1897

Contact plane concentration

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THESIS

for the degree
of

B. S.

in

MINING ENGINEERING

1897

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CONTACT PLANE CONCENTRATION.

CONCENTRATION ON CONTACT PLANE CONCENTRATORS.

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Contact plane concentration depends upon the prinple that a thin sheet or film of water flowing over a plane surface may be so adjusted that its quantity and velocity are just sufficient to bear away the lighter particles of gangue, leaving behind only the heavier particles of the mineral to be concentrated, adhering by friction to the plane, the concentrates being removed by any convenient method.

Thus we see it is best adapted to the concentration of minerals having widely differing specific gravities but may be used for the concentration of all ores and minerals with any specific gravity whatsoever.

The forms of machines of this class are various, embracing the simple Launder or Labyrinth, Sluices with or without riffles, Buddles, Slime tables, Bumping tables, Vanners &etc.,some of which are stationary, some with an oscillation from side to side, some with an end oscillation, and some e.g. Vanners with a horizontal travel combined with the side oscillation, and still others, e.g. Buddles and Slime tables have a simple rorary motion.

Whatever the form, and however complicated the machine may be, the principle of concentration remains the same, viz.- it depends upon the transporting power of a thin sheet of water and upon the friction of the ore particles upon the plane. The economy in concentration by this method is very great since the machines require but little and sometimes no power. Also the amount of water required for the concentration is comparatively small.

In concentration upon any of the simple stationary machines of this class, we have four quantities which may be varied at will, viz:-

First:- Fineness of the pulp delivered to the machine.

Second:- Dilution of the pulp.

Third:- Amount of water used in the concentration.

Fourth:- The angle of the inclination of the plane.

In certain machines of this class we have combined with the above condition an oscillatory, linear or rotary motion of the plane or any combination of these motions, the adjustment of which are necessary for the successful working of the machine.

In the following experiments only the concentration upon the first or simple stationary plane was investigated to determine, if possible, a law governing concentration upon this class of machines.

Takeing the above variable conditions in the order named, we have:-

First:- Fine ness of the pulp delivered to the machine.

It is found by experiment that only the finer sands can be successfully concentrated on machines of this class. More-over the concentration of the coarser material is found to be much more perfect and much more economical in hydraulic classifiers and on jigs than on contact plane concentrators. Thus we are practically limited to material which is too fine to be successfully jigged which will vary from about sixty mesh up to the finest slimes. In fact, no other type of machine has been found which will successfully concentrate the finest slimes.

In some ores which break fine or shatter in crushing we sometimes find that 20% to 40% of the entire mineral contents of the ore is carried off as slimes and hence we see the great importance of their successful concentration..

Second:- In regard to the dilution of the pulp we find that we have a great variation according to what use the concentrator is put. For instance, a machine of this kind often receives the overflow from other machines directly without any intermediate sizing. In this case the dilution would be very great and the seperation very imperfect, but the pulp would be divided into two or more grades which could subsequently be treated seperately.

Again, it is usual with the finer material to settle out the pulp from excess of water and then dilute with just enough water to allow the material to be handled by a centrifugal pump, the remainder of the water necessary for the concentration being fed upon the machine sometimes in the form of a spray, and sometimes as a thin ~~as~~ a sheet.

In some cases the dilution is so calculated that the whole amount of water required for the concentration is fed with the pulp in which case it is fed in a continous stream, e.g. Bumping tables (Parsons- Rittinger).

Third:- The amount of water used in concentration will vary with the dilution of pulp. The inclination of the plane, and the size of the material to be concentrated.

If the amount of water be too great the concentrates may be very rich but this would cause enrichment of the tails, which would require retreatment. The amount is adjusted by experiment to what will give the most ecomomical concentration. (Note- see Page 14 for apparent exception.)

Fourth:- The inclination of the plane varies with the size of the material to be concentrated.

Also it may vary as the difference between the specific gravities of the mineral and gangue is large or small, smaller difference requiring a less inclination, as upon the inclination depends the velocity of the flow of the water and consequently its transporting power, and also, to some extent the friction upon the plane of the ore particles. But it depends more directly upon the material of which the plane is constructed.

It is also found by experiment that the angle of most economical concentration increases as the size of the material concentrated, but the variation is within narrow limits.

In the following experiments a lead ore consisting of Galena and a gangue which was almost pure limestone, was used. The samples were picked out by hand and were consequently very rich in Galena. Most of the experiments were conducted upon a wide shallow launder made of wood which at first was used witout covering and afterward covered with oilcloth. The wood appeared to give the best concentration for the same angle and amount of water. This is due probably to greater friction.

A rapid approximate method of determining the Pb.S. contents was used as follows:-

A equals weight of the mixture in air.

B " weight of the mixture in water.

C " Specific gravity of Pb.S.

D " Specific gravity of gangue.

X " weight of Pb.S. in the mixture.

A-X " weight of gangue.

Then (d-c)x equals dc(a-b) -ac

or x " $\frac{dc(a-b) -ac}{a-c}$

The above is the method given by Ricketts to determine the weight of gold in an alloy.

In the following experiments Tables, one to eight inclusive, the size, amount, and dilution of pulp was kept constant, also the amount of water fed upon the table was kept constant at the amount which by experiment gave the best average concentration.

The angle of inclination was varied starting from a point where no separation could be obtained and gradually increasing the inclination until the material was all washed away thus determining the extreme limits of concentration.

The discrepancies in the results are due to unavoidable errors in performing the experiment, viz.- of obtaining exactly similar conditions with each experiment.

TABLE 1.

Ore 16# to 2o#.

	Ore		Heads		Tails	
θ	Sp.G	Pb.S%	Sp.G	Pb.S%	Sp.G	Pb.S%
11,3o	3.2	24.o5	3.44	34.94	3.1o	2o.2o
17,3o	3.2	24.o5	3.5o	37.75	3.1o	2o.2o
23.3o	3.2	24.o5	3.33	3o.6o	3.11	2o.85

Amount of water used was seven liters per minute The ore was found to be entirely too large, instead of flowing down the plane as a sheet , the water was broken up into little rivulets thus preventing concentration. The results obtained have little or no value except that they show that a very large amount of water would be necessary for the concentration of the material.

Owing to the form of apparatus we were unable to use a larger amount than seven liters per minute.

Table 2. (Covered Launder.)

Ore 24# to 3o#.

	Ore		Heads		Tails	
θ	Sp.G	Pb.S%	Sp.G	Pb.S%	Sp.G	Pb.S%
4	3.33	3o.6o	no separation			
5	"	"	4.54	65.23	2.85	7.32
6	"	"	5.oo	76.35	3.33	3o.6o
7	"	" "	6.45	96.82	3.1o	2o.2o
8	"	"	5.oo	76.35	3.25	27.32
9	"	"	6.2o	93.63	3.o8	19.45
1o	"	"	5.85	89.58	3.o8	19.45
12	"	"	4.oo	56.81	3.25	28.25
15.	"	"	all washed away			

Water used eqauls five liters per minute . In this experiment the plane was covered with oil cloth. The separation was not very good, the friction between the pulp and the plane being too small for this size of material.

The limits within which concentration is possible for the given surface and material was found to be between four degrees and fifteen degrees with a maxium concentration at about nine or ten degrees.

This inclination will not give an eco nomical separation as the tails carry considerable galena, as seen from the table. Hence, from the above data it will be seen that concentration of this material by contact plane concentration would not be economical.

TABLE 3. (Covered Launder.)

Ore 3o to 4o.

	θ	Ore		Heads		Tails	
		Sp.G	Pb.S.%	Sp.G	Pb.S%	Sp.g	PbS%
Test No.1.	4	3.65	42.64		No separation		
" " 2	5	3.65	42.64	4.65	69.o8	2.93	12.o5
" " 3	6	3.65	42.64	4965	69.o8	3.11	2o.9
" " 4	7	3.65	42.64	4.25	61.2o	3.12	21.51
" " 6	9	3.65	42.64	4.42	64.34	3.oo	15.55
" " 7	1o	3.65	42.64	4.54	67.98	3.o1	17.77
" " 8	11	3.65	42.64	all	washed	down	the plane

Water used equal to five liters per minute, Dilution, Size and amount of pulp constant, inclination of the plane varied.

TABLE 4.

Ore 4o to 5o.

θ	Ore Sp.G.	Ore Pb.S%	Heads Sp.g	Heads Pb.S%	Tails Sp.G	Tails Pb.S%
4	3.33	3o.6	4.65	69.08	3.oo	15.55
5	3.33	3o.6	5.oo	76.35	2.93	12.42
6	3.33	3o.6	5.4o	83.17	3.oo	i5.55
7	3.33	3o.6	5.	76.35	3.2	25.
8	3.33	3o.6	5.oo	76.35	3.08	19.45
9	3.33	3o.6	5.33	8o.15	3.17	23.53
1o	3.33	3o.6	5.4o	81.07	3.2o	25.oo
11	3.33	3o.6	all	washed	away	

Water five liters per minute., inclination varied. The explanation of the narrow limits of concentration is that the plane was freshly covered with oilcloth and had not yet been scoured or worn rough.

TABLE 5.

Ore 5o to 6o.

θ	Ore Sp.G	Ore Pb.S%	Heads Sp.G	Heads Pb.S%	Tails Sp.G	Tails Pb.S%
[illegible]	3.81	47.8o	no separation			
5	"	"	5.3	81.48	3.oo	15.55
6	"	"	5.77	88.o3	3.11	2o.9
7	"	"	5.4	83.1o	3.12	21.51
8	"	"	6.45	96.9o	3.22	26.16
9	"	"	6.46	96.95	3.2o	25.
1o	"	"	5.7	87.63	3.2	25.
11	"	"	5.7	87.63	3.33	3o.6
12	"	"	all washedaway.			

Amount of water five liters per minute. Dilution amount and size of pulp constant, inclination varied.

TABLE 6

See curve No.1.

Ore 60# to 70#.

θ	Ore Sp.G	Ore Pb.S%	Heads Sp.G	Heads Pb.S%	Tails Sp.G	Tails Pb.S%
4	3.74	45.56	no separation			
5	"	"	5.00	76.35	2.97	14
6	"	"	5.12	78.40	2.9	10.3
7	"	"	5.56	85.03	2.96	13.55
8	"	"	6.24	94.42	3.12	21.51
9	"	"	6.67	99.1	3.25	27.32
10	"	"	6.69	99.54	3.27	29.01
11	"	"	6.75	100.00	3.48	36.31
12	"	"	all washed away.			

Dilution, size and amount constant, water five liters per minute, inclination varied.

It was with this material that the first good concentration was obtained which shows that the beginning of the economical application of this class of machines is practically where economical concentration by jigging ends.

Table 7.

Ore 80# to 90#. See curve No.2.

θ	Ore Sp.G	Ore Pb.S%	Heads Sp.G	Heads Pb.S%	Tails Sp.G	Tails Pb.S%
2,30-0	3.33	30.6	no concentration			
3.	"	"	3.75	45.85	2.90	10.30
4	"	"	5.00	76.35	2.92	11.52
5	"	"	5.55	85.11	3.02	16.58
6	"	"	5.88	90.00	2.94	12.45
7	"	"	6.06	92.25	3.03	17.01
8	"	"	6.21	93.44	3.04	17.58
9	"	"	6.25	94.56	3.08	19.45
10	"	"	6.25	94.56	3.08	19.45
11	"	"	"	"	"	"
12	"	"	all washed away.			

Ore finer than one hundred mesh.

TABLE 8. See curve No.3.

θ	Ore Sp.G	Ore Pb.S%	Heads Sp.G	Heads Pb.S%	Tails Sp.G	Tails Pb.S%
2-3o	3.75	45.85	no concentration			
3	"	"	4.44	63.76	2.9	1o.3
4	"	"	4.82	72.8o	2.96	13.55
5	"	"	4.98	75.92	3.o5	17.77
6	"	"	5.oo	76.35	3.ol	15.o6
7	"	"	5.25	8o.o8	3.12	21.51
8	"	"	5.75	88.21	3.2o	24.o5
9	"	"	6.2o	93.63	3.21	25.48
1o	"	"	6.45	97.o4	3.25	27.32
11	"	"	6.46	97.21	3.26	28.o8
12	"	"	6.67	99.1o	3.41	33.82
13	"	"	6.75	1oo.	3.44	34.94

Water five liters per minute, dilution, size and amount of pulp constant, inclination varied.

The wider limits of concentration may be explained by the fact that the oil cloth covering had become rough with wear and therefore the friction was greatly increased.

Material unsized finer than 60#,

TABLE 9.

O	Ore Sp.G	Ore Pb.S%	Heads Sp.G	Heads Pb.S%	Tails Sp.G	Tails Pb.S%
4	3.48	36.31	no separation			
0 5	"	"	4.44	63.76	2.85	7.32
6	"	"	4.67	69.80	2.90	10.30
7	"	"	4.70	70.05	2.92	11.52
8	"	"	4.82	74.80	2.94	12.45
9	"	"	5.00	76.35	2.95	12.85
10	"	"	5.00	76.35	3.00	17.77
11	"	"	5.43	84.27	3.23	26.52
12.	"	"	6.15	87.59	3.33	30.6
13.	"	"	all washedaway .			

Water five liters per minute, inclination varied .

TABLE 10.

Material used finer than 70#.

O	Ore Sp.G	Ore Pb.S%	Heads Sp.G	Heads Pb.S%	Tails Sp.G	Tails Pb.S%
4	3.64	41.74	no separation			
5	"	"	4.67	69.80	2.9	10.30
6	"	"	4.98	75.92	2.92	11.52
7	"	"	4.99	76.25	3.00	15.55
8	"	"	5.12	78.40	3.05	17.77
9	"	"	5.50	84.78	3.12	21.51
10	"	"	5.56	85.23	3.25	27.23
11	"	"	6.00	91.56	3.33	30.60
12	"	"	all washed away.			

Water five liters per minute, inclination varied. Amount , dilution, size of pulp constant.

Fromthe above tables we see that close sizing is not absolutely essential though in most cases it gives cleaner tails than where the material is unsized. Since the cost of close sizing for fine material is very great, we see that while the loss of Galena carried off by theoverflow is considerable it is not sufficiently great to pay for the extra expense of close sizing.

We see from the foregoing tables that there exists a certain relation between the inclination of the plane and the concentration o f the pulp, the other quantities remaining constant.

To find this relation and establish, if possible, a definite law concerning it , let us plot the angle of inclination as abscissae and the per cent of Galena in the Heads and Tails as ordinates.

Plotting the results as obtained we get a curve beginning at a point (h,k) some distance from the origin and rising rapidly, finally becoming parallel to the axis of X. Moving the origin to this point we may assume the equation of the curve to be of the general form

y equals ax plus bx^2 .

We may write this $\frac{y}{x}$ equals bx plus a. If the equation fits the curve, we should expect $\frac{y}{X}$ and x to plot as a straight line since $\frac{y}{x}$ equals a plus bx – is the general equation to a straight line having a slope(b) and the intercept (a) on the axis of Y.

Upon plotting $\frac{y}{x}$ and x we find that this is very nearly true, the discrepancies being due probably to errors ~~and~~ in experiment.

If we sibstitute (y-k) for y and (x-h) for x in the general equation, we get,

y-k equals a(x-h) plus $b(x-h)^2$ as the equation of the curve referred to 'O' as origin.

The ordinate "k" is determined by the percent Galena in the ore used and similarly the point "h" is determined by the angle at which no concentration is possible i.e. where the ore is all left upon the plane.

This equation is applicable to the curve only between the limits ,per cent Galena in the ore, and per cent Galena in the highest concentrates and it is useful to use only between these limits since in the first case all of the ore is left upon the machine and in the second case all is washed away, i.e. it applies between the extreme limits of concentration.

The same general equation is found to apply to the curve of concentration of the tails, the only difference being that the curve has an origin (h.o) i.e. starts from a point in the axis of X.

The quantity "a" is the intercept of the line $\frac{y}{x}$ plus bx on the axis of Y, and the quantity "b" is the tangent of the angle which the line makes with the axis of X.

These values may be taken directly from the plot and substituted in the equation and the origin changed by substituting the coordinates h.k. as taken from the plot, in the equation,

(y-k) equals a(x-h) plus $b(x-h)^2$

Applying this equation to the curve obtained from plotting the concentration of 6o# to 7o# we have the equation referred to O as origin

y equals 16x plus$(\frac{-1}{10})x^2$ equals 16x $-\frac{x^2}{10}$ and moving to the point O as origin we have

y-46 equals 16(x-4) $-\frac{1}{10}(x-4)^2$ or reducing we have

10y plus 196 equals 168x $-x^2$.

The concentration of the tails in this case plots as a straight line. Referring, to the point 4 as origin we find that the general equation holds true o nly when "b" equals "o" or the equation is y equals ax. Now referring this to the point O as origin we have y equals a(x-4) as the equation of the line. This would mean that the concentration is directly proportioned to the inclination of the plane.

Referring to the curve obtained from the concentration of the ore from 8o# to 9o# we have

y equals $188x - \frac{5}{48}(x^2)$ as the equation referred to the point O' as an origin or

$y - 30.6$ equals $18.8(x - \frac{21}{2})^2 - \frac{5}{48}(x - \frac{21}{2})^2$ as the equation referred to O as origin or

y plus 64 equals $18.8x - \frac{5}{48}(x - \frac{21}{2})^2$.

The equation of the curve obtained from the material finer than 1oo# we have for heads

y equals $17x - \frac{x^2}{10}$ for O' as origin or

$y - 45.85$ equals $17(x - \frac{5}{2}) - \frac{(x - \frac{5}{2})^2}{10}$ reducing

$10y - 27.5$ equals $175x - x^2$ for O as origin .

For tails we have,

y equals $3.5x - \frac{x^2}{10}$ for pt $\frac{21}{2}$ as origin or

y equals $3.5(x - \frac{5}{2}) - \frac{(x - \frac{5}{2})^2}{10}$

$10y$ plus 15 equals $35x - x^2$.

TABLE 11.

Ore finer than 100#, inclination constant equals 7°, water varied. See curve No.5.

Water ~~7liters per minute~~.

Water	Ore		Heads		Tails	
	Sp.G	Pb.S%	Sp.G	Pb.S%	Sp.G	Pb.S%
1 1/2 liters	3.75	45.85	5.12	76.4o	3.26	26.o8
2 "	"	"	5.oo	76.35	3.33	3o.6o
2 1/2 "	"	"	5.27	81.oo	3.25	27.36
3 "	"	"	5.oo	76.35	3.27	29.o1
3 1/2 "	"	"	5.00	76.35	3.25	27.36
5 1/2 "	"	"	5.oo	76.35	3.33	3o.6
8 "	"	"	5.12	78.12	3.2o	25.oo
14 "	"	"	5.55	85.ii	3.22	26.16
16 "	"	"	5.25	8o.o8	3.17	23.74
18 "	"	"	5.13	81.85	3.25	28.25
2o "	"	"	5.oo	76.35	3.33	3o.6o
22 "	"	"	5.oo	76.35	3.33	3o.6o
24 "	"	"	5.oo	91.56	3.48	36.31
3o "	"	"	5.3o	81.84	3.27	29.o1

If we plot the water in liters per minute as abscissae and the concentration as ordinates we get two straight lines parallel to the axis of X. This would mean that the concentration for a given angle is independent of the amount of water used. This may be explained by the fact that the transporting power of water does not increase as the depth after it has attained a depth sufficient to immerse the body, but varies only with the velocity of flow. Since the material used was so fine, a very thin sheet or film was sufficient to immerse the particles and the concentration would remain the same however great the amount of water varied i.e. providing the velocity remained constant.

The variations of the points froma straight line is probally due to errors in experiment viz.- the difficulty of feeding so large a quantity of water in an even sheet over the entire plane.

TABLE 12.

Inclination constant equals 5 degrees, water constant e quals 5 liters per minute, Size of pulp varied .

Ore finer than 100"

See curve No.4.

		Ore		Heads		Tails	
Mesh	Av.	SP/G	Pb.S%	Sp.G	Pb.S%	Sp.G	Pb.S%
16-2o	18	3.2o	24.o5	3.2o	24.o5		
24-3o	27	3.33	3o.6o	4.54	65.23	2.88	7.32
3o-4o	35	3.65	42.64	4.65	69.o8	2.93	12.o5
4o-5o	45	3.33	3o.6o	5.oo	76.35	2.93	12.o5
5o-6o	55	3.81	47.8o	5.3o	81.48	2.97	14.oo
6o-7o	65	3.74	45.56	5.oo	76.35	3.oo	15.55
8o-9o	85	3.33	3o.6o	5.55	85.11	3.o9	16.o1
(finer than loo.)	loo	3.75	45.85	4.98	75.92	3.o5	17.77

If we keep the water constant and also the inclination we have as the only variables the mesh and the concentration.

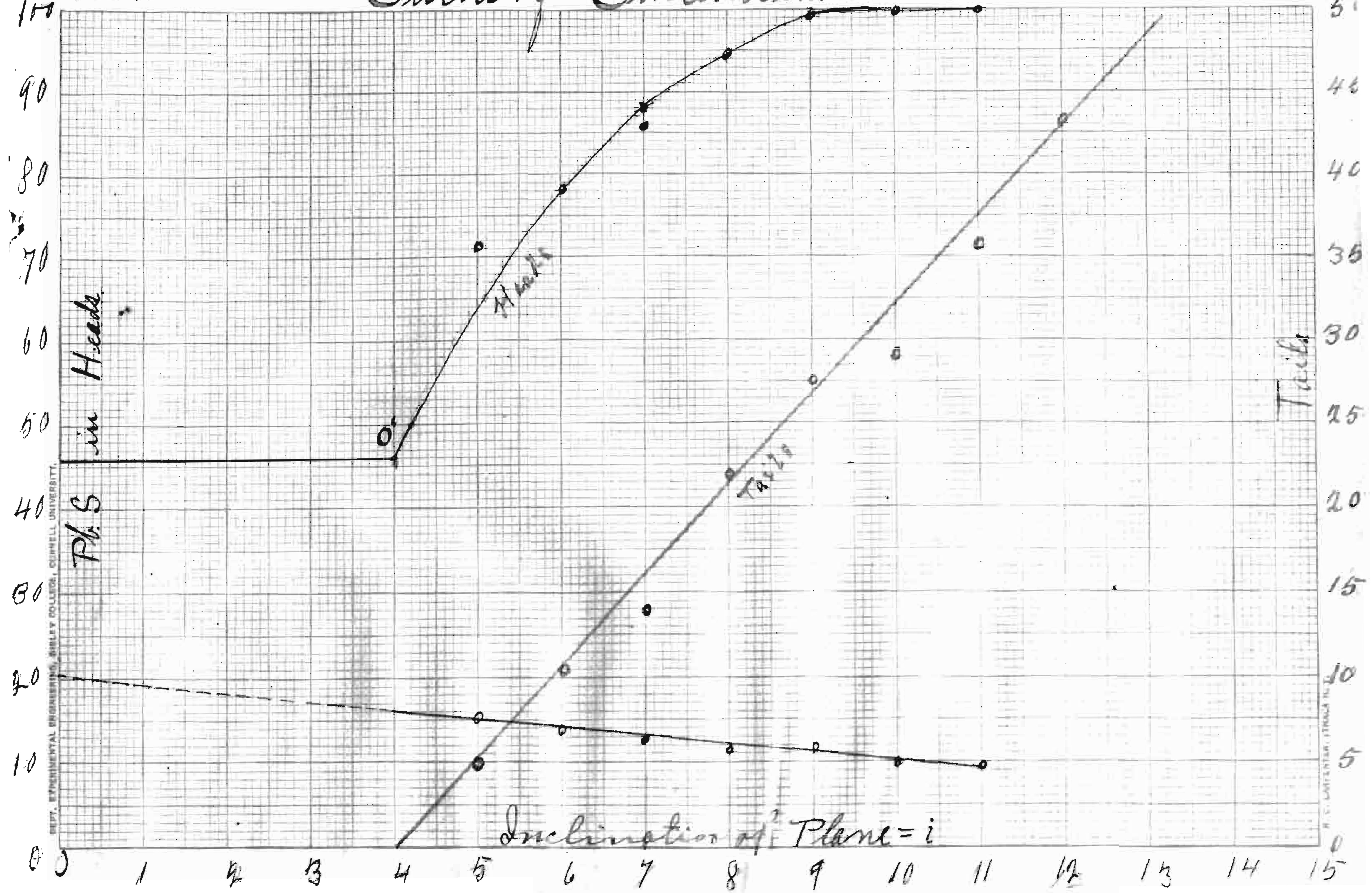
Now if we keep the water constant and also the inclination we have as the only varieties the mesh and the ~~concentration~~.

Now if we plot mesh as abscissae and per cent Pb.S in the heads and tails as ordinates we obtain curves very sililar in appearance to those obtained by varing the angle of inclination.

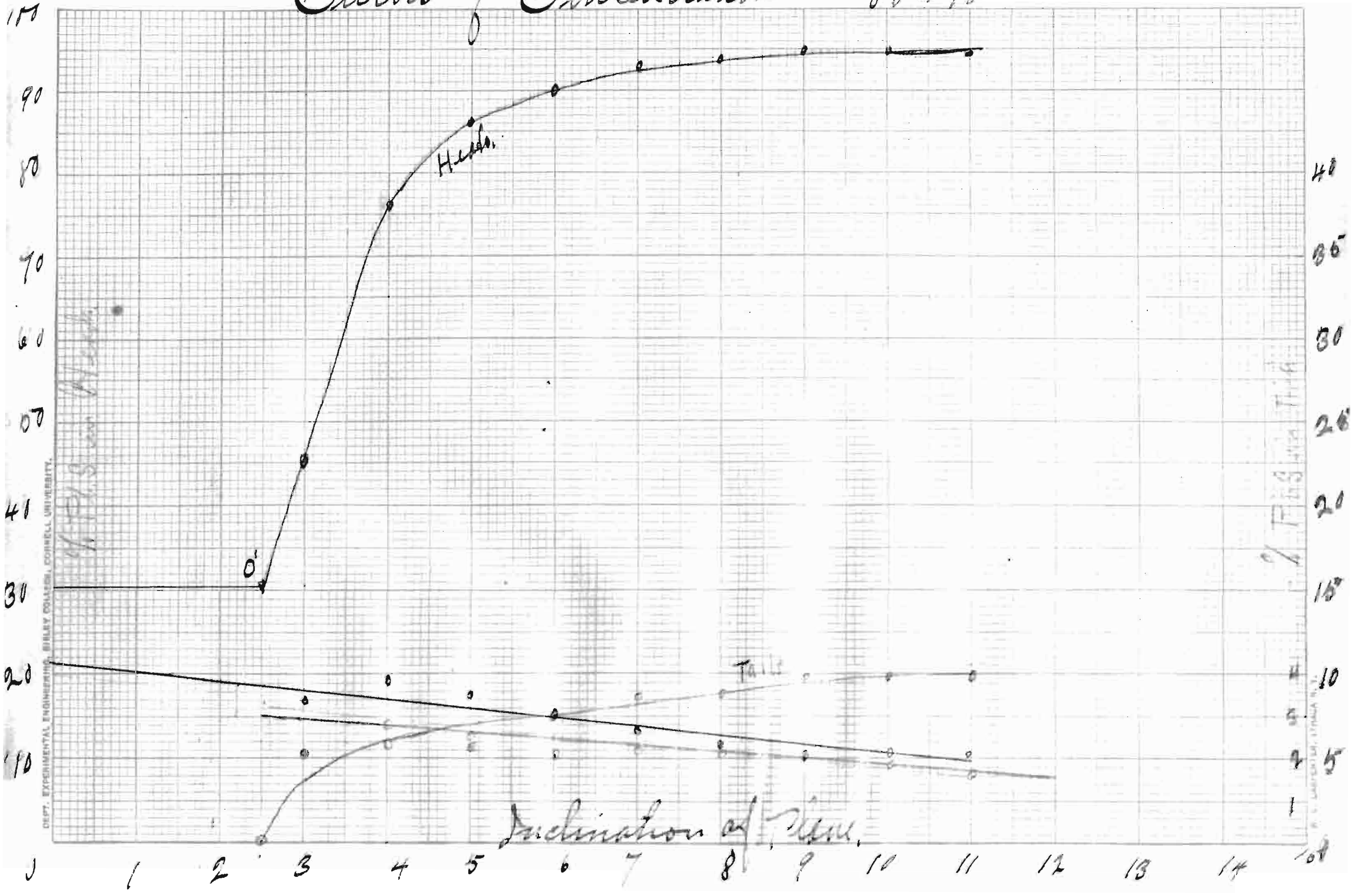
Applying the same equation we find that $\frac{y}{x}$ and x plot as a straight line and hence we may say that the equation y equals ax plus bx^2 is also true for this case.

Hence the general conclusion that, within certain limits, the effects of varying the size of the material used, and the inclination of the plane for constant size are similar.

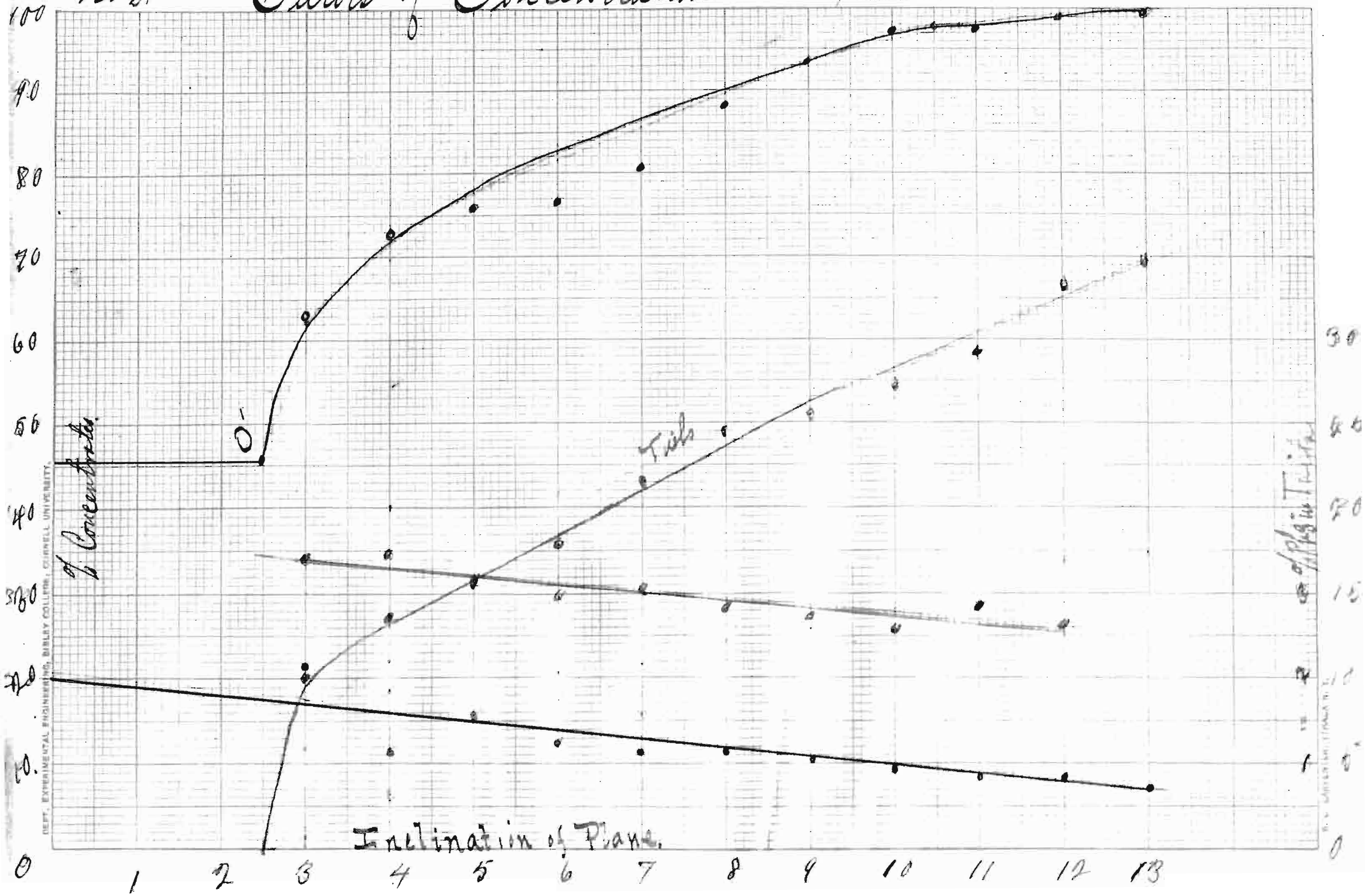
No. 7. Curves of Concentration. 60# to 70#



No. 2. Curves of Concentration 80° & 90°

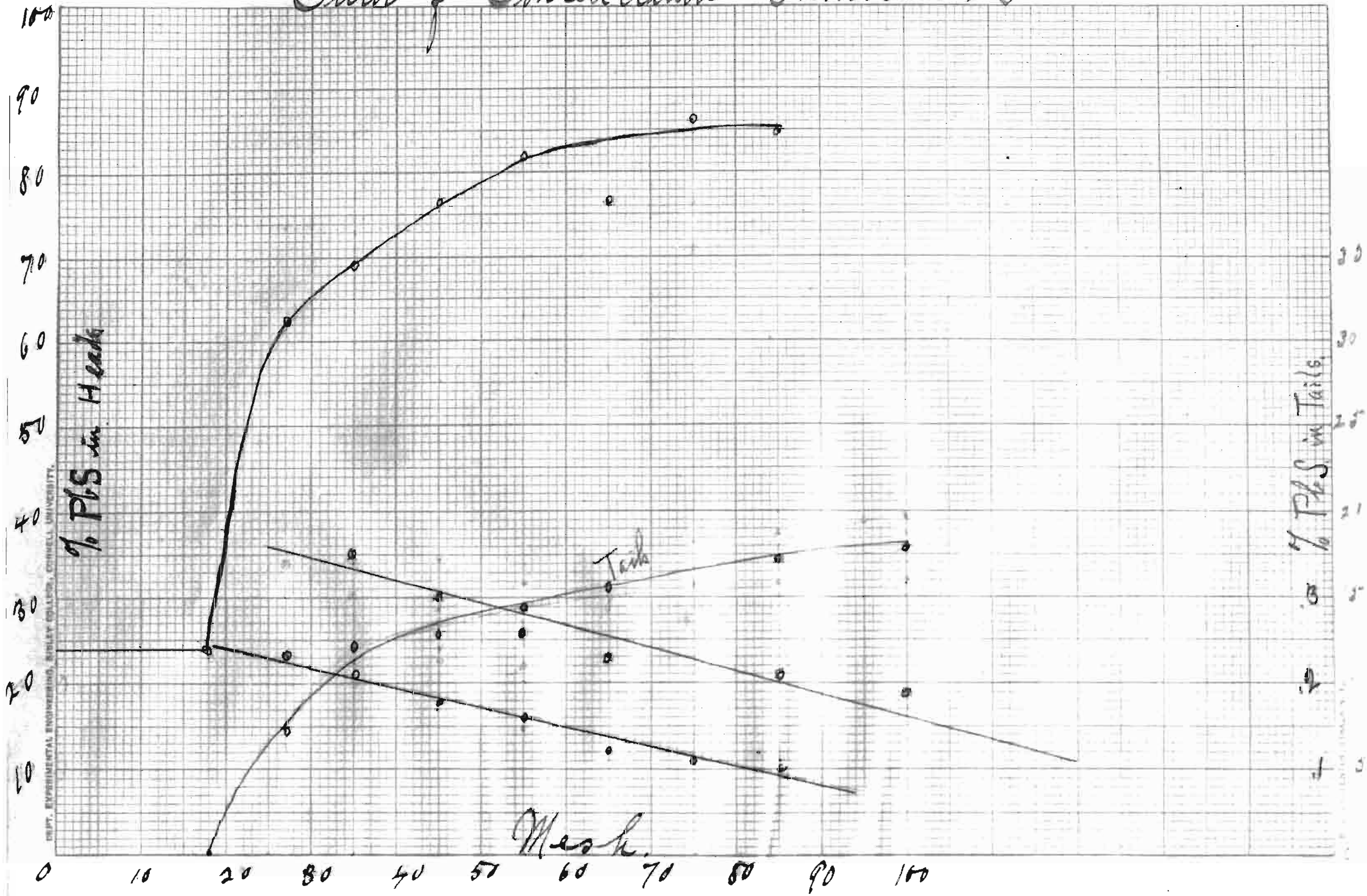


No 3. Curves of Concentration Finer than 100#

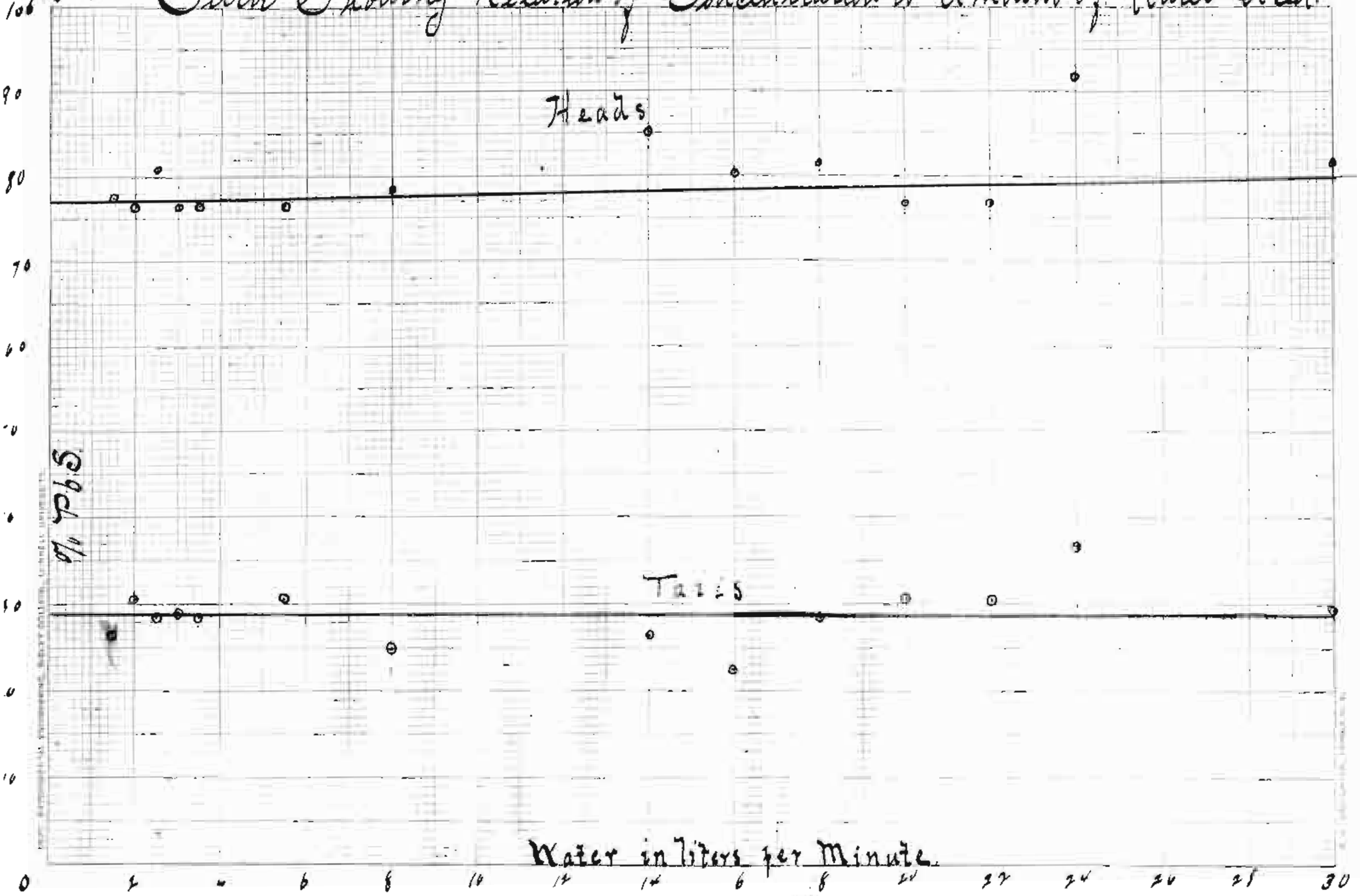


No. 4

Curve of Concentration θ constant = 5°



No 5. Curve Showing Relation of Concentration to Amount of Water Used.



S U M M A R Y .

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From the foregoing equations we may determine the concentration at any given angle or, given the reqd. concentration, we can determine the angle at which to set the plane to obtain the desired result.

Also, between certain limits, the effect of varying the inclination of the plane, and of varyingthe size of pulp delivered to the machine, the inclination remaining the same, is similar, since the same equation may be applied to the curve obtained in either case, the equation differing only in the absolute terms i.e. the coefficients "a" and "b".

Again we see that after sufficient water is fed upon the plane to form a film of depth sufficient to immerse the particles of ore, no increase in the volume of water, however great it may be, will increase the concentration for the given angle, the velocity of flow remaining constant.

Also it was found that in order to obtain good concentration, it was necessary to comb or brush the material upon the plane so that the water could have free access to every particle upon the plane.

A new Process for Lead Smelting.

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This process is based upon the following reaction:- PbS plus $2PbO$ aquals $3Pb$ plus So_2.

The Pb.S and Pb.O are melted in separate vessels and then poured together in the proportion calculated from the above reaction. The formation of the So_2 is attended with a great liberation of heat. This heat is sufficient to keep the whole mass molten until the reaction is complete and the Lead can be ladled into moulds.

The reaction is complete in from two to three minutes after the molten Pb.S and Pb.O are poured together.

It is found advisable to pour the two simultaneously into a receiving vessel for the liberation of So_2 takes place with such rapidity that if the above precaution is not observed, the contents of the receiver will often be blown out by the escaping gas.

The greatest difficulty experienced in the Laboratory work was to get a material for crucibles which would not be corroded so rapidly by the Pb.o. Ordinary crucibles were eaten through before the fusion was complete, and the best grade of fireclay crucibles would last for about one fusion.

The Pb.S corroded the crucibles very rapidly also. A lining for the crucibles consisting of

Calcine two parts by volume

Raw fireclay one part by volume

Coke, forty mesh, one part by volume

was tried with varying success.

The linings were very rapidly corroded by the litharge and in no case could be used the second time, but the Pb.S did not corrode so badly.

The results of the experiments were not satisfactory as there was always considerable loss of Pb.O in cracks in the lining, reduction by the Carbon of the lining etc., so the materials were not poured together in the proper proportion.

In most cases the reduction was incomplete but in a few cases bright, malleable Lead was obtained which shows that the method is feasible if a non-corrosive lining could be obtained for the crucibles. It also has the advantage of being very rapid.

The principal disadvantages are the corrosive character of the Pb.o and Pb.S and loss by oxidation. The Pb.O fumes make the method dangerous unless proper precautions are taken.

Owing to the lack of material we were obliged to discontinue our investigation of this subject and take up another.