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Investigation of hindered-settling ratio of galena and quartz in air

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THESIS

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T241.

INVESTIGATION OF HINDERED-SETTLING RATIO OF GALENA AND QUARTZ IN AIR.

-BY-

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-PROBLEM-

The object of this Thesis is to determine the hindred-settling ratio in air of Galena and Quartz, and to verify if possible the result of the work done in 1909 by W. D. Clark and R. W. Watson.

References Used:

Richards Ore Dressing, and Clark and Watson's Thesis.

Prof. Richards, in his book, "Ore Dressing," page 610, says,-"Hindered-settling takes place when particles of mixed sizes, shapes and gravities in a mass, free to move among themselves, are sorted in a rising current of water, the rising current having much less velocity than the free settling of the particles, but yet enough so that the particles are kept in motion. The arrangement of the particles is so positive that if one of them be moved up or down from its chosen companions, it will be found, when set free, to return immediately to practically the same group as before."

Prof. Richards used water in his work, but in the following tests air was used as a medium in which hindered-settling was to take place.

The hindered-settling ratio of Galena as compared to Quartz means, the ratio of the diameter of a quartz particle to the diameter of a Galena particle with which it is in equilibrium: i.,e., with which it occupies the same level in the sorting column.

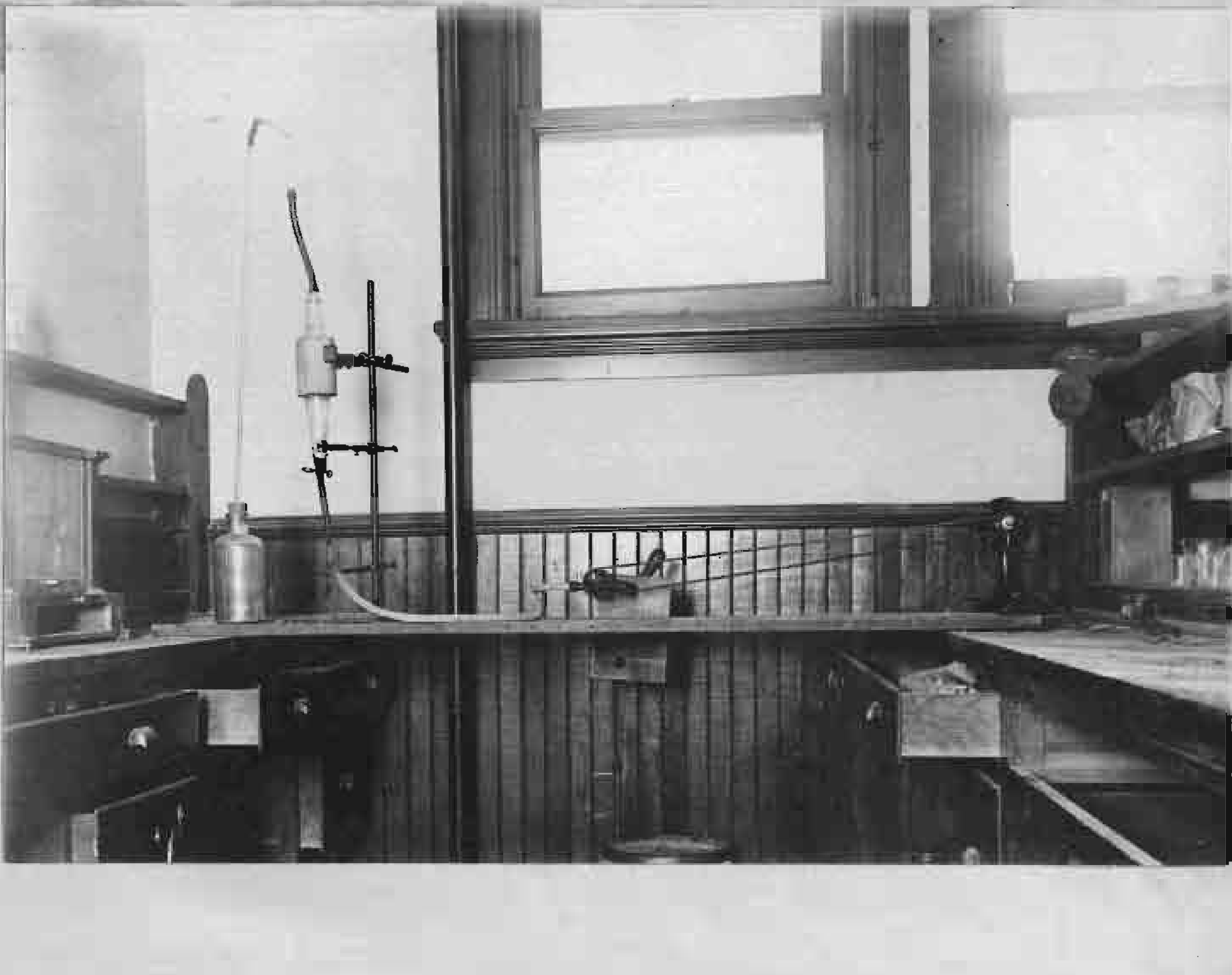
Minerals Used:

Pure crystalline galena of a specific gravity of 7.7 and pure glassy quartz of a specific gravity of 2.9 (note high specific gravity of Quartz). The specific gravity of Quartz is usually from 2.65 to 2.66

Apparatus Used: See plate I.

This consisted of a wooden cylinder 3 inches in length and with an inside diameter of 2 inches, into each end of which was closely fitted a conical tube, 6 inches in length and tapering from 2 inches at the large end to 1/2 inch at the small end. This classifier arrangement is essentially similar to the one used by Prof. Richards in his experiment with water. This tube was held in a vertical position and to the bottom of the tube was attached a rubber tube thru which air was led into the classifier. The upper end of the classifier tube was connected with a glass bottle by

PLATE NO. I.



means of a small glass tube, the bottle being used as a collector of dust particles.

The rubber tube was connected to a pipe into which was set a revolving valve. This valve was fitted with a small pulley and was revolved by a motor, thus alternately opening and closing the air passage and thereby giving pulsations in the ore column. The number of revolutions made by the motor could be regulated so as to give the desired number of pulsations.

The air supply came from the compressed air main of the school and was admitted to the revolving valve thru a 1/2 inch needle valve, which permitted of a close regulation of the amount of air used.

Operations:

The Galena and Quartz were separately crushed and sized the sizes ranging from, on 12 mesh. (1.755 M.M Diam.) to thru 200 mesh. (0.038 M.M.Dia.) See Table No.I for screen sizes.

Equal parts of each size of both Quartz and Galena were then taken and thoroughly mixed. A bed of the resulting ore 3 inches in depth in the tube was then taken, previous experiments having shown that this was the most practical depth that could be perfectly agitated by our apparatus.

The maximum air pressure needed to produce perfect agitation was 0.144 pounds per square inch, measured by a U tube water guage inserted just below the sorting column.

There were three different numbers of pulsations available with the apparatus, namely, 900, 1800, and 2400 pulsations per minute. With an air pressure of 0.144 pounds per square inch we found that with 900 pulsations per minute we obtained in the classifier tube a piston action of the bed but no agitation. With 1800 pulsations per minute we obtained perfect agitation and no piston action. While with 2400 pulsations we got a combined agitation and piston action. The 1800 pulsations per minute were used, as that rate gave best agitation.

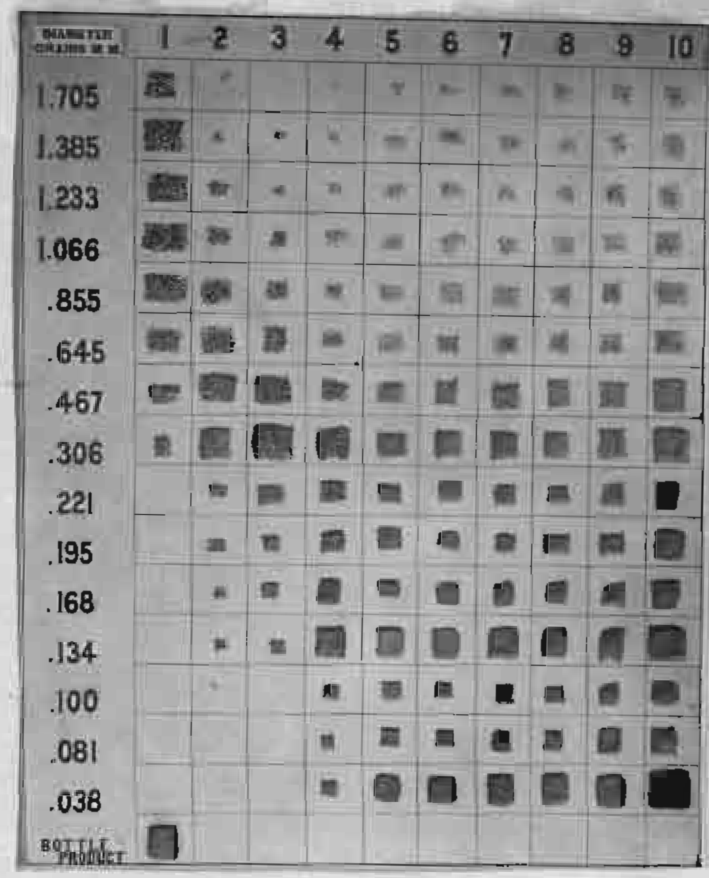
It was found impossible to obtain a perfect agitation of the whole bed where it was made up of sizes ranging from 1.755 M.M. diameter to 0.038 M.M. diameter, as we found that much less air in proportion was needed for the small than the large sizes.

After running for 15 minutes under the above conditions, the minerals having arranged themselves so that the various sizes assumed a definite position in the sorting column, the product was drawn off in equal and consecutive portions, ten in number.

Each layer was put thru the nest of screens before mentioned, and the product on each screen was removed and placed on a chart in its proper position. The product of each screen forming a "hill". Each row of "hills" taken up and down the board being a consecutive layer according to numbers at the top. A photograph of this was taken. See Plate No.II.

Then the hills of layers No.4, 5, 6, and 7, were successively taken and the amount of quartz and galena, were determined. The method of determining the composition of the hill was to weigh each, and then dissolve out the galena by means of Nitric acid, afterwards treating with ammonium aceatate to dissolve any lead sulphate that may have formed. The Quartz was then weighed and the weight of galena was determined by difference. For these weights see Tables Number 2, 3, 4, and 5.

PLATE NO.II



1
2
3
4
5
6
7
8
9
10
1.705
1.385
1.233
1.066
.855
.645
.467
.306
.221
.195
.168
.134
.100
.081
.038
BOTTLE PRODUCT

The method of calculating the hindered-settling ratio was the same as that used by Prof. Richards, and is as follows: Each layer from the sorting tube was screened and the product on each screen called a "hill" as described above. The average of the diameters of the two adjacent screens was considered to represent the average diameter of the grains passing thru the coarser and resting on the finer screen. Hence the average diameter of the grains in each hill is known. The summation of the products obtained by multiplying each diameter by its weight of galena, divided by the total weight of the galena in the layer, gives the average diameter of the galena in the layer in question. The average diameter of the quartz in each layer was obtained in a similar manner. The tables No. 2, 3, 4, and 5 show the calculation of the average diameter of the quartz, and galena in layers No. 4, 5, 6, and 7, respectively.

The hindered-settling ratio is the average diameter of the quartz in each layer divided by the average diameter of the galena in that layer.

The hindred settling ratio for each layer was as follows:

Layer No.	Galena.	Quartz.
4	1	2.6
5	1	2.
6	1	5.
7	1	3.8

The preceding gives an average ratio for all layers of quartz to galena as 3.4 to 1.

To check this result a different method was used , as follows: portions of quartz and galena were taken that according to screen diameter would give a ratio approximately 3.4 to 1 and then subjected to the action in the sorting tube. A small amount of pure galena settled and a small amount of pure quartz came to the top.

The pure galena was drawn off and a layer selected containing both quartz and galena. Since the mineral grains in this layer were in equilibrium in the tube, a correct determination of the average diameter of the quartz and galena should give the hindred-settling ratio with great exactness.

The comparative diameters of the two minerals were obtained by measuring two dimensions of fifty grains, each, of quartz and galena, 5 samples of each being used and 10 grains from each sample were measured.

The measurements were made by using a microscope with a micrometer eye-piece, Care being used to obtain a good average of the grains in each sample. The results obtained were as follows:

Quartz.	Galena.	Screen Ratio.	Ratio obtained.
1.755	0.515	3.4	3.35
1.066	0.325	3.14	3.7
0.645	0.221	2.95	4.1

Giving an average ratio for all of 3.75 to 1. See Tables No. 6, 7, and 8 for the data and calculations.

It was found that when taking quartz of a diameter 4 or 5 times greater than that of the galena, the quartz did not settle to the bottom and the galena layer itself at the top as was expected, but the quartz and galena remained indiscriminately mixed in the tube. This seems to be due to the galena filling the interstices between the quartz grains and having its upward passage hindered by the quartz. We found however that by decreasing the air pressure until the bed was in a weak state of agitation that the particles of galena would settle thru the interstitical current, thru the air column and into the reject tube below the classifier while the quartz remained in the classifier.

It was obvious that had we had alternative pulsion and suction this action would have taken place more readily.

On experimenting with fine material, finer than 100 mesh, we could obtain no agitation of the bed, nor a hindered-settling action, a whirling motion resulting from the action of the air.

Ratio of diameter of quartz to that of galena by calculation and by direct measurement.

	By Calculation.	By Measurement.
Galena	1	1.
Quartz	3.4	3.7

Practical Application of Results:

Referring to Table IX we find, that in an air jig or classifier for a perfect separation, the diameter of the largest particle of quartz should never be more than about 3.4 to 3.7 times the diameter of the smallest particle of galena.

TABLE NO-I.

SCREEN.

Sieve Mesh.	Size of openingin M.M.	Average of each size and ave. above it.
10	1.949	1.785
12	1.462	1.705
14	1.309	1.385
16	1.158	1.233
18	0.974	1.066
24	0.737	0.855
30	0.554	0.645
40	0.381	0.467
60	0.232	0.306
70	0.210	0.221
80	0.181	0.195
100	0.156	0.168
120	0.113	0.134
150	0.087	0.100
200	0.076	0.081
Thru 200	0.000	0.038

-TABLE NO II-

Layer No.4.

Mesh.	Total Wt. hill.	Wt.Quartz.	Wt.Gal.	Wt.time ave.dia. Quartz.	Wt.time ave.dia. Galena.
12	0.050	0.050	0.00	0.085	
14	0.120	0.091	0.029	0.126	0.040
16	0.140	0.085	0.105	0.068	0.063
18	0.320	0.175	0.145	0.187	0.155
24	0.370	0.134	0.236	0.115	0.202
30	0.490	0.142	0.348	0.092	0.224
40	1.6	0.24	0.36	0.112	0.168
60	5.735	0.286	0.5449	0.088	1.667
70	1.753	0.052	1.701	0.011	0.376
80	2.435	0.082	2.353	0.016	0.459
100	2.67	0.042	2.628	0.007	0.441
120	4.90	0.117	4.783	0.016	0.642
150	0.775	0.023	0.752	0.002	0.075
200	0.310	0.015	0.295	0.001	0.024
Thru.	0.547	0.038	0.509	0.001	0.019
Aver-age	1.572	19.643	0.964	4.560	

-TABLE NO. III-

Layer No. 5.

Mesh.	Total Wt. hill.	Wt. Quartz.	Wt. Gal.	Wt. time ave. dia. Quartz.	Wt. time ave. dia. Galena.
10					
12	0.121	0.121	0	0.206	0.000
14	0.273	0.262	0.011	0.363	0.015
16	0.332	0.315	0.017	0.388	0.021
18	0.285	0.275	0.010	0.293	0.011
24	0.337	0.332	0.003	0.284	0.004
30	0.373	0.342	0.031	0.221	0.012
40	0.739	0.557	0.182	0.260	0.085
60	1.605	0.844	0.161	0.258	0.493
70	0.823	0.191	0.632	0.042	0.140
80	1.248	0.334	0.914	0.065	0.178
100	162	0.294	1.326	0.049	0.233
120	3.648	0.306	3.342	0.041	0.448
150	0.790	0.112	0.688	0.011	0.069
200	0.797	0.153	0.644	0.012	0.052
Thru	2.450	0.411	2.039	0.016	0.775
Total-		4.949	10.022	2.529	2.526

-TABLE NO. IV-

Layer No. 6.

Mesh.	Total Wt. hill.	Wt.Quartz.	Wt.Gal.	Wt.time ave.dia. quartz.	Wt.time ave.dia. Galena.
10					
12	0.147	0.147	0.00	0.251	0.000
14	0.447	0.447	0.00	0.630	0.000
16	0.277	0.277	0.00	0.341	0.000
18	0.302	0.302	0.00	0.322	0.000
24	0.380	0.380	0.00	0.365	0.000
30	0.354	0.394	0.04	0.300	0.026
40	0.648	0.497	0.151	0.232	0.071
60	1.270	0.894	0.376	0.275	0.115
70	0.470	0.177	0.293	0.392	0.065
80	0.695	0.286	0.409	0.056	0.080
100	0.867	0.215	0.652	0.036	0.110
120	2.237	0.447	1.790	0.060	0.240
150	0.686	0.1509	0.535	0.015	0.054
200	0.66	0.139	0.522	0.011	0.042
Thru.	2.530	0.329	2.201	0.012	0.084
Total		4.9819	3.148	0.887	

-TABLE NO. V-

Layer No. 7.

Mesh.	Total Wt. Mill.	Wt.Quartz.	Wt.Gal.	Wt.time ave.dia. quartz.	Wt.time ave.dia. Galena.
10					
12	0.217	0.217	0.000	0.370	
14	0.300	0.300	0.000	0.416	
16	0.291	0.291	0.000	0.359	
18	0.330	0.330	0.000	0.352	
24	0.465	0.423	0.042	0.362	0.036
30	0.403	0.258	0.045	0.166	0.093
40	0.895	0.801	0.094	0.374	0.044
60	1.454	1.167	0.278	0.357	0.085
70	0.566	0.251	0.315	0.055	0.070
80	0.885	0.403	0.482	0.079	0.094
100	0.922	0.346	0.576	0.058	0.097
120	2.570	0.822	1.648	0.110	0.221
150	0.743	0.193	0.019	0.550	0.055
200	0.963	0.246	0.717	0.020	0.058
Thru	3.036	0.385	2.673	0.014	0.102
Total		6.406	7.525	3.111	0.955

-TABLE NO. VI.- Part I.

GALENA Average Screen Diameter = 0.515 M.M.

SAMPLE NO.

	I		2		3		4		5	
Gr.No.	L.	W.	L.	W.	L.	W.	L.	W.	L.	W
1	10	10	30	10	15	12	30	10	15	10
2	25	12	10	8	15	12	20	10	15	12
3	17	11	22	10	18	12	20	10	25	10
4	12	5	15	15	15	10	20	9	15	15
5	18	5	15	12	20	15	20	15	15	10
6	20	10	18	8	12	10	18	15	20	10
7	10	10	15	12	35	10	20	15	13	12
8	21	16	18	15	20	10	18	12	13	9
9	15	15	10	10	20	12	25	12	25	8
10	30	12	8	8	20	15	20	12	15	10
average	17.8	11.1	16.1	10.8	20.0	13.8	21.1	12.0	11.1	10.6

Average width of grain= 11.66 spaces

" length " " = 18.4 "

Measurements are in spaces on micrometer eye piece, and have a comparative value only.

-TABLE NO. VI- Part II.

QUARTZ. Average SCreen Diameter = 1.755mm

	SAMPLE NO.									
	1		2		3		4		5	
Gr.No	L	W	L	W	L	W	L	W	L	W
1	100	50	70	60	90	60	120	63	95	60
2	90	65	80	75	100	55	90	55	160	55
3	90	10	170	50	120	10	115	70	100	70
4	80	55	95	70	80	65	80	60	70	68
5	130	65	120	70	90	65	70	65	85	59
6	70	60	100	70	145	65	135	70	70	73
7	80	70	90	60	70	55	80	55	95	60
8	110	60	70	65	80	60	90	65	75	64
9	80	70	85	50	70	65	75	60	120	57
10	75	55	90	55	90	70	80	55	80	60
aver-age	90.5	62.0	97.0	62.5	94.5	63.0	93.5	61.8	95.0	62.6

Average width of grain = 43.35 spaces.

" length " " = 73.6 "

Measurements are in spaces on micrometer eye piece and have only a comparative value.

-TABLE NO. VII- Part I.

GALENA. Average Screen Diameter = 0.325 M M

	SAMPLE NO.									
	1		2		3		4		5	
Gr. No.	L	W	L	W	L	W	L	W	L	W
1	23	20	25	21	25	17	45	15	30	15
2	50	15	25	20	20	18	38	15	30	13
3	20	18	25	15	40	17	25	20	35	17
4	30	15	40	15	30	20	25	20	25	15
5	20	21	35	15	35	18	30	20	37	21
6	40	13	20	20	30	13	35	17	30	20
7	25	17	35	20	20	20	20	13	30	13
8	30	20	35	13	40	18	20	17	35	13
9	25	20	20	15	25	15	30	15	20	20
10	23	21	70	23	30	20	35	25	30	20
average	28.6	18.5	28.7	18.1	28.5	18.1	28.3	18.0	27.2	18.2

Average width of grain = 18.2 space

" length " " = 28.3 "

Measurements are in spaces on micrometer eye piece and have a comparative value only.

-TABLE NO. VII- Part II.

QUARTZ. Average Screen Diameter = 1.066 M M

	SAMPLE NO.									
	1		2		3		4		5	
Gr.No.	L	W	L	W	L	W	L	W	L	W
1	100	50	70	60	90	60	120	63	95	60
2	90	65	80	75	100	55	90	55	160	55
3	90	70	170	50	120	70	115	70	100	70
4	80	55	95	70	80	65	80	60	70	68
5	130	65	120	70	90	65	70	65	85	59
6	70	60	100	70	145	65	135	70	70	73
7	80	70	90	60	70	55	80	55	95	60
8	110	60	70	65	80	60	90	65	75	64
9	80	70	85	50	70	65	75	60	120	57
10	75	55	80	65	90	70	80	55	80	60
Average	90.5	62.0	97.0	62.5	94.5	63.0	93.5	61.8	95.0	62.6

Average width of grain = 60.4 spaces

" length " " = 94.1 "

Measurements are in spaces on micrometer eye piece and have a comparative value only.

-TABLE NO. VIII- Part I.

GALENA. Average Screen Diameter =0.221 M M

	SAMPLE NO.									
	1		2		3		4		5	
Gr.No	L	W	L	W	L	W	L	W	L	W
1	15	6	13	6	14	6	10	7	8	5
2	15	7	15	5	9	7	14	6	10	6
3	13	7	15	5	13	6	8	7	14	7
4	10	5	12	7	10	6	13	6	15	5
5	12	9	20	7	7	6	9	7	8	6
6	7	7	13	6	9	5	8	5	15	7
7	9	6	8	7	10	7	13	6	9	6
8	10	5	10	7	15	7	11	6	20	5
9	13	7	7	7	10	5	9	5	8	5
10	8	6	8	6	8	6	10	8	15	7
Average	11.2	5.5	11.3	6.4	10.5	6.1	10.5	6.3	12.2	6

Average width of grain = 6.06 spaces.

" length " " = 11.14 "

Measurements are in spaces on micrometer eye piece and have a comparative value only.

-TABLE NO. VIII- Part II.

QUARTZ Average Screen Diameter = 0.645 M M

	SAMPLE NO.									
	1		2		3		4		5	
Gr.No.	L	W	L	W	L	W	L	W	L	W
1	60	20	40	30	35	30	35	18	45	20
2	40	30	25	25	40	30	40	28	50	25
3	70	25	40	20	60	20	50	20	50	30
4	30	20	38	20	60	25	60	25	30	18
5	30	25	45	30	35	25	50	30	60	25
6	40	30	70	30	50	25	35	25	45	18
7	40	25	65	20	60	30	40	25	60	20
8	48	25	60	20	35	20	60	30	60	20
9	65	20	50	25	50	20	40	25	50	30
10	60	23	45	20	30	20	50	20	60	25
Aver-age	48.3	24.3	50.3	24.0	45.5	23.5	46.0	23.6	51.0	23.1

Average width of grain = 23.75 spaces.

" lentgh " " = 48.3 "

Measurements are in spaces on micrometer eye piece and have a comparative value only.