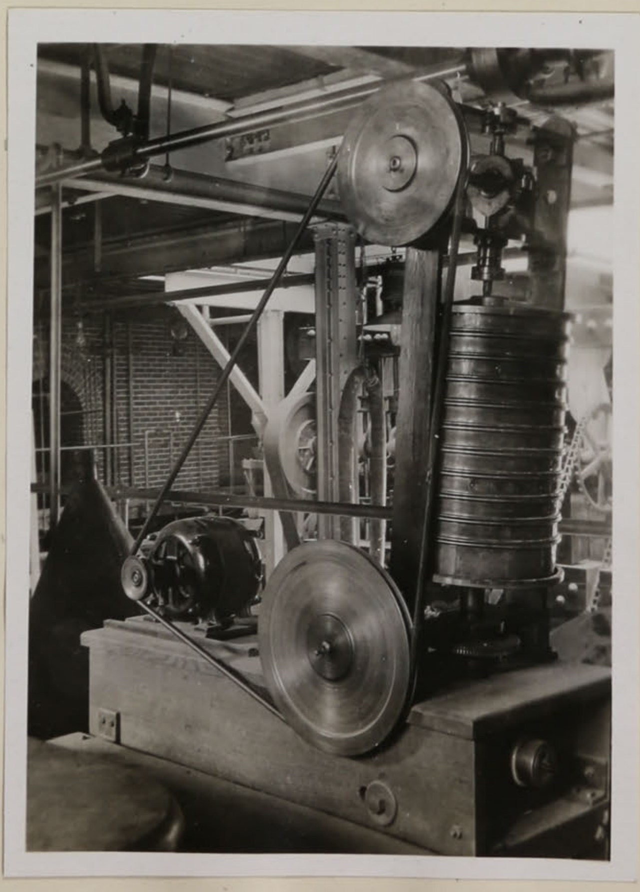




MILL with SPIRAL FEEDER before HOPPER was added.



MILL IN RUNNING ORDER.



B. Screening Machine.

EFFICIENCY TEST

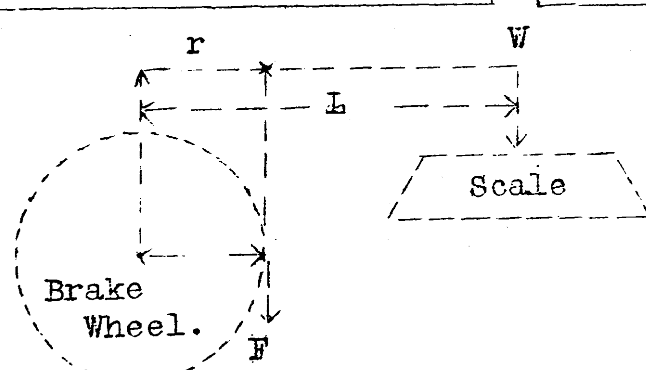
Test No. B.   Date February 8th, 1921.

Machine Tested 5 H.P. Shunt C.C. Motor

Time			Wattmeter		Volts	Amps.	Revolutions	R.P.M.
H	M	S	Dial	Revs				
1	45	0			224	18.2		
	50	0		5.53	224	18.4		1031
	55	0			225	18.4		1044
2	00	0			225	18.4		1051
	05	0			226	18.4		1057
	10	0			226	18.5		1061
	15	0			225	18.6		1062
	20	0			224	18.7		1063
	30	0			225	18.7		1067
	35	0			225	18.75		1068
	40	0			225	18.70		1072
	45	0			224.5	18.8		1070
Average					225.0	18.50		

Wattmeter		
Revolutions		Per Hr.
Value 1 Rev		Watt H.
Input		H.P.

Gross Weight	18.75	Lbs.
Tare	7.75	Lbs.
Nett Weight (W)	11.00	Lbs.
Average (N)		R.P.M
Brake		H.P.
Water Resistance		H.P.
Total Output		H.P.
Efficiency		%



$Fr = WL \qquad F = \frac{WL}{r}$

$Work = Fs = 2\pi NWL \qquad L = 2'$

$H.P. = 0.000381\ W\ N$.

EFFICIENCY TEST

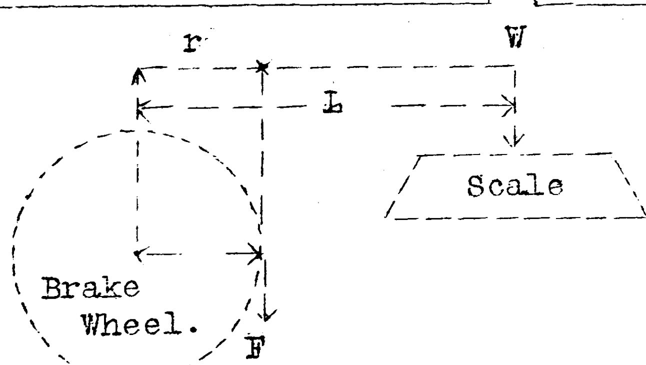
Test No. B. Cont'd. Date February 8th, 1921.

Machine Tested 5 H.P. Shunt C.C. Motor

Time			Wattmeter		Volts	Amps.	Revolutions	R.P.M.
H	M	S	Dial	Revs				
2	50	0			224	18.8		1070
	55	0			225	18.8		1067
3	00	0			225	18.8		1071
3	05	0			222	18.9		1063
	10	0			220	18.95		1057
	15	0			223	18.9		1060
	25	0			224	18.8		1076
	30	0			224	18.9		1086
	35	0			225	18.9		1085
	40	0			224	18.9		1051
	45	0			227	18.8		1059
	55	0			225	18.9		1080
Average								

Wattmeter		
Revolutions		Per Hr.
Value 1 Rev		Watt H.
Input		H.P.

Gross Weight		Lbs.
Tare		Lbs.
Nett Weight (W)		Lbs.
Average (N)		R.P.M
Brake		H.P.
Water Resistance		H.P.
Total Output		H.P.
Efficiency		%



$Fr = WL$ $F = \frac{WL}{r}$

$\text{Work} = Fs = 2\pi NWL$ $L = 2'$

$\text{H.P.} = 0.000381\ W\ N$.

EFFICIENCY TEST

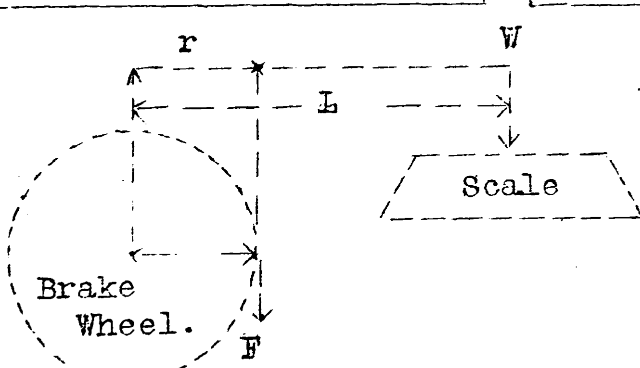
Test No. B. Cont'd. Date February 8th, 1921.

Machine Tested 5 H.P. Shunt C.C. Motor

Time			Wattmeter		Volts	Amps.	Revolutions	R.P.M.
H	M	S	Dial	Revs				
4	00	0			224	18.9		1071
	05	0			222	19.0		1062
	10	0			224	18.9		1066
	15	0			224	18.9		1070
	20	0			227	18.7		1075
	25	0			226	18.8		1079
	30	0			226	18.8		1081
	35	0			226	18.7		1080
	40	0			225	18.8		1073
	45	0			226	18.8		1079
	50	0			224	18.8		1079
	55	0			226	18.8		1077
5	00	0			224	18.8		1075
Average					225	18.8		1076 Mean

Wattmeter		
Revolutions		Per Hr.
Value 1 Rev		Watt H.
Input	5.66	H.P.

Gross Weight	18.75	Lbs.
Tare	7.75	Lbs.
Nett Weight (W)	11.00	Lbs.
Average (N)	1076	R.P.M
Brake		H.P.
Water Resistance		H.P.
Total Output	4.51	H.P.
Efficiency	79.7	%



$Fr = WL \qquad F = \frac{WL}{r}$

$Work = Fs = 2\pi NWL \qquad L = 2'$

$H.P. = 0.000381\ W\ N$.

Date Ball Mill Test No. 1

Grade	Feed %	Feed 1/D	Feed S.U.	Discharge A %	Discharge A 1/D	Discharge A S.U.	Discharge B %	Discharge B 1/D	Discharge B S.U.	Grade
							0.5	4		+ 3
							0.1	7		5
							0.1	9		6
							0.4	11		8
+ 10							1.1	14	0.2	10
14							1.6	20	0.3	14
20							2.2	30	0.7	20
28							3.4	40	1.4	28
35							6.6	60	4.0	35
48							7.4	80	5.9	48
65							10.2	120	12.2	65
100							10.2	170	17.3	100
150							11.8	240	28.3	150
200							6.5	330	21.4	200
-200							37.9	800	303.2	-200
Total							100.0		394.9	Total
					-48%, 76.6					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	53.5	%
Moisture in Feed	46.5	%
Output of -48 mesh material per Hour	49.6	Lbs.
Output of -200 mesh material	24.6	Lbs.
Mechanical Value of Discharge	394.9	S.U
Mechanical Value of Feed	3.2	S.U.
Work done per Ton	391.7	S.U
Feed Rate - 24 Hours	0.778	Tons
Total Work done per 24 Hours	304.5	S.U.
Power expended	0.90	H.P.
P.M.E. or Work done per H.P. per 24 Hours	339.0	S.U
Nett	448	

Mean RME. 412

Nett " " 586

Date   Ball Mill Test No. 2

Grade	Feed %	Feed I/D	Feed S.U.	A Discharge %	A Discharge I/D	A Discharge S.U.	B Discharge %	B Discharge I/D	B Discharge S.U.	Grade
				0.9	4	..	0.9		..	+ 3
				0.1	7	..	0.1		..	5
				0.1	9	..	0.1		..	6
				0.5	11	0.1	0.6		0.1	8
+ 10				1.3	14	0.2	1.2		0.2	10
14				2.5	20	0.5	2.4		0.5	14
20				3.1	30	0.9	3.1		0.9	20
28				4.7	40	1.9	4.8		1.9	28
35				8.3	60	5.0	8.4		5.0	35
48				8.4	80	6.7	8.7		7.0	48
65				10.2	120	12.3	10.6		12.7	65
100				10.6	170	18.0	10.7		18.2	100
150				10.7	240	25.7	11.3		27.2	150
200				5.8	330	19.2	5.6		18.5	200
-200				32.8	800	262.4	31.5		252.0	-200
Total				100.0		352.9	100.0		344.2	Total

-48% = 69.7

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	44.4	%
Moisture in Feed	55.6	%
Output of -48 mesh material per Hour	50.2	Lbs.
Output of -200 mesh material	22.7	Lbs.
Mechanical Value of Discharge	344.2	S.U
Mechanical Value of Feed	3.2	S.U
Work done per Ton	341.0	S.U
Feed Rate - 24 Hours	0.864	Tons
Total Work done per 24 Hours	295	S.U.
Power expended	0.63	H.P.
P.M.E. or Work done per H.P. per 24 Hours	468	S.U
Nett	720	

Mean P.M.E. 398

Nett " " 567

Date Ball Mill Test No. 3

Grade	Feed %	Feed 1/D	Feed S.U.	A Discharge %	A Discharge 1/D	A Discharge S.U.	B Discharge %	B Discharge 1/D	B Discharge S.U.	Grade
				0.8	4	..	0.8		..	+ 3
				0.3	7	..	0.2		..	5
				0.2	9	..	0.2		..	6
				0.6	11	0.1	0.7		0.1	8
+ 10				1.7	14	0.2	1.5		0.2	10
14				2.3	20	0.5	2.3		0.5	14
20				3.3	30	1.0	2.9		0.9	20
28				4.9	40	2.0	4.9		2.0	28
35				8.4	60	5.0	8.6		5.2	35
48				8.4	80	6.7	8.9		7.1	48
65				10.8	120	13.0	11.1		13.3	65
100				10.7	170	18.2	10.6		18.0	100
150				11.1	240	26.6	11.1		26.6	150
200				5.8	330	19.1	5.9		19.5	200
-200				30.7	800	245.5	30.3		242.4	-200
Total				100.0		337.9	100.0		335.8	Total
				-48% = 69.0						

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	26.8	%
Moisture in Feed	73.2	%
Output of -48 mesh material per Hour	45.5	Lbs.
Output of -200 mesh material	20.0	Lbs.
Mechanical Value of Discharge	335.8	S.U
Mechanical Value of Feed	3.2	S.U.
Work done per Ton	332.6	S.U
Feed Rate - 24 Hours	0.792	Tons
Total Work done per 24 Hours	263	S.U.
Power expended	0.680	H.P.
P.M.E. or Work done per H.P. per 24 Hours	387	S.U
Nett	572	
Mean R.M.E.	356	
Nett " "	503	

Date   Ball Mill Test No. 4.

	Feed			A. Discharge			B. Discharge			
Grade	%	I/D	S.U	%	I/D	S.U.	%	I/D	S.U.	Grade
				1.8	4	0.1	1.8		0.1	+ 3
				0.5	7	..	0.7		..	5
				0.7	9	0.1	0.6		0.1	6
				1.5	11	0.2	1.6		0.2	8
+ 10				2.6	14	0.4	2.7		0.4	10
14				4.3	20	0.9	4.1		0.8	14
20				5.7	30	1.7	5.3		1.6	20
28				8.0	40	3.2	7.6		3.0	28
35				11.4	60	6.8	10.8		6.4	35
48				9.9	80	7.9	9.5		7.6	48
65				10.6	120	12.7	10.4		12.5	65
100				8.6	170	14.6	8.8		15.0	100
150				8.7	240	20.9	8.5		20.4	150
200				4.3	330	14.2	4.2		13.9	200
-200				21.4	800	171.2	23.4		187.2	-200
Total				100.0		254.9	100.0		269.2	Total
					-48 %	= 55.3				

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	21.4	%
Moisture in Feed	78.6	%
Output of -48 mesh material per Hour	54.6	Lbs.
Output of -200 mesh material	23.2	Lbs.
Mechanical Value of Discharge	269.2	S.U
Mechanical Value of Feed	3.2	S.U.
Work done per Ton	266.0	S.U
Feed Rate - 24 Hours	1.188	Tons
Total Work done per 24 Hours	316.0	S.U.
Power expended	0.70	H.P.
P.M.E. or Work done per H.P. per 24 Hours	452	S.U
Nett	658	
Mean P.M.E.	427	
Nett " "	607.	

Date   Ball Mill Test No. 5

Grade	Feed %	Feed 1/D	Feed S.U.	A Discharge %	A Discharge 1/D	A Discharge S.U.	B Discharge %	B Discharge 1/D	B Discharge S.U.	Grade
				9.2	4	0.4	9.2		0.4	+ 3
				2.5	7	0.24	2.6		0.2	5
				2.5	9	0.2	2.4		0.2	6
				4.5	11	0.5	5.0		0.6	8
+ 10				6.2	14	0.9	6.1		0.9	10
14				7.8	20	1.6	7.8		1.6	14
20				7.5	30	2.3	7.4		2.2	20
28				8.5	40	3.4	8.5		3.4	28
35				9.7	60	5.8	9.3		5.6	35
48				7.1	80	5.7	7.0		5.6	48
65				6.9	120	8.3	7.0		8.4	65
100				5.7	170	9.7	5.7		9.7	100
150				5.4	240	13.0	5.5		13.2	150
200				2.9	330	9.6	2.9		9.6	200
-200				13.6	800	108.8	13.6		108.8	-200
Total				100.0		170.4	100.0		170.4	Total
					- 48 = 34.7%					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	22.2	%
Moisture in Feed	77.8	%
Output of -48 mesh material per Hour	53.5	Lbs.
Output of -200 mesh material	20.95	Lbs.
Mechanical Value of Discharge	170.4	S.U
Mechanical Value of Feed	3.2	S.U.
Work done per Ton	167.2	S.U
Feed Rate - 24 Hours	1.882	Tons
Total Work done per 24 Hours	310	S.U.
Power expended	0.64	H.P.
R.M.E. or Work done per H.P. per 24 Hours	484	S.U
Nett	738	
Mean R.M.E.	419	
Nett " "	596	

Date Ball Mill Test No. 6.

Grade	Feed %	Feed 1/D	Feed S.U.	A Discharge %	A Discharge 1/D	A Discharge S.U.	B Discharge %	B Discharge 1/D	B Discharge S.U.	Grade
				19.5	4	0.7	19.5		0.8	+ 3
				5.0	7	0.4	5.3		0.4	5
				4.2	9	0.4	4.8		0.4	6
				7.6	11	0.8	7.0		0.8	8
+ 10				5.3	14	0.7	7.2		1.0	10
14				8.0	20	1.6	7.8		1.6	14
20				6.6	30	2.0	6.5		2.0	20
28				6.9	40	2.8	6.4		2.6	28
35				7.1	60	4.3	6.5		3.9	35
48				5.0	80	4.0	4.6		3.7	48
65				5.0	120	6.0	4.5		5.4	65
100				4.4	170	7.5	3.9		6.6	100
150				4.1	240	9.8	3.6		8.6	150
200				2.3	330	7.6	1.9		6.3	200
-200				11.0	800	88.0	10.4		83.2	-200
Total				100.0		136.6	100.0		127.3	Total
					-48	= 24.3%				

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	19.5	%
Moisture in Feed	80.5	%
Output of -48 mesh material per Hour	42.3	Lbs.
Output of -200 mesh material	18.1	Lbs.
Mechanical Value of Discharge	127.3	S.U
Mechanical Value of Feed	3.2	S.U.
Work done per Ton	124.1	S.U
Feed Rate - 24 Hours	2.085	Tons
Total Work done per 24 Hours	259	S.U.
Power expended	0.69	H.P.
P.H.E. or Work done per H.P. per 24 Hours	375	S.U
Nett	551	

Mean R.M.E. 350

Nett " " 498

Date Ball Mill Test No. 7

	Feed			A Discharge			B Discharge			
Grade	%	1/D	S.U	%	1/D	S.U.	%	1/D	S.U.	Grade
				0.1	4	..	0.1		..	+ 3
				0.1	7	..	0.1		..	5
				0.1	9	..	0.1		..	6
				0.4	11	..	0.4		0.1	8
+ 10				1.0	14	0.1	0.8		0.1	10
14				1.5	20	0.3	1.6		0.3	14
20				2.3	30	0.7	2.2		0.7	20
28				3.9	40	1.6	3.7		1.5	28
35				7.8	60	4.7	7.6		4.6	35
48				8.5	80	6.8	8.1		6.5	48
65				10.8	120	13.0	10.6		12.7	65
100				10.8	170	18.3	10.9		18.5	100
150				11.2	240	26.9	11.2		26.9	150
200				6.0	330	19.8	5.8		19.3	200
-200				35.5	800	284.0	36.8		294.4	-200
Total				100.0		376	100.0		385.5	Total
				-48	-48 =	75.3%				

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	57.4	%
Moisture in Feed	42.6	%
Output of -48 mesh material per Hour	52.4	Lbs.
Output of -200 mesh material	25.6	Lbs.
Mechanical Value of Discharge	385.5	S.U
Mechanical Value of Feed	5.1	S.U.
Work done per Ton	380.4	S.U
Feed Rate - 24 Hours	0.835	Tons
Total Work done per 24 Hours	318	S.U.
Power expended	0.83	H.P.
P.M.E. or Work done per H.P. per 24 Hours	383	S.U
Nett	522	

Mean P.M.E. 430

Nett " " 611

Date Ball Mill Test No. 8

	Feed			A Discharge			B Discharge			
Grade	%	I/D	S.U.	%	I/D	S.U.	%	I/D	S.U.	Grade
				0.0	4	..	0.0		..	+ 3
				0.1	7	..	0.1		..	5
				0.2	9	..	0.2		..	6
				0.8	11	0.1	0.9		0.1	8
+ 10				1.0	14	0.1	1.2		0.1	10
14				2.8	20	0.6	2.7		0.5	14
20				3.8	30	1.1	3.9		1.2	20
28				6.5	40	2.6	6.3		2.5	28
35				11.3	60	6.8	10.9		6.5	35
48				10.3	80	8.2	10.0		8.0	48
65				11.3	120	13.6	10.9		13.1	65
100				9.7	170	16.5	9.9		16.8	100
150				9.5	240	22.8	9.4		22.8	150
200				5.1	330	16.8	5.0		16.5	200
-200				27.6	800	220.8	28.6		228.6	-200
Total				100.0		310.0	100.0		316.5	Total
				-48 =	65.8 %					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M.
Solids in Feed	51.2	%
Moisture in Feed	48.8	%
Output of -48 mesh material per Hour	61.3	Lbs.
Output of -200 mesh material	27.5	Lbs.
Mechanical Value of Discharge	316.5	S.U.
Mechanical Value of Feed	5.1	S.U.
Work done per Ton	311.4	S.U.
Feed Rate – 24 Hours	1.15	Tons
Total Work done per 24 Hours	358.0	S.U.
Power expended	0.71	H.P.
R.M.E. or Work done per H.P. per 24 Hours	504.9	S.U.
Nett	731	

Mean R.M.E. 484

Nett " " 689

Date

Ball Mill Test No. 9

	Feed			A Discharge			B Discharge			
Grade	%	1/D	S.U.	%	1/D	S.U.	%	1/D	S.U.	Grade
				0.1	4	..	0.2		..	+ 3
				0.3	7	..	0.3		..	5
				0.3	9	..	0.2		..	6
				0.7	11	0.1	0.7		0.1	8
+ 10				1.3	14	0.2	1.3		0.2	10
14				2.6	20	0.5	2.3		0.5	14
20				3.7	30	1.1	3.7		1.1	20
28				5.7	40	2.3	6.0		2.4	28
35				10.1	60	6.1	10.0		6.0	35
48				9.7	80	7.8	9.8		7.8	48
65				11.5	120	13.8	11.3		13.6	65
100				10.4	170	17.7	10.3		17.5	100
150				10.2	240	24.5	10.2		24.5	150
200				5.5	330	18.1	5.1		16.8	200
-200				27.9	800	223.0	28.6		228.6	-200
Total				100.0		315.2	100.0		319.1	Total
					-48 =	65.5%				

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	32.2	%
Moisture in Feed	67.8	%
Output of -48 mesh material per Hour	55.9	Lbs.
Output of -200 mesh material	24.4	Lbs.
Mechanical Value of Discharge	319.1	S.U
Mechanical Value of Feed	5.1	S.U.
Work done per Ton	314.0	S.U
Feed Rate - 24 Hours	1.026	Tons
Total Work done per 24 Hours	322.0	S.U.
Power expended	0.78	H.P.
P.M.E. or Work done per H.P. per 24 Hours	413	S.U
Nett	575	

Mean R.M.E. 435

Nett " " 620

Date Ball Mill Test No. 10

Grade	Feed %	Feed I/D	Feed S.U.	A Discharge %	A Discharge I/D	A Discharge S.U.	B Discharge %	B Discharge I/D	B Discharge S.U.	Grade
				0.9	4	..	0.6		..	+ 3
				1.2	7	0.1	1.1		0.1	5
				1.0	9	0.1	0.9		0.1	6
				2.2	11	0.2	2.5		0.3	8
+ 10				3.6	14	0.5	3.5		0.5	10
14				6.6	20	1.3	6.9		1.4	14
20				7.4	30	2.2	7.8		2.3	20
28				9.9	40	4.0	10.0		4.0	28
35				12.4	60	7.4	12.4		7.4	35
48				9.4	80	7.5	9.5		7.6	48
65				9.1	120	10.9	9.3		11.1	65
100				7.7	170	13.1	7.4		12.6	100
150				7.1	240	17.0	7.0		16.8	150
200				3.2	330	10.6	3.4		11.2	200
-200				18.3	800	146.4	17.7		141.8	-200
Total				100.0		221.3	100.0		217.2	Total
					- 48 = 44.8%					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	26	%
Moisture in Feed	74	%
Output of -48 mesh material per Hour	62.0	Lbs.
Output of -200 mesh material	24.4	Lbs.
Mechanical Value of Discharge	217.2	S.U
Mechanical Value of Feed	5.1	S.U.
Work done per Ton	212.1	S.U
Feed Rate - 24 Hours	1.655	Tons
Total Work done per 24 Hours	351.0	S.U.
Power expended	0.76	H.P.
P.M.E. or Work done per H.P. per 24 Hours	462	S.U
Nett	651	

Mean R.M.E. 474

Nett " " 675

Date   Ball Mill Test No. 11

	Feed			A Discharge			B Discharge			
Grade	%	1/D	S.U.	%	1/D	S.U.	%	1/D	S.U.	Grade
				1.9	4	0.1	2.2		0.1	+ 3
				2.9	7	0.2	2.8		0.2	5
				2.1	9	0.2	2.2		0.2	6
				4.3	11	0.5	4.5		0.5	8
+ 10				6.6	14	0.9	6.2		0.9	10
14				9.2	20	1.8	9.2		1.8	14
20				9.4	30	2.8	9.6		2.9	20
28				10.8	40	4.3	10.8		4.3	28
35				11.4	60	6.8	11.2		6.7	35
48				7.9	80	6.3	7.8		6.2	48
65				7.4	120	8.9	7.3		8.8	65
100				5.6	170	9.5	5.7		9.7	100
150				5.3	240	12.7	5.2		12.5	150
200				2.8	330	9.2	2.8		9.2	200
-200				12.4	800	99.3	12.5		100.0	-200
Total				100.0		168.5	100.0		164.0	Total
				-48 = 33.5%						

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	26.1	%
Moisture in Feed	73.9	%
Output of -48 mesh material per Hour	61.7	Lbs.
Output of -200 mesh material	23.0	Lbs.
Mechanical Value of Discharge	164.0	S.U
Mechanical Value of Feed	5.1	S.U.
Work done per Ton	158.9	S.U
Feed Rate - 24 Hours	2.21	Tons
Total Work done per 24 Hours	351	S.U.
Power expended	0.72	H.P.
P.M.E. or Work done per H.P. per 24 Hours	486	S.U
Nett	702	
Mean P.M.E.	474	
Nett " "	675	

Date

Ball Mill Test No. 12

Grade	Feed %	Feed 1/D	Feed S.U.	A Discharge %	A Discharge 1/D	A Discharge S.U.	B Discharge %	B Discharge 1/D	B Discharge S.U.	Grade
				9.2	4	0.4	10.9		0.4	+ 3
				8.9	7	0.6	9.9		0.6	5
				6.5	9	0.6	7.0		0.6	6
				12.2	11	1.3	10.9		1.2	8
+ 10				11.0	14	1.5	11.2		1.6	10
14				11.1	20	2.2	10.3		2.1	14
20				7.4	30	2.2	7.2		2.2	20
28				6.5	40	2.6	6.5		2.4	28
35				5.9	60	3.5	5.9		3.5	35
48				3.9	80	3.1	3.9		3.1	48
65				3.5	120	4.2	3.5		4.2	65
100				2.8	170	4.8	2.8		4.8	100
150				2.5	240	6.0	2.6		6.2	150
200				1.5	330	5.0	1.4		4.6	200
-200				7.1	800	56.8	6.9		55.2	-200
Total				100.0		94.8	100.0		92.7	Total
					-48 =	17.2%				

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	26.4	%
Moisture in Feed	73.6	%
Output of -48 mesh material per Hour	44.83	Lbs.
Output of -200 mesh material	17.8	Lbs.
Mechanical Value of Discharge	92.7	S.U
Mechanical Value of Feed	5.1	S.U.
Work done per Ton	87.6	S.U
Feed Rate - 24 Hours	3.095	Tons
Total Work done per 24 Hours	271.4	S.U.
Power expended	0.77	H.P.
P.M.E. or Work done per H.P. per 24 Hours	352	S.U
Nett	493	
Mean R.M.E.	366	
Nett "	522	

Date Ball Mill Test No. 13

Grade	Feed %	I/D	S.U	A Discharge %	I/D	S.U.	B Discharge %	I/D	S.U.	Grade
				7.4	4	0.3	10.1		0.4	+ 3
				10.8	7	0.7	9.1		0.6	5
				7.3	9	0.7	7.3		0.7	6
				12.0	11	1.3	11.3		1.2	8
+ 10				11.2	14	1.6	10.6		1.5	10
14				10.7	20	2.1	10.6		2.1	14
20				7.9	30	2.4	7.8		2.3	20
28				7.1	40	2.8	7.2		2.9	28
35				6.2	60	3.7	6.2		3.7	35
48				4.1	80	3.3	3.9		3.1	48
65				3.6	120	4.3	3.6		4.3	65
100				2.9	170	4.9	2.8		4.8	100
150				2.5	240	6.0	2.6		6.2	150
200				1.3	330	4.3	1.3		4.3	200
-200				5.0	800	40.0	5.6		44.8	-200
Total				100.0		78.4	100.0		82.9	Total
					-48 =	15.9%				

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	24.9	%
Moisture in Feed	75.1	%
Output of -48 mesh material per Hour	48.8	Lbs
Output of -200 mesh material	17.22	Lbs.
Mechanical Value of Discharge	82.9	S.U
Mechanical Value of Feed	5.1	S.U
Work done per Ton	77.8	S.U
Feed Rate - 24 Hours	3.690	Tons
Total Work done per 24 Hours	287.4	S.U.
Power expended	0.83	H.P.
R.M.E. or Work done per H.P. per 24 Hours	346	S.U
Nett	471	

Mean R.M.E. 388

Nett " " 553

Date

Ball Mill Test No. 14.

	Feed			A Discharge			B Discharge			
Grade	%	1/D	S.U.	%	1/D	S.U.	%	1/D	S.U.	Grade
				0.0	4		0.0			+ 3
				0.0	7		0.0			5
				0.3	9		0.2			6
				0.7	11	0.1	0.8		0.1	8
+ 10				1.4	14	0.2	1.2		0.2	10
14				2.2	20	0.4	2.3		0.5	14
20				3.2	30	1.0	3.4		1.0	20
28				5.7	40	2.3	5.6		2.2	28
35				10.0	60	6.0	10.1		6.0	35
48				9.7	80	7.8	9.9		7.9	48
65				11.3	120	13.6	11.1		13.3	65
100				10.5	170	17.8	10.5		17.8	100
150				10.3	240	24.8	9.9		23.8	150
200				5.4	330	17.8	6.5		18.2	200
−200				29.3	800	234.4	29.5		236.0	−200
Total				100.0		326.2			327	Total
				-48 = 66.5%						

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	41.7	%
Moisture in Feed	58.3	%
Output of −48 mesh material per Hour	57.2	Lbs.
Output of −200 mesh material	25.4	Lbs.
Mechanical Value of Discharge	327	S.U
Mechanical Value of Feed	8.8	S.U.
Work done per Ton	318.2	S.U
Feed Rate – 24 Hours	1.032	Tons
Total Work done per 24 Hours	328.5	S.U.
Power expended	0.73	H.P.
R.M.E. or Work done per H.P. per 24 Hours	450	S.U
Nett	644	

Mean R.M.E. 444

Nett " " 632

Date Ball Mill Test No. 15.

Grade	Feed %	Feed 1/D	Feed S.U.	A Discharge %	A Discharge 1/D	A Discharge S.U.	B Discharge %	B Discharge 1/D	B Discharge S.U.	Grade
				0.0	4	..	0.0		..	+ 3
				0.2	7	..	0.2		..	5
				1.1	9	0.1	0.9		0.1	6
				2.3	11	0.2	1.9		0.2	8
+ 10				2.5	14	0.4	3.1		0.4	10
14				5.7	20	1.1	6.2		1.2	14
20				7.9	30	2.4	7.7		2.3	20
28				10.5	40	4.2	10.9		4.4	28
35				13.1	60	7.9	12.8		7.7	35
48				9.8	80	7.8	9.6		7.7	48
65				9.1	120	10.9	9.3		11.2	65
100				7.7	170	13.1	7.5		12.8	100
150				7.0	240	16.8	6.8		16.3	150
200				3.7	330	12.2	3.7		12.2	200
-200				19.4	800	155.2	19.4		155.2	-200
Total				100.0		232.3	100.0		231.7	Total
					-48 = 46.7%					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	39.4	%
Moisture in Feed	60.6	%
Output of -48 mesh material per Hour	69.3	Lbs.
Output of -200 mesh material	28.7	Lbs.
Mechanical Value of Discharge	231.7	S.U
Mechanical Value of Feed +8	8.8	S.U.
Work done per Ton	222.9	S.U
Feed Rate - 24 Hours	1.775	Tons
Total Work done per 24 Hours	3962	S.U.
Power expended	0.74	H.P.
P.M.E. or Work done per H.P. per 24 Hours	535	S.U
Nett	762	

Mean R.M.E. 535

Nett " " 762

Date

Ball Mill Test No. 187

Grade	Feed %	Feed 1/D	Feed S.U.	A Discharge %	A Discharge 1/D	A Discharge S.U.	B Discharge %	B Discharge 1/D	B Discharge S.U.	Grade
				0.0	4	..	0.0		...	+ 3
				1.0	7	..	0.8		..	5
				3.2	9	...	2.9		....	6
				5.7	11	0.1	5.7		0.1	8
+ 10				7.7	14	1.1	8.3		1.2	10
14				11.9	20	2.4	12.0		2.4	14
20				11.6	30	3.5	11.1		3.3	20
28				11.0	40	4.4	11.2		4.5	28
35				10.5	60	6.3	10.5		6.3	35
48				6.9	80	5.5	7.0		5.6	48
65				6.3	120	7.6	6.3		7.6	65
100				5.1	170	8.7	5.0		8.0	100
150				4.5	240	10.8	4.4		10.6	150
200				2.5	330	8.3	2.5		8.3	200
-200				12.1	800	96.8	12.3		98.4	-200
Total				100.0		165.5	100.0		156.3	Total
					-48 = 30.5%					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	37.9	%
Moisture in Feed	62.1	%
Output of -48 mesh material per Hour	65.8	Lbs.
Output of -200 mesh material	26.6	Lbs.
Mechanical Value of Discharge	156.3	S.U
Mechanical Value of Feed	8.8	S.U
Work done per Ton	147.5	S.U
Feed Rate - 24 Hours	2.591	Tons
Total Work done per 24 Hours	382	S.U.
Power expended	0.73	H.P.
P.M.E. or Work done per H.P. per 24 Hours	523	S.U
Nett	749	
Mean P.M.E.	516	
Nett " "	735	

Date . Ball Mill Test No. 17

Grade	Feed %	Feed I/D	Feed S.U	A. Discharge %	A. Discharge I/D	A. Discharge S.U.	B. Discharge %	B. Discharge I/D	B. Discharge S.U.	Grade
				0.0	4	. .	0.0		. .	+ 3
				0.0	7	. .	0.1		. .	5
				0.3	9	. .	0.3		. .	6
				0.8	11	0.1	0.8		0.1	8
+ 10				1.4	14	0.2	1.2		0.2	10
14				2.1	20	0.4	2.3		0.5	14
20				3.2	30	1.0	3.2		1.0	20
28				5.7	40	2.3	5.7		2.3	28
35				10.2	60	6.0	10.1		6.0	35
48				9.7	80	7.8	10.0		8.0	48
65				11.6	120	13.2	11.6		13.9	65
100				10.8	170	18.4	10.7		18.2	100
150				10.5	240	25.2	10.2		24.5	150
200				5.4	330	17.8	5.3		17.5	200
-200				28.3	880	226.1	28.5		228.0	-200
Total				100.0		318.5	100.0		320.2	Total
					-48 = 66.3%					

Ball Load	297	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	32.2	%
Moisture in Feed	67.8	%
Output of -48 mesh material per Hour	55.7	Lbs.
Output of -200 mesh material	23.9	Lbs.
Mechanical Value of Discharge	320.2	S.U
Mechanical Value of Feed	8.8	S.U.
Work done per Ton	311.4	S.U
Feed Rate - 24 Hours	1.009	Tons
Total Work done per 24 Hours	313.9	S.U.
Power expended	0.84	H.P.
P.M.E. or Work done per H.P. per 24 Hours	373	S.U
Nett	506	
Mean R.M.E.	424	
Nett " "	603	

Date

Ball Mill Test No. 18.

	Feed			A. Discharge			B. Discharge			
Grade	%	1/D	S.U.	%	1/D	S.U.	%	1/D	S.U.	Grade
				0.0	4		0.0			+ 3
				0.2	7		0.2			5
				0.8	9	0.1	0.8		0.1	6
				2.2	11	0.2	2.2		0.2	8
+ 10				2.8	14	0.4	2.8		0.4	10
14				5.0	20	1.0	5.5		1.1	14
20				6.6	30	2.0	7.0		2.1	20
28				10.0	40	4.0	10.7		4.3	28
35				13.5	60	8.1	13.3		8.0	35
48				10.5	80	8.4	10.1		8.1	48
65				10.3	120	12.4	9.9		11.9	65
100				8.5	170	14.5	8.2		13.9	100
150				7.6	240	18.2	7.3		17.5	150
200				4.0	330	13.2	3.7		12.2	200
-200				18.0	800	144.0	18.3		146.4	-200
Total				100.0		226.5	100.0		226.2	Total
					-48 = 47.4%					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M.
Solids in Feed	27.9	%
Moisture in Feed	72.1	%
Output of -48 mesh material per Hour	65.4	Lbs.
Output of -200 mesh material	25.2	Lbs.
Mechanical Value of Discharge	226.2	S.U
Mechanical Value of Feed	8.8	S.U.
Work done per Ton	217.4	S.U
Feed Rate - 24 Hours	1.656	Tons
Total Work done per 24 Hours	360	S.U.
Power expended	0.79	H.P.
P.M.E. or Work done per H.P. per 24 Hours	456	S.U
Nett	632	
Mean R.M.E.	486	
Nett " "	692	

Date

Ball Mill Test No. 19.

Grade	Feed %	Feed I/D	Feed S.U.	A. Discharge %	A. Discharge I/D	A. Discharge S.U.	B. Discharge %	B. Discharge I/D	B. Discharge S.U.	Grade
				...	4	..	..		..	+ 3
				0.5	7	..	0.4		..	5
				1.7	9	0.2	1.8		0.2	6
				3.7	11	0.4	4.1		0.5	8
+ 10				5.3	14	0.7	5.0		0.7	10
14				8.5	20	1.7	8.6		1.7	14
20				9.5	30	2.9	10.3		3.1	20
28				11.5	40	4.6	12.7		4.8	28
35				12.8	60	7.7	12.8		7.7	35
48				8.9	80	7.1	8.8		7.0	48
65				8.1	120	9.7	8.1		9.7	65
100				6.7	170	11.4	6.5		11.1	100
150				5.7	240	13.7	5.6		13.4	150
200				3.0	330	9.9	3.0		9.9	200
-200				14.1	800	112.8	12.9		103.2	-200
Total				100.0		182.8	100.0		173.0	Total
					-48 = 36.1%					

Ball Load	2097	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	27.2	%
Moisture in Feed	72.8	%
Output of -48 mesh material per Hour	68.1	Lbs.
Output of -200 mesh material	24.4	Lbs.
Mechanical Value of Discharge	173.0	S.U
Mechanical Value of Feed	8.8	S.U
Work done per Ton	164.2	S.U
Feed Rate - 24 Hours	2.266	Tons
Total Work done per 24 Hours	372	S.U.
Power expended	0.74	H.P.
P.M.E. or Work done per H.P. per 24 Hours	503	S.U
Nett	715	

Mean P.M.E. 503

Nett " " 715.

Date Ball Mill Test No. 220

	Feed			A Discharge			B. Discharge			
Grade	%	1/D	S.U	%	1/D	S.U.	%	1/D	S.U.	Grade
				0.0	4	..	0.8		..	+ 3
				1.4	7	0.2	1.1		0.1	5
				4.0	9	0.4	4.3		0.4	6
				7.7	11	0.8	8.9		0.9	8
+ 10				9.2	14	1.3	10.6		1.5	10
14				12.7	20	2.5	13.4		2.7	14
20				11.3	30	3.4	11.5		3.5	20
28				11.1	40	4.4	11.0		4.4	28
35				10.1	60	6.1	9.9		5.9	35
48				6.6	80	5.3	6.2		5.0	48
65				5.9	120	7.1	5.3		6.4	65
100				4.6	170	7.8	4.2		7.1	100
150				3.9	240	9.4	3.7		8.9	150
200				2.0	330	6.6	2.0		6.6	200
-200				9.5	800	76.0	7.9		63.2	-200
Total				100.0		131.23	100.0		116.6	Total
				+48 = 23.1%						

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	26.5	%
Moisture in Feed	73.5	%
Output of -48 mesh material per Hour	59.6	Lbs.
Output of -200 mesh material	20.4	Lbs.
Mechanical Value of Discharge	116.6	S.U
Mechanical Value of Feed	8.8	S.U.
Work done per Ton	107.8	S.U
Feed Rate - 24 Hours	3.096	Tons
Total Work done per 24 Hours	333.0	S.U.
Power expended	0.72	H.P.
P.M.E. or Work done per H.P. per 24 Hours	462	S.U
Nett	666	
Mean P.M.E.	450	
Nett " "	641	

Date Ball Mill Test No. 21.

	Feed			A. Discharge			B. Discharge			
Grade	%	1/D	S.U.	%	1/D	S.U.	%	1/D	S.U.	Grade
				1.1	4	..	0.8		..	+ 3
				3.4	7	0.2	4.3		0.3	5
				11.9	9	1.1	13.0		1.2	6
				21.2	11	2.3	19.2		2.1	8
+ 10				15.8	14	2.2	14.2		2.0	10
14				12.5	20	2.5	14.0		2.8	14
20				8.4	30	2.5	8.6		2.6	20
28				6.7	40	2.7	6.7		2.7	28
35				5.2	60	3.1	5.4		3.2	35
48				3.2	80	2.6	3.3		2.6	48
65				2.7	120	3.2	2.8		3.4	65
100				2.0	170	3.4	2.1		3.6	100
150				1.7	240	4.1	1.8		4.3	150
200				0.9	330	3.0	0.9		3.0	200
-200				3.3	800	26.4	2.9		23.2	-200
Total				100.0		59.3	100.0		57.0	Total
				-48 = 10.5%						

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	28.3	%
Moisture in Feed	71.7	%
Output of -48 mesh material per Hour	47.25	Lbs.
Output of -200 mesh material	13.05	Lbs.
Mechanical Value of Discharge	57.0	S.U
Mechanical Value of Feed	8.8	S.U.
Work done per Ton	48.2	S.U
Feed Rate - 24 Hours	5.4	Tons
Total Work done per 24 Hours	259.2	S.U.
Power expended	0.71	H.P.
P.M.E. or Work done per H.P. per 24 Hours	365	S.U
Nett	530	

Mean R.M.E. 351

Nett " " 499

Date   Ball Mill Test No. 22.

	Feed			A	Discharge		B	Discharge		
Grade	%	1/D	S.U.	%	1/D	S.U.	%	1/D	S.U.	Grade
				0.0	4	..	0.0		..	+ 3
				0.0	7	..	0.0		..	5
				0.0	9	..	0.0		..	6
				0.2	11	..	0.2		..	8
+ 10				0.9	14	0.1	0.5		0.1	10
14				1.2	20	0.2	0.9		0.2	14
20				1.5	30	0.5	1.4		0.4	20
28				2.6	40	1.0	2.7		1.1	28
35				6.2	60	3.7	6.2		3.7	35
48				7.7	80	6.2	7.8		6.2	48
65				11.3	120	13.6	11.4		13.7	65
100				11.9	170	20.2	12.1		20.6	100
150				13.1	240	31.4	12.7		30.5	150
200				7.1	330	23.4	7.1		23.4	200
−200				36.3	800	290.0	36.6		292.8	−200
Total				100.0		390.3	100.0		392.7	Total
				−48 = 79.9%						

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	20.7	%
Moisture in Feed	79.3	%
Output of −48 mesh material per Hour	37.2	Lbs.
Output of −200 mesh material	17.0	Lbs.
Mechanical Value of Discharge	392.7	S.U
Mechanical Value of Feed +6	12.5	S.U
Work done per Ton	380.2	S.U
Feed Rate – 24 Hours	0.558	Tons
Total Work done per 24 Hours	212	S.U.
Power expended	0.84	H.P.
P.M.E. or Work done per H.P. per 24 Hours	252	S.U
Nett	342	
Mean P.M.E.	286	
Nett " "	408	

Date

Ball Mill Test No. 23.

Grade	Feed %	Feed 1/D	Feed S.U.	A. Discharge %	A. Discharge 1/D	A. Discharge S.U.	B. Discharge %	B. Discharge 1/D	B. Discharge S.U.	Grade
				0.0	4	..	0.0		..	+ 3
				0.0	7	..	0.0		..	5
				0.0	9	..	0.0		..	6
				0.6	11	0.1	0.6		0.1	8
+ 10				1.9	14	0.3	2.4		0.3	10
14				3.0	20	0.6	3.7		0.7	14
20				4.2	30	1.3	4.4		1.3	20
28				6.9	40	2.8	7.3		2.9	28
35				11.8	60	7.1	12.3		7.4	35
48				11.2	80	9.0	11.1		8.9	48
65				12.0	120	14.4	11.8		14.2	65
100				10.5	170	17.8	9.6		16.3	100
150				9.4	240	22.6	9.3		22.3	150
200				4.6	330	15.2	4.5		14.9	200
-200				23.9	800	191.2	23.0		184.0	-200
Total				100.0		282.4	100.0		273.3	Total

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	22.1	%
Moisture in Feed	77.9	%
Output of -48 mesh material per Hour	58.3	Lbs.
Output of -200 mesh material	23.5	Lbs.
Mechanical Value of Discharge	273.3	S.U
Mechanical Value of Feed	12.5	S.U.
Work done per Ton	260.8	S.U
Feed Rate - 24 Hours	1.223	Tons
Total Work done per 24 Hours	319	S.U.
Power expended	0.90	H.P.
R.M.E. or Work done per H.P. per 24 Hours	355	S.U
Nett	470	
Mean R.M.E.	431	
Nett " "	614	

Date Ball Mill Test No. 24.

Grade	Feed %	Feed 1/D	Feed S.U.	A Discharge %	A Discharge 1/D	A Discharge S.U.	B Discharge %	B Discharge 1/D	B Discharge S.U.	Grade
				0.0	4	..	0.0		....	+ 3
				0.0	7	...	0.0		...	5
				0.0	9	..	0.0		...	6
				1.6	11	0.2	1.6		0.2	8
+ 10				5.1	14	0.7	6.3		0.9	10
14				6.7	20	1.3	7.4		1.5	14
20				7.4	30	2.2	8.7		2.6	20
28				10.6	40	4.3	11.4		4.6	28
35				13.6	60	8.2	13.7		8.2	35
48				10.3	80	8.2	10.0		8.0	48
65				9.9	120	11.9	9.4		11.3	65
100				7.6	170	12.9	7.3		12.4	100
150				7.7	240	17.0	6.4		15.3	150
200				3.4	330	11.2	3.3		10.9	200
-200				16.7	800	133.6	14.5		116.0	-200
Total				100.0		211.7	100.0		191.9	Total
				-48 = 40.9%						

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	23.1	%
Moisture in Feed	76.9	%
Output of -48 mesh material per Hour	64.8	Lbs.
Output of -200 mesh material	23.0	Lbs.
Mechanical Value of Discharge	191.9	S.U
Mechanical Value of Feed	12.5	S.U
Work done per Ton	179.4	S.U
Feed Rate - 24 Hours	1.902	Tons
Total Work done per 24 Hours	341	S.U.
Power expended	0.76	H.P.
P.M.E. or Work done per H.P. per 24 Hours	450	S.U
Nett	632	
Mean P.M.E	461	
Nett " "	656	

Date Ball Mill Test No. 25.

	Feed			A. Discharge			B. Discharge			
Grade	%	1/D	S.U.	%	1/D	S.U.	%	1/D	S.U.	Grade
				0.0	4	..	0.0		..	+ 3
				0.0	7	..	0.0		..	5
				0.0	9	..	0.0		..	6
				2.3	11	0.3	2.5		0.3	8
+ 10				7.1	14	1.0	8.3		1.2	10
14				10.0	20	2.0	16.8		2.2	14
20				10.6	30	3.2	10.8		3.2	20
28				12.7	40	5.1	12.7		5.1	28
35				13.6	60	8.2	13.1		7.9	35
48				9.1	80	7.3	8.8		7.0	48
65				8.1	120	9.7	7.8		9.4	65
100				6.1	170	10.4	6.0		10.2	100
150				5.2	240	12.5	5.1		12.2	150
200				2.6	330	8.6	2.6		8.6	200
-200				12.6	800	100.7	11.5		92.0	-200
Total				100.0		169.0	100.0		159.3	Total

Ball Load	207	Lbs.
Mill Speed	42	R.P.M
Solids in Feed	22.4	%
Moisture in Feed	77.6	%
Output of -48 mesh material per Hour	69.3	Lbs.
Output of -200 mesh material	24.2	Lbs.
Mechanical Value of Discharge	159.3	S.U
Mechanical Value of Feed	12.5	S.U
Work done per Ton	146.8	S.U
Feed Rate - 24 Hours	2.526	Tons
Total Work done per 24 Hours	370	S.U.
Power expended	0.80	H.P.
R.M.E. or Work done per H.P. per 24 Hours	462	S.U
Nett	638	
Mean R.M.E.	500	
Nett " "	711	

Date Ball Mill Test No. 26.

Grade	Feed %	Feed 1/D	Feed S.U	A. Discharge %	A. Discharge 1/D	A. Discharge S.U.	B. Discharge %	B. Discharge 1/D	B. Discharge S.U.	Grade
				0.6	4	..	0.6		..	+ 3
				0.3	7	..	0.4		..	5
				0.5	9	..	0.5		..	6
				1.6	11	0.2	1.7		0.2	8
+ 10				4.0	14	0.6	3.4		0.5	10
14				6.6	20	1.3	6.4		1.3	14
20				8.1	30	2.4	7.6		2.3	20
28				10.6	40	4.2	10.1		4.0	28
35				12.9	60	7.7	13.1		7.9	35
48				10.0	80	8.0	10.0		8.0	48
65				9.4	120	11.3	9.8		11.8	65
100				8.0	170	13.6	8.0		13.6	100
150				7.2	240	17.3	7.4		17.8	150
200				3.6	330	11.9	3.5		11.6	200
−200				16.6	800	132.8	17.5		140.0	−200
Total				100.0		211.3	100.0		219.0	Total
					−48 = 46.2 %					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M.
Solids in Feed	35.7	%
Moisture in Feed	64.3	%
Output of −48 mesh material per Hour	63.7	Lbs.
Output of −200 mesh material	24.2	Lbs.
Mechanical Value of Discharge	219.0	S.U
Mechanical Value of Feed	7.4	S.U.
Work done per Ton	211.6	S.U
Feed Rate – 24 Hours	1.655	Tons
Total Work done per 24 Hours	349.0	S.U.
Power expended	0.70	H.P.
P.M.E. or Work done per H.P. per 24 Hours	499.0	S.U
Nett	727	

Mean P.M.E. 471

Nett " " 672

Date Ball Mill Test No. 27.

Grade	Feed %	Feed I/D	Feed S.U	A. Discharge %	A. Discharge I/D	A. Discharge S.U.	B. Discharge %	B. Discharge I/D.	B. Discharge S.U.	Grade
				1.5	4	0.1	1.8		0.1	+ 3
				1.0	7	0.1	1.6		0.1	5
				1.2	9	0.1	1.4		0.1	6
				3.6	11	0.4	3.4		0.4	8
+ 10				6.1	14	0.9	5.9		0.8	10
14				9.1	20	1.8	9.1		1.8	14
20				10.0	30	3.0	9.6		2.9	20
28				11.4	40	4.6	11.3		4.5	28
35				12.2	60	7.3	11.9		7.1	35
48				8.5	80	6.8	8.3		6.6	48
65				7.8	120	9.4	7.7		9.2	65
100				6.2	170	10.5	6.3		10.7	100
150				5.5	240	13.2	5.6		13.4	150
200				2.9	330	9.6	2.6		8.6	200
-200				13.0	800	104.0	14.0		112.0	-200
Total				100.0		171.8	100.0		178.3	Total
					-48 = 36.2					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M.
Solids in Feed	29.6	%
Moisture in Feed	70.4	%
Output of -48 mesh material per Hour	66.6	Lbs.
Output of -200 mesh material	25.8	Lbs.
Mechanical Value of Discharge	178.3	S.U
Mechanical Value of Feed	7.4	S.U.
Work done per Ton	170.9	S.U
Feed Rate - 24 Hours	2.212	Tons
Total Work done per 24 Hours	377.5	S.U.
Power expended	0.71	H.P.
P.M.E. or Work done per H.P. per 24 Hours	531	S.U
Nett	770	

Mean RME 510

Nett " " 725

Date Ball Mill Test No. 28

	Feed			A Discharge			B Discharge			
Grade	%	1/D	S.U.	%	1/D	S.U.	%	1/D	S.U.	Grade
				4.1	4	0.2	6.2		0.2	+ 3
				2.9	7	0.2	2.8		0.2	5
				4.3	9	0.4	4.5		0.4	6
				8.2	11	0.9	9.6		1.1	8
+ 10				10.6	14	1.5	11.3		1.6	10
14				12.2	20	2.5	12.4		2.5	14
20				9.7	30	2.9	9.2		2.8	20
28				9.2	40	3.7	8.9		3.6	28
35				8.6	60	5.2	8.2		4.9	35
48				5.6	80	4.5	5.1		4.1	48
65				5.0	120	6.0	4.7		5.7	65
100				3.9	170	6.6	3.7		6.3	100
150				3.6	240	8.6	3.3		7.9	150
200				1.9	330	6.3	1.7		5.6	200
-200				8.2	800	65.6	8.4		67.2	-200
Total				100.0		115.1	100.0		114.1	Total
					-48 = 21.8%					

Ball Load	207	Lbs.
Mill Speed	42	R.P.M.
Solids in Feed	31.0	%
Moisture in Feed	69.0	%
Output of -48 mesh material per Hour	57.5	Lbs.
Output of -200 mesh material	22.2	Lbs.
Mechanical Value of Discharge	114.1	S.U
Mechanical Value of Feed	7.4	S.U.
Work done per Ton	106.7	S.U
Feed Rate - 24 Hours	3.170	Tons
Total Work done per 24 Hours	337.9	S.U.
Power expended	0.77	H.P.
R.M.E. or Work done per H.P. per 24 Hours	438	S.U
Nett	614	

Mean R.M.E. 456

Nett " " 650

The Elutriation Tests

These tests were carried out by Mr. Harding assisted by the writer. The object was to establish a number which would be representative of the reciprocal of the diameter of -200 mesh. In order to obtain this number the -200 mesh product from a number of machines was classified into the following sizes:-

- 700, - 500, -300, -200 and oversize.

It was necessary to employ classification methods because the mechanical difficulties in making a wire mesh smaller than -200 are enormous and also there is the trouble due to clogging which is encountered in the actual screening.

That it is important to be able to determine of what -200 mesh consists can be readily understood by considering that, in working out the Relative Mean Efficiencies of a crushing machine, the most important factor is really the amount and relative value of -200 mesh produced. In order to find the reciprocal of the diameter which is the multiplier in the product (percentage x 1/D) it is necessary to find some means of ascertaining of what actual sizes -200 mesh is made. This has been attempted first by Richards in his determination of sizes of particles falling in water and again by H. Stadler in his work on elutriation. The latter method was the one used in this work and was as follows:- A glass tube as shewn in the accompanying blue print is fitted with a funnel and a bent outlet tube at the top, and an inlet tube for water at the bottom. The outlet tube was connected to a piezometer which when calibrated for different velocities gave an easy means of determining the flow of water. The inlet tube was connected to a constant head water tank.

The theory is as follows:- The cross-section area of the large tube can be determined fairly accurately by measuring the volume of water between two levels marked on the glass. Then the material which has been charged in through the funnel and accumulates at the bottom of the large tube and in the inlet pipe, is forced to rise a little distance or becomes well loosened up by the incoming water, but as the water rises with a constant velocity, through the section of the large tube that has already been calibrated, only those particles which are fine enough will be carried up. The coarser particles due to gravity fall. After allowing the water to run with this velocity until it is seen that no more material is coming over, the velocity is increased so that particles of a larger size will be carried over. This process is repeated until nothing but the oversize remains. This classification by a rising current depends on two laws which may be stated thus:

(a) The velocity of fall of roundish grains appreciably above 1.55 m.m. in diameter, when eddying resistance only is encountered is a constant multiple of the square root of the diameter of the grains, or

$$\text{Vel.} = C\sqrt{D(\delta - 1)}$$

where D = Diameter
δ = Specific gravity
and C = Constant
112 for SiO_2

(b) The velocity of fall of roundish grains appreciably below 1.55 m.m. in diameter when viscous resistance alone is encountered is a constant multiple of the square of the average diameter of the particle, or

$$\text{Vel.} = \frac{2}{9}\, g \left(\frac{\delta - 1}{s} \right) r^2$$

When δ is the specific gravity of the particle.
r " " radius of the particle.
and S " " coefficient of viscosity of water.

This is known as Stokes' Law.

(c) For particles about 1.55 m.m. in diameter which come under neither (a) nor (b) no definite law has been found to hold consistently. The velocity for particles of this size should be determined by actual experiment.

(d) For particles so small that they become colloidal, microscopic investigation by Perrin has shewn that they are in a state of continuous erraetic motion (called Brownian Movement) similar in all respects to the motion of gaseous molecules, for which average velocity, mean free path, number per cubic centimeter, rate of diffusion, etc., are determinable by the Kinetic theory of matter.

(References - "Kinetic Theory of Gases", Jeans)
("General Physics" - Edser)

Now the velocities were calculated which would carry over particles of diameters to correspond to -200, -300, -500 and -700 mesh - these velocities are tabulated below.

The material which was collected at one velocity was allowed to settle and finally filtered on weighed filter papers. These were dried and the weight of material ascertained. In this way it was possible to examine the product of different machines to find out of what the -200 mesh material was composed.

In general it would appear that the nature of the -200 mesh for tinguaite was independent of the machine in which it was crushed. That is to say, [redacted] the crushing, whether it be in the Comet, ball mill or rolls, produces the same quality of -200 mesh.

Furthermore, it would appear that in dealing with tinguaite thus crushed one is dealing with the constituent minerals but as these are approximately of the same size and with no great differences in specific gravities there evidently is little classification according to minerals.

Minerals present	Specific Gravities
Orthoclase	2.5
Nepheline	3.2
Hornblende	2.9
Pyroxene	3.2
Aegirine Augite	3.2
Hauyne) Sphene)	3.4
Epidote	3.2
Iron Ore	5.0 (very little of this)

Table of Mesh, Velocities and Diameters

Mesh	Vel. m.m./sec.	Average Diam. of grains m.m.	Inches	1/D
200	3.94	0.0781	0.00308	325
300	1.58	0.0485	0.00191	524
500	0.619	0.0281	0.00111	904
700	0.245	0.0100	0.000394	2540

Table of the Results of Elutriation Tests

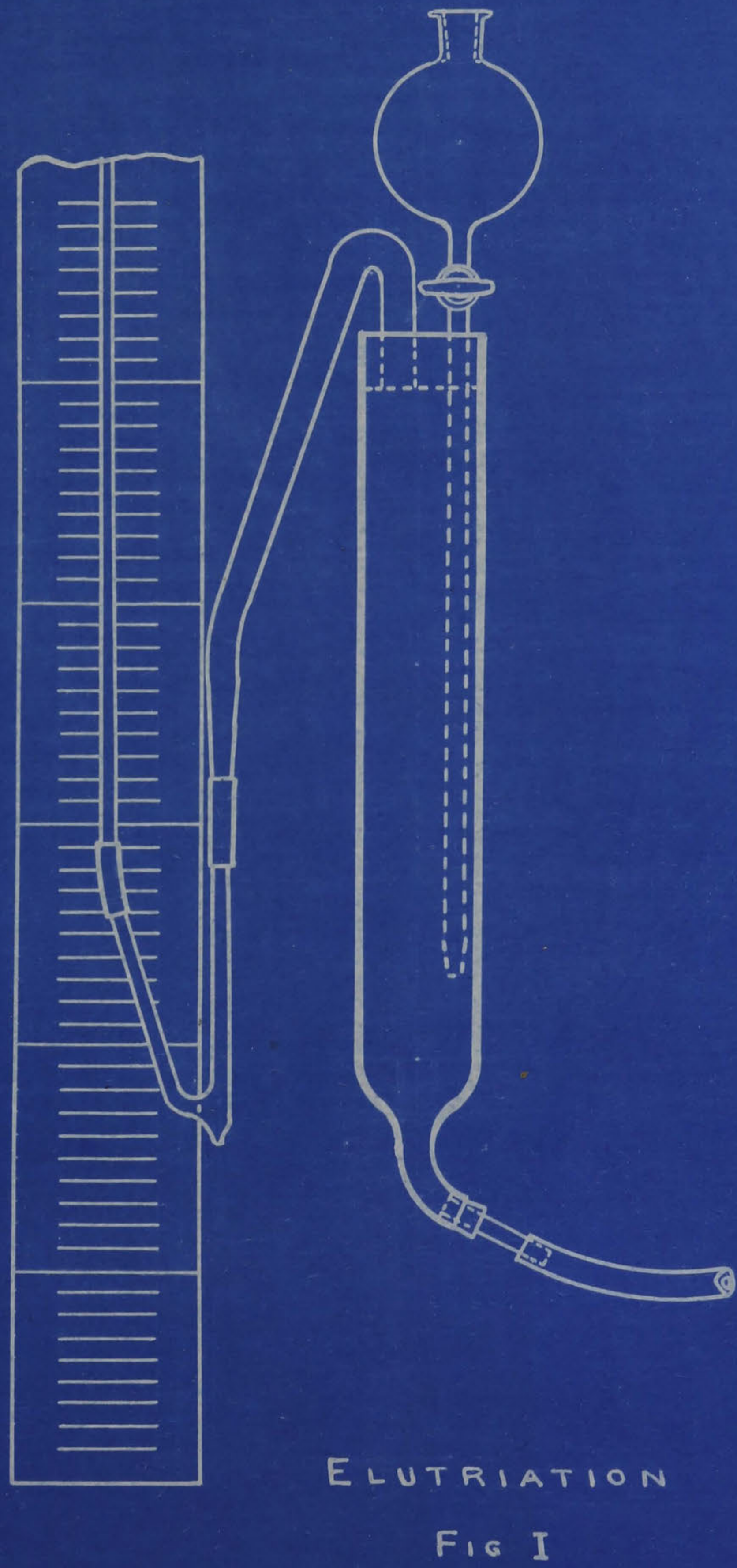
Mesh	I.	II.	III.	IV.	V.	VI.	VII.
Over-size	5.5	3.5	4.5	13.5	12.5	12.75	6.75
200	24.0	23.0	25.0	14.0	7.0	8.0	7.0
300	22.0	23.0	25.0	13.0	11.0	17.0	9.0
500	12.0	13.0	15.0	19.0	11.0	18.0	17.0
700	36.0	37.0	30.0	40.0	58.0	43.5	60.0
loss	0.5	0.5	0.5	0.5	0.5	0.75	0.25
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

I =	-200 mesh product	Tinguaite	4 inch diam. Comet Crusher			
II =	" " "	"	Ball mill 1 hr. crushing			
III =	" " "	"	Rolls set 3/8" apart			
IV =	" " "	Rand Banket	- Ball Mill,	7	hrs.	crushing
V =	" " "	Tinguaite	" "	2½	"	"
VI =	" " "	Quartz	" "	2½	"	"
VII =	" " "	"	" "	"	"	"

Now when the number in the 1/Diam. column of the table of velocities is applied to the percentages in the next table the following result is obtained:-

I - 1233
II - 1264
III - 1126
IV - 1345
V - 1692
VI - 1425
VII - 1771

It is not fair to include test No. V as in this case there was possibly overgrinding. So if the averages of the first three be considered the number is 1207.6, or in round numbers 1208.



ELUTRIATION

FIG I

E.G.H.

The Examination of the -200 Product from the Comet Crusher.

The original Tinguaite before it was crushed was examined microscopically and was found to contain the following minerals:- Orthoclase felspar and the ordinary alteration products which follow, chiefly calcite and kaolin, although there was a little sericite also seen. Nepheline which is hard to distinguish from the Orthoclase. The larger cyrstals of Nepheline sometimes contain Haüyne and Apatite. Hornblende is present also pyroxene and biotite. All through the slide this variety of pyroxene known as Aegirine Augite, long laths of a dark black green colour are very conspicuous.

The Aegirine Augite is younger than the Nepheline and Haüyne. Then there are some cyrstals of sphene, leucoxene, epidote and rinkite. The latter cyrstals are distinguished by their clear lath like appearance - the laths seem to bunch together and the ends seem to fray. It is also reported that this mineral is slightly radioactive. There is considerable ilmenite and magnetite as crystals and also as microscopic dust.

The secondary minerals present were epidote, calcite, kaolin, and muscovite.

After this rock was crushed and classified in the elutriation tests some of the product was taken smeared on a slide and the slide examined and photographed. These photographs were not a great success. This examination showed that from -200 down to -700 that there were very few composite grains. In other words, nearly every grain was a mineral crystal so that breaking must have taken place in the cement of the rock before the crystals were broken.

<u>-700 mesh</u> minerals present were Pyroxene and Hornblende with many inclusions of black iron ore

Nepheline and Orthoclase in rather limited amounts.
Epidote - numerous crystals.
Hauyne - a few grains.
Aegirine Augite - a considerable number of grains of all sizes, one or two very long.

<u>-500 mesh:</u>

Hauyne - a number of comparatively large grains.
Pyroxene - as in -700.
Aegirine Augite- in considerable quantity.
Black Iron Ore - " " "
Nepheline - numerous large grains.
Orthoclase - " " "
Epidote - a few comparatively small grains.

-300 Mesh:

Orthoclase - many large grains containing calcite and sericite and Black Iron ore dust.
Nepheline - in considerable quantity.
Aegirine Augite - numerous long laths.
Hauyne - in considerable quantity.
Black Iron Ore - plentiful.

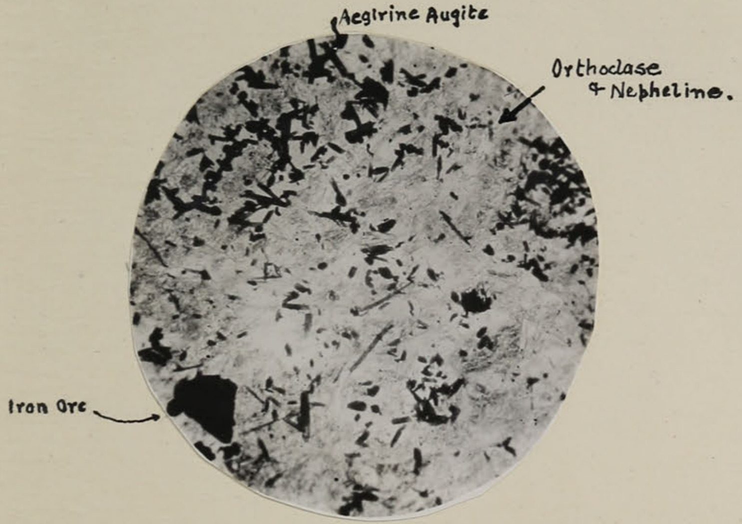
-200 Mesh:

Orthoclase - as for -300
Nepheline - in considerable quantity.
Hauyne - very few grains.
Aegirine Augite - a few grains.
Black Iron Ore - very little.

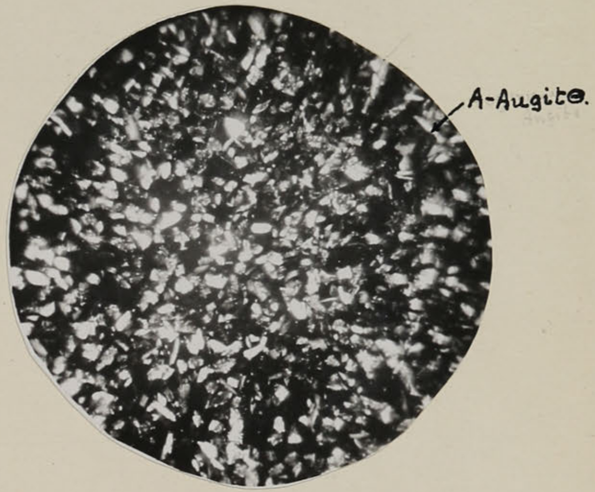
+200 Mesh:

The grains are comparatively coarse and orthoclase and nepheline are predominant. Epidote and Aegirine Augite in small quantities and no Iron Ore.

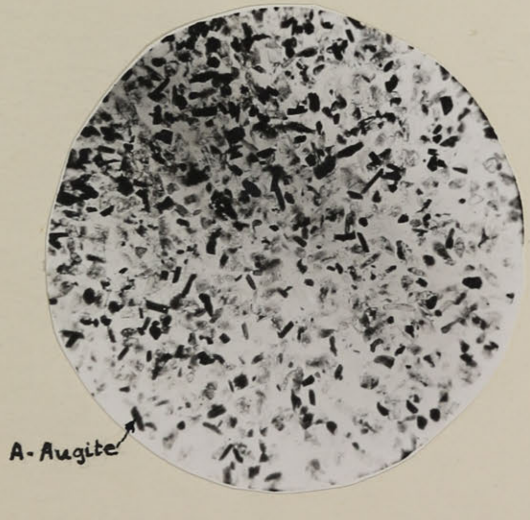
G. Vibert Douglas.
15-4-21.



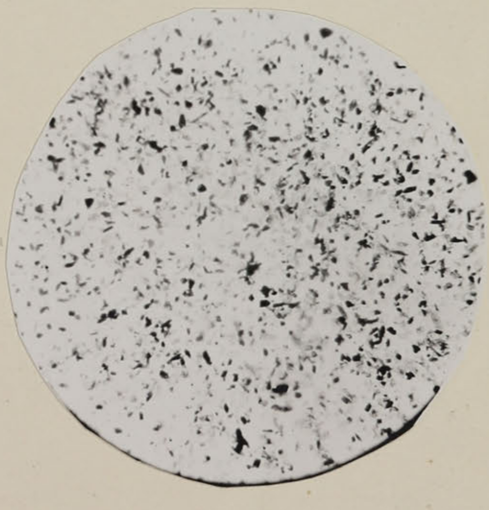
ORIGINAL TINGUAITE X80



-300 PRODUCT X80
X-NICOLS.



-500 PRODUCT X80.



-800 PRODUCT X80.