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# The effect of impeller speed and air-volume on the flotation rate with respect to particle size

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# THE EFFECT OF IMPELLER SPEED AND AIR VOLUME ON THE FLOTATION RATE WITH RESPECT TO PARTICLE SIZE

BY

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# INTRODUCTION

In the early days of mining, the ore deposits were high grade and the ore could be sent directly to the smelter. Since this time, the high grade deposits have almost vanished and low grade ores had to be mined. The need for concentrating the mined ore became apparent and various concentrating devices such as jigs and tables were developed.

Today the ore being mined is low grade and the mineralization has become very complex. In order to concentrate a complex ore, the requirement of grinding the ore very fine is imposed. The process of flotation was developed to concentrate the finely ground ore particles; however, the finer size fractions of the ore still present a concentrating problem.

The fact has been established that the flotation rate which is the recovery that can be attained during a given time interval varies with particle size.(1) The Flotation

(1) Morris, T. M., Measurement of flotation rate as a function of particle size, Thesis, Missouri School of Mines and Metallurgy, Rolla, Mo., 1950.

rate increases with an increase in particle size until the maximum flotation rate is reached. Morris found the maximum flotation rate to occur in the size range of 50 to 60 microns for copper and pyrite. After the maximum flotation rate is reached, the flotation rate decreases with an increase in particle size.

The results of the investigation in which the impeller speed and air volume are varied indicates what effects these variables have on the flotation rate in regard to the particle size. Knowledge of these effects would be of great importance in determining the impeller speed and air volume necessary for each flotation cell in a bank of flotation cells in order to attain the maximum recovery. Impeller speed and volume of air are two important factors upon which the flotation rate of various sizes of particles depends.

The problem of measuring the flotation rate has been considered by many investigators and their methods of expressing the flotation rate have been varied. In order to compare flotation rates, it is more satisfactory to compare straight lines than exponential curves which result from plotting cumulative recovery versus cumulative flotation time from the results of a flotation test. The equation from this type of exponential curve was expressed in 1935 by H. Garcia Zuniga[2] to be,

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(2) Zuniga, H. Garcia, Bol. Minero Soc. Nacl. Mineria, Chile. vol. 47, pp. 83-86, 1935.

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$$r = R(1 - e^{-kt})$$

where $r$ = amount recovery

$R$ = original amount

$t$ = flotation time

$k$ = a constant.

The equation may be rearranged and the resulting form will be

$$K = \frac{1}{T} \ln \frac{R}{R - r}.$$

This form of the equation is comparable to a unimolecular first order reaction,[3] and was used by Morris[4] in

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(3) Prutton, C. F., and Maron, S. H., Fundamental principles of physical chemistry, pp. 608-650, New York, The Macmillan Company, 1948.

(4) Morris, T. M., op. cit.

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measuring the flotation rate constant, K, for various particle sizes used in flotation tests that he conducted.

Volkova[5] suggested that an equation similar in form

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(5) Volkova, Z., Acta Physicochimica U.R.S.S., vol. 22, p. 331, 1947.

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to a second order reaction equation should apply under certain conditions to the exponential curve, but he gave no experimental confirmation. Arbiter[6] gave a presentation

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(6) Arbiter, Nathaniel, Flotation rates and flotation efficiency: Am. Inst. Min. Met. Trans., T. P. 3193, p. 991, 1951.

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of the use of a second order peaction equation and supported it with experimental flotation results. This type of equation is expressed as

$$R = \frac{A^2 K T}{1 + AKT}$$

WHERE $R$ = CUMULATIVE RECOVERY

$T$ = FLOTATION TIME

$A$ = MAXIMUM POSSIBLE RECOVERY

$K$ = A CONSTANT.

# MEASUREMENT OF THE FLOTATION RATE

The law of mass action which states that the rate of a chemical reaction is proportional to the active masses of the reacting substances at any time may be used as a basis for determining the equation of the exponential curve resulting from a plot of recovery versus time. The application of this law to flotation would involve the modifications of the terms flotation reaction for chemical reaction and flotable masses for active masses. A reaction of this nature may be of the following type;

$$A(\text{solids}) + B(\text{air}) \longrightarrow \text{Products}(\text{froth}).$$

However, the exact mechanism is not known. During this operation the concentration of air is kept constant. With this condition existing the possibility exists that the reaction would act similar to a first order reaction, and may be classified as a pseudo-first-order reaction[7].

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(7) Hougen, O. A. and Watson, K. M., Chemical process principles, Part three, Kinetics and catalysis, p. 828, New York, John Wiley and Sons, 1947.

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In this case only the reactant A, the solids, would affect the rate of the reaction. Similarly if 1.5 or 2 A (solids) would react with air to form the product (froth), the reactions would be classified as a pseudo-three-halves-order or pseudo-second-order reaction respectively.

The material used in the investigation was pyrite-pyrrhotite concentrate. Since all of the material had

BEEN FLOATED, IT WAS ASSUMED THAT ALL OF THE MATERIAL WAS CAPABLE OF BEING REFLOATED. THIS ASSUMPTION IS WITHIN REASON; HOWEVER, OXIDATION OF THE PARTICLES WOULD TEND TO DEPRESS THEM.

FIRST AND SECOND ORDER RATE EQUATIONS WERE TRIED IN ORDER TO EVALUATE THE FLOTATION RATE FROM THE EXPERIMENTAL RESULTS. THESE METHODS DID NOT FIT THE DATA AS WELL AS WHEN USING A THREE-HALVES ORDER RATE EQUATION. LAIDLER[(8)] EXPLAINS THAT THE MOST DIRECT METHOD OF FINDING THE ORDER OF A REACTION IS TO TAKE THE VARIOUS INTEGRATED RATE EQUATIONS AND DETERMINE WHICH ONE BEST DESCRIBES THE REACTION. THIS PROCEDURE INVOLVES THE DETERMINATION OF THE SPECIFIC RATE CONSTANT WHICH SHOULD NOT DRIFT AS THE VALUES OF TIME INCREASE. THIS METHOD IS NOT VERY SENSITIVE FOR DISTINGUISHING BETWEEN ORDERS SUCH AS UNITY AND THREE-HALVES.

SINCE THE THREE-HALVES ORDER RATE EQUATION FITS THE EXPERIMENTAL RESULTS BEST OF THE THREE RATE EQUATIONS, IT WAS CHOSEN TO EVALUATE THE FLOTATION RATE. IT MUST BE REMEMBERED THAT EVALUATING THE FLOTATION RATE IS THE IMPORTANT FACTOR, AND NO ATTEMPT IS MADE TO ESTABLISH THE ORDER OF THE REACTION SINCE THE EXACT MECHANISM IS NOT KNOWN. THE RATE OF A THREE-HALVES ORDER REACTION MAY BE

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(8) LAIDLER, K. J., CHEMICAL KINETICS, P. 13, NEW YORK, MCGRAW-HILL BOOK COMPANY, 1950.

EXPRESSED AS

$$\frac{dX}{dT} = K(A-X)^{1.5} \qquad \text{(Eq. 1)}$$

WHERE X = CUMULATIVE RECOVERY

A = INITIAL CONCENTRATION

T = FLOTATION TIME

K = A CONSTANT, FLOTATION RATE CONSTANT.

INTEGRATION OF EQUATION 1 GIVES THE EQUATION

$$\frac{1}{(A-X)^{\frac{1}{2}}} = \frac{K}{2}T + \frac{1}{A^{\frac{1}{2}}}. \qquad \text{(Eq. 2)}$$

BY PLOTTING $1/(A-X)^{\frac{1}{2}}$ VERSUS THE FLOTATION TIME, T, THE FLOTATION RATE CONSTANT, K, CAN BE DETERMINED SINCE IT WILL BE EQUAL TO TWICE THE SLOPE OF THE RESULTING LINE. THE ORDINATE INTERCEPT WOULD BE EQUAL TO $1/A^{\frac{1}{2}}$, AND IF A IS 100 PER CENT, THIS INTERCEPT SHOULD BE 0.1(PER CENT)$^{-\frac{1}{2}}$.

THE FLOTATION RATE CONSTANT AND THE INTERCEPT WERE CALCULATED BY THE METHOD OF LEAST SQUARES[9] AFTER THE DATA

(9) HOUGEN, O. A., AND WATSON, K. M., OP. CIT., PP. 938-942.

WAS PLOTTED IN ACCORDANCE WITH EQUATION 2. FOR AN EQUATION OF A STRAIGHT LINE

$$Y = A + BX. \qquad \text{(Eq. 3)}$$

THE EQUATIONS WITH RESPECT TO THE CONSTANTS A AND B USING THE METHOD OF LEAST SQUARES ARE

$$NA + B\sum X - \sum Y = 0 \qquad \text{(Eq. 4)}$$

$$A\sum X + B\sum X^2 - \sum YX = 0 \qquad \text{(Eq. 5)}$$

WHERE N IS THE NUMBER OF OBSERVATIONS. SOLVING EQUATIONS

4 and 5 simultaneously for the constants A and B gives

$$A = \frac{\Sigma Y \, \Sigma X^2 - \Sigma YX \, \Sigma X}{N \, \Sigma X^2 - (\Sigma X)^2} \qquad \text{(Eq. 6)}$$

and

$$B = \frac{\Sigma Y \, \Sigma X - N \, \Sigma YX}{(\Sigma X)^2 - N \, \Sigma X^2} \, . \qquad \text{(Eq. 7)}$$

The constants in the rate equation, equation 2, which is also the equation of a straight line may be substituted for their equals into equations 6 and 7. That is,

$$\frac{K}{2} = B$$

and

$$\frac{1}{A^{\frac{1}{2}}} = A.$$

Therefore it follows that,

$$\frac{1}{A^{\frac{1}{2}}} = \frac{\Sigma Y \, \Sigma X^2 - \Sigma YX \, \Sigma X}{N \, \Sigma X^2 - (\Sigma X)^2}$$

and

$$K = \frac{2(\Sigma Y \, \Sigma X - N \, \Sigma YX)}{(\Sigma X)^2 - N \, \Sigma X^2} \, .$$

An example of the calculations is shown using the data for the 89 micron size fraction of Test I-I.

Table I

CALCULATED DATA FOR 89 MICRON SIZE FRACTION OF TEST I-I

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | $T^2$ | $T/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|
| 20 | 22.75 | 77.25 | 0.1138 | 400 | 2.276 |
| 40 | 12.47 | 64.78 | 0.1242 | 1600 | 4.968 |
| 60 | 8.14 | 56.64 | 0.1329 | 3600 | 7.974 |
| 90 | 12.10 | 44.54 | 0.1498 | 8100 | 13.482 |
| 150 | 15.90 | 28.64 | 0.1868 | 22500 | 28.020 |
| 360 | | | 0.7075 | 36200 | 56.720 |

$$\frac{1}{A^{\frac{1}{2}}} = \frac{(0.7075)(36200) - (56.720)(360)}{(5)(36200) - (360)^2}$$

$$\frac{1}{A^{\frac{1}{2}}} = 0.1012 \ \frac{1}{(\text{PER CENT})^{\frac{1}{2}}}$$

$$K = 2 \ \frac{(0.7075)(360) - 5(56.720)}{(360)^2 - 5(36200)}$$

$$K = 0.001125 \ \frac{1}{(\text{SEC.})(\text{PER CENT})^{\frac{1}{2}}}$$

$$K = (0.001125)(60)$$

$$K = 0.0675 \ \frac{1}{(\text{MIN.})(\text{PER CENT})^{\frac{1}{2}}}$$

## PREPARATION OF CONCENTRATES FOR EXPERIMENTAL WORK

Three attrition tests were made on Tennessee Copper Company ore[(10)] that had been crushed to $-\frac{1}{4}$ inch in a jaw

(10) Taggart, A. F., Handbook of mineral dressing, *chap. 2, pp. 67-68, New York, John Wiley and Sons, 1945.*

crusher and ground to -35 mesh in rolls. A 330 gram sample of the -35 mesh ore was thoroughly mixed and rolled on a rolling cloth. Then three 100 gram samples were weighed for subsequent treatment.

The size distribution of the 330 gram sample of -35 mesh ore is shown in Table 2. Tables 3, 4, and 5 show the size distribution of the three 100 gram samples after they had been agitated in a mechanical type flotation cell, with

Table 2

SIZE DISTRIBUTION OF 330 GRAM SAMPLE OF -35 MESH ORE

| Size Mesh | Wt. Held (gms) | Per cent Held | Cum. Per cent Held |
|---|---|---|---|
| -35, +48 | 72.8 | 22.13 | 22.13 |
| -48, +65 | 65.0 | 19.76 | 41.89 |
| -65, +100 | 56.9 | 17.29 | 59.18 |
| -100, +150 | 39.0 | 11.85 | 71.03 |
| -150, +200 | 27.6 | 8.39 | 79.42 |
| -200 | 67.7 | 20.58 | 100.00 |
| Sum | 329.0 | 100.00 | |

TABLE 3

SIZE DISTRIBUTION OF 100 GRAM SAMPLE
*AFTER 2 MINUTES OF AGITATION IN CELL*

| SIZE MESH | WT. HELD (GMS) | PER CENT HELD | CUM. PER CENT HELD |
|---|---|---|---|
| -35, +48 | 22.1 | 22.48 | 22.48 |
| -48, +65 | 18.8 | 19.13 | 41.61 |
| -65, +100 | 17.0 | 17.29 | 58.90 |
| -100, +150 | 11.5 | 11.70 | 70.60 |
| -150, +200 | 8.2 | 8.34 | 78.94 |
| -200 | 20.7 | 21.06 | 100.00 |
| SUM | 329.0 | 100.00 | |

TABLE 4

SIZE DISTRIBUTION OF 100 GRAM SAMPLE
AFTER 4 MINUTES OF AGITATION IN CELL

| SIZE MESH | WT. HELD (GMS) | PER CENT HELD | CUM. PER CENT HELD |
|---|---|---|---|
| -35, +48 | 20.7 | 21.19 | 21.19 |
| -48, +65 | 18.6 | 19.04 | 40.23 |
| -65, +100 | 16.9 | 17.30 | 57.53 |
| -100, +150 | 11.7 | 11.97 | 69.50 |
| -150, +200 | 8.1 | 8.29 | 77.79 |
| -200 | 21.7 | 22.21 | 100.00 |
| SUM | 97.7 | 100.00 | |

TABLE 5

SIZE DISTRIBUTION OF 100 GRAM SAMPLE
AFTER 8 MINUTES OF AGITATION IN CELL

| SIZE MESH | WT. HELD (GMS) | PER CENT HELD | CUM. PER CENT HELD |
|---|---|---|---|
| -35, +48 | 20.7 | 21.27 | 21.27 |
| -48, +65 | 19.0 | 19.53 | 40.80 |
| -65, +100 | 16.9 | 17.37 | 58.17 |
| -100, +150 | 11.5 | 11.82 | 69.99 |
| -150, +200 | 7.9 | 8.12 | 78.11 |
| -200 | 21.3 | 21.89 | 100.00 |
| SUM | 97.3 | 100.00 | |

700 cc. of water. All of the samples were screened for 15 minutes using a Ro-Tap testing sieve shaker. The agitation time in the flotation cell for the three samples was 2, 4, and 8 minutes respectively.

The results of the attrition tests showed that the size of the particles of the Tennessee Copper Company ore remained, within reason, the same after being subjected to agitation for varied periods of time. Therefore this ore was found suitable to use in preparing pyrite concentrate for use in the experimental work. It is very important that the size of the particles in the concentrates remain constant during the experimental work in order to attain accurate results since the flotation rate constant was studied with respect to particle size.

The next step required was the preparation of 10,000 grams of pyrite concentrate from the Tennessee Copper Company ore. This concentrate also contained some pyrrhotite. The desired size distribution of the concentrate is shown in Table 6.

Table 6

DESIRED SIZE DISTRIBUTION OF CONCENTRATES
FOR EXPERIMENTAL WORK

| Size Mesh | Per cent | Weight (gms) |
|---|---|---|
| -48, +65 | 6 | 600 |
| -65, +100 | 8 | 800 |
| -100, +150 | 9 | 900 |
| -150, +200 | 12 | 1200 |
| -200 | 65 | 6500 |
| Sum | 100 | 10000 |

A 20,000 gram portion of ore, chiefly -3/4 inch size, was crushed in a jaw crusher to -3/8 inch and ground in rolls. The product from the rolls was screened on a 48 mesh screen and the oversize material was given another pass through the rolls. This procedure was repeated until all of the material passed the 48 mesh screen.

The -48 mesh ore was concentrated in a 500 gram Fagergren flotation machine. The rougher concentrate was cleaned twice. The final cleaned concentrate was filtered, washed with water, and washed three times with acetone. The reagents used for concentrating the ore are shown in Table 7.

TABLE 7

REAGENTS USED FOR CONCENTRATING
TENNESSEE COPPER COMPANY ORE

| Reagent | Lbs./Ton |
|---|---|
| Sodium Xanthate | 0.20 |
| Amyl Xanthate | 0.10 |
| Sulfuric Acid | (to obtain pH about 6) |
| Pine Oil | 0.15 |

About 10,000 grams of pyrite-pyrrhotite concentrate was produced. A Ro-Tap testing sieve shaker was used to size the concentrate. Lots of 200 grams each were screened for 20 minutes. The final size distribution of the concentrate was in close agreement with the desired distribution as shown in Table 6. Each size fraction of the concentrate was carefully rolled to assure uniformity. The concentrate was then in the final stage, and the experimental work began.

# EXPERIMENTAL PROCEDURE

The preliminary tests and final tests were made using a 250 gram mechanical type flotation machine similar to the one described by W. F. Dietrich[11] et al. The cell

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(11) Dietrich, W. F., Engel, A. L., and Guggenheim, Morris, U. S. Bur. Mines Rept. Inv. 3328, p. 26, 1937.

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was charged with 75 grams of concentrate and 700 cc. of water. A series of preliminary tests were made to determine the optimum conditions for conducting the final tests. From these tests it was found that the average pH during flotation reached a critical point around 3.5. On either side of a pH of 3.5 the recovery and flotation rate were markedly decreased.

Potassium ethyl xanthate was the collector used. As the amount of xanthate was increased the recovery also increased. The recovery reached a maximum when the xanthate addition was 37 milligrams per 75 grams of concentrate fed to the cell. This indicates that all of the particles in the cell are able to gain maximum collector coating. This is necessary to give all of the particles the maximum opportunity to be floatable.

Terpineol was used as the frothing agent in the amount of 10 milligrams per 75 grams of concentrate fed to the cell.

Twenty final tests were made varying the volume of air and impeller speed. Compressed air was fed to the cell. A gauge, calibrated in liters per minute, was connected in the air line so direct readings could be made. The impeller speeds were 863, 1294, 1725 and 2048 revolutions per minute. Five air volumes, 1.0, 2.0, 2.5, 3.0, and 3.5 liters per minute, were used for each impeller speed.

Table 8 shows the constituents charged to the flotation cell for each run. Four runs were made having the same air volume and impeller speed, and the three runs having the most similar flotation rate constants were combined to make one test. This was necessary in order to have a sufficient amount of solids, about 20 grams, in each froth before being sized. If the weight of the material charged to the infrasizer is too small, the three finer size fractions have the tendency to hold up and not elutriate in the proper manner. It is also important to have sufficient weights of material in each size fraction so that a small loss of material would not noticeably affect the results.

Table 8

FLOTATION FEED FOR EACH RUN

| Constituent | Amount |
|---|---|
| Pyrite-pyrrhotite concentrate | 75 gms. |
| Distilled water | 700 cc. |
| Sulfuric acid (conc.) | 0.2 cc. |
| Potassium ethyl xanthate | 37 mg. |
| Terpineol | 10 mg. |

The potassium ethyl xanthate that was used had been purified.[12] This was done each day a test was made,

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(12) Wark, I. W., and Cox, A. B., Principles of flotation, I - An experimental study of the effect of xanthates on contact angles at mineral surfaces: Am. Inst. Min. Met. Trans., vol. 26, pp. 193-194, 1935.

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and enough purified xanthate was made for use in four runs.

The flotation cell was charged in the following manner. The sulfuric acid was added to 700 cc. of distilled water and approximately 400 cc. of the resulting mixture was poured into the cell. One drop, 10 mg., of terpineol was added to the remaining water acid mixture. Then 75 grams of pyrite-pyrrhotite concentrate having the size distribution as shown in Table 6 was added to the cell. Next, 37 mg. of purified potassium ethyl xanthate was added to the cell followed by the remaining portion of the water acid mixture containing the terpineol. The air, motor, and a stop watch were started simultaneously and flotation began. During the flotation operation distilled water, containing 10 mg. of terpineol per 700 cc., was added to keep the pulp level in the cell constant.

The froth for the first 20 seconds was collected in a pan. The froth from the second 20 second interval was collected in a second pan. This procedure was repeated for three more time intervals of 20, 30, and 60 seconds. Froth was also collected in a sixth pan to assure that flotation had not stopped prior to the termination of the fifth time interval. The froth appeared to be barren during the first 60 second of the sixth time interval. After each run the froth collected in the sixth pan was combined with the final tailings.

It was important to keep the concentration of frothing agent, terpineol, constant throughout each run since this reagent affects the surface tension. Consequently, it also affects the size distribution of the bubbles.

Each froth was filtered, washed twice with acetone, dried, and weighed. A plot of time versus $1/(A-X)^{\frac{1}{2}}$ was made for each run to determine the flotation rate constant, K, for each run. An example of the data that was

Table 9

OBSERVED DATA FROM FOUR RUNS HAVING THE SAME AIR VOLUME AND IMPELLER SPEED

Test 2-3 Impeller Speed---2048 rpm
Air Volume---2.5 liters/min.

| Run | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Gms. of Solids in Froth after | | | | |
| 20 sec. | 18.3 | 20.8 | 19.7 | 20.2 |
| 40 sec. | 10.4 | 10.8 | 15.0 | 11.6 |
| 60 sec. | 7.5 | 9.4 | 8.2 | 10.3 |
| 90 sec. | 7.3 | 8.8 | 7.2 | 8.0 |
| 150 sec. | 10.0 | 8.2 | 6.4 | 7.1 |
| Tails | 19.8 | 15.5 | 16.7 | 16.2 |
| Sum | 73.3 | 73.5 | 73.2 | 73.4 |
| K $(1/\text{min.})(\text{per cent})^{\frac{1}{2}}$ | 0.066 | 0.089 | 0.086 | 0.085 |

collected for the four runs is shown in Table 9. On the basis of the flotation rate constant, K, runs 2, 3, and 4 were combined to make Test 2-3. That is, the froths from the first time interval were combined, the froths from the second time interval were combined, and so forth. Likewise the tailings were combined.

The combined froths and tailings were each screened for 40 minutes using a Ro-Tap testing sieve shaker. The screens used were 35, 48, 65, 100, 150, and 200 mesh. The -200 mesh fraction was then elutriated with air for 2 hours using a Haultain infrasizer. The resulting size fractions from the screens and infrasizer were weighed to the nearest milligram. The mean diameter of the particles in each size fraction is shown in Table 10.(13) The loss during

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(13) Taggart, A. F., Handbook of Mineral Dressing, chap. 19, pp. 115-116, New York, John Wiley and Sons, 1945.

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the sizing operation varied from 2 to 3 per cent. This loss was assumed to be equally distributed throughout the size fractions. The validity of this assumption in questionable; however, the small per centage of material that was lost in sizing would not significantly alter the final results.

The data obtained from the twenty experimental tests appears in the Tables 11 to 30. The calculated data are included in the appendix. Figures 1 to 20 which follow

TABLE 10

MEAN DIAMETER OF PARTICLES IN EACH SIZE FRACTION

| | Size Fraction | Size Range (Microns) | Mean Diameter (Microns) |
|---|---|---|---|
| Screen (Mesh) | -48, +65 | 208-295 | 252 |
| | -65, +100 | 147-208 | 178 |
| | -100, +150 | 104-147 | 126 |
| | -150, +200 | 74-104 | 89 |
| Infrasizer (Cones) | 1 | 46-74 | 60 |
| | 2 | 32-46 | 39 |
| | 3 | 23-32 | 27.5 |
| | 4 | 16-23 | 19.5 |
| | 5 | 11.5-16 | 13.8 |
| | 6 | 8-11.5 | 9.8 |
| | 7 | Less than 8 | -8 |

THE EXPERIMENTAL RESULTS SHOW A GRAPHIC REPRESENTATION OF THE FINAL RESULTS. THE SLOPE OF THE LINES ON THESE FIGURES IS A MEASURE OF THE FLOTATION RATE. THE FLOTATION RATE CONSTANTS FOR ALL OF THE SIZE FRACTIONS FOR EACH TEST APPEAR IN TABLES 31 AND 32.

## Table II

### Size Distribution of Particles in Froth

Test 1-1 Impeller Speed --- 1725 RPM Air Volume --- 1.0 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.058 | 0.039 | 0.027 | 0.058 | 0.203 | 10.428 | 10.813 |
| 178 | 0.769 | 0.522 | 0.352 | 0.834 | 2.115 | 14.568 | 19.160 |
| 126 | 2.642 | 1.656 | 1.207 | 2.349 | 3.552 | 7.260 | 18.666 |
| 89 | 5.279 | 2.892 | 1.889 | 2.807 | 3.690 | 6.646 | 23.203 |
| 60 | 20.102 | 12.896 | 8.034 | 9.101 | 9.172 | 17.865 | 77.170 |
| 39 | 5.110 | 3.090 | 2.135 | 2.499 | 2.254 | 5.681 | 20.769 |
| 27.5 | 3.418 | 2.250 | 1.298 | 2.280 | 2.123 | 4.389 | 15.758 |
| 19.5 | 2.337 | 1.348 | 1.482 | 1.846 | 1.705 | 3.061 | 11.779 |
| 13.8 | 1.812 | 0.791 | 0.774 | 0.861 | 0.902 | 2.350 | 7.490 |
| 9.8 | 0.924 | 0.417 | 0.254 | 0.224 | 0.252 | 1.428 | 3.499 |
| -8 | 0.127 | 0.150 | 0.137 | 0.177 | 0.157 | 0.835 | 1.583 |
| Sum | 42.578 | 26.051 | 17.589 | 23.036 | 26.125 | 74.511 | 209.890 |
| Original Gms. of Froth | 43.523 | 27.761 | 18.940 | 23.461 | 28.385 | 77.985 | 220.055 |

TABLE 12

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST I-2 IMPELLER SPEED --- 1725 RPM AIR VOLUME --- 2.0 LITERS/MIN.

| MEAN DIA. | GRAMS OF SOLIDS IN FROTH AFTER | | | | | GMS. SOLIDS | |
|---|---|---|---|---|---|---|---|
| MICRONS | 20 SEC. | 40 SEC. | 60 SEC. | 90 SEC. | 150 SEC. | IN TAILS | TOTALS |
| 252 | 0.090 | 0.083 | 0.055 | 0.122 | 0.510 | 10.068 | 10.928 |
| 178 | 1.984 | 0.646 | 0.373 | 0.803 | 1.847 | 14.223 | 19.876 |
| 126 | 5.760 | 1.925 | 1.091 | 1.733 | 2.334 | 7.170 | 20.013 |
| 89 | 5.528 | 2.871 | 1.740 | 2.086 | 2.520 | 9.260 | 24.005 |
| 60 | 9.865 | 5.229 | 2.553 | 2.206 | 3.046 | 14.138 | 37.037 |
| 39 | 11.002 | 5.500 | 2.742 | 3.190 | 3.452 | 7.587 | 33.473 |
| 27.5 | 7.044 | 4.332 | 2.530 | 2.607 | 2.838 | 5.361 | 24.712 |
| 19.5 | 3.868 | 2.852 | 1.776 | 1.906 | 2.095 | 4.041 | 16.538 |
| 13.8 | 2.401 | 1.832 | 1.219 | 1.340 | 1.560 | 2.891 | 11.243 |
| 9.8 | 0.531 | 0.983 | 0.213 | 0.347 | 0.866 | 2.541 | 5.481 |
| -8 | 2.745 | 1.963 | 1.626 | 1.958 | 1.421 | 3.774 | 13.487 |
| SUM | 50.818 | 28.216 | 15.918 | 18.298 | 22.489 | 81.054 | 216.793 |
| ORIGINAL GMS. OF FROTH | 52.508 | 29.196 | 16.807 | 19.191 | 23.868 | 82.196 | 223.766 |

## Table 13

### SIZE DISTRIBUTION OF PARTICLES IN FROTH

Test 1-3 Impeller Speed --- 1725 rpm Air Volume --- 2.5 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.060 | 0.050 | 0.079 | 0.120 | 0.178 | 10.817 | 11.304 |
| 178 | 1.057 | 0.940 | 0.956 | 1.097 | 1.250 | 14.695 | 19.995 |
| 126 | 3.670 | 2.756 | 2.326 | 2.016 | 1.939 | 7.515 | 20.222 |
| 89 | 6.519 | 3.745 | 2.630 | 2.283 | 2.174 | 6.414 | 23.765 |
| 60 | 12.331 | 5.031 | 3.554 | 2.459 | 1.475 | 11.363 | 36.213 |
| 39 | 12.017 | 8.300 | 3.459 | 2.367 | 2.808 | 4.062 | 33.013 |
| 27.5 | 7.580 | 4.773 | 2.920 | 2.432 | 2.241 | 5.176 | 25.122 |
| 19.5 | 4.220 | 3.274 | 2.036 | 1.757 | 1.668 | 3.860 | 16.815 |
| 13.8 | 2.656 | 2.152 | 1.425 | 1.310 | 1.330 | 2.309 | 11.182 |
| 9.8 | 1.142 | 1.033 | 0.738 | 0.522 | 0.696 | 1.474 | 5.605 |
| -8 | 3.074 | 3.112 | 1.857 | 1.607 | 1.344 | 2.234 | 13.228 |
| Sum | 54.326 | 35.166 | 21.980 | 17.970 | 17.103 | 69.919 | 216.464 |
| Original Gms. of Froth | 55.587 | 35.569 | 22.505 | 18.769 | 18.188 | 71.414 | 222.032 |

## Table 14

### Size Distribution of Particles in Froth

Test I-4 Impeller Speed --- 1725 rpm Air Volume --- 3.0 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.101 | 0.057 | 0.045 | 0.070 | 0.252 | 13.300 | 13.825 |
| 178 | 1.427 | 0.725 | 0.559 | 0.857 | 1.935 | 14.160 | 19.663 |
| 126 | 4.019 | 2.032 | 1.525 | 1.969 | 2.967 | 7.522 | 20.034 |
| 89 | 6.220 | 2.962 | 2.236 | 2.372 | 2.976 | 5.865 | 22.631 |
| 60 | 23.050 | 10.838 | 8.131 | 7.461 | 8.000 | 13.306 | 70.786 |
| 39 | 7.153 | 4.252 | 2.770 | 2.910 | 2.337 | 5.060 | 24.482 |
| 27.5 | 4.072 | 2.692 | 1.918 | 1.906 | 1.763 | 3.669 | 16.020 |
| 19.5 | 3.109 | 2.265 | 1.206 | 1.952 | 1.809 | 2.651 | 12.992 |
| 13.8 | 1.731 | 1.326 | 0.975 | 0.970 | 0.902 | 1.904 | 7.808 |
| 9.8 | 0.506 | 0.564 | 0.218 | 0.230 | 0.333 | 0.541 | 2.392 |
| -8 | 0.449 | 0.328 | 0.186 | 0.233 | 0.248 | 0.408 | 1.852 |
| Sum | 51.837 | 28.041 | 19.769 | 20.930 | 23.522 | 68.386 | 212.485 |
| Original Gms. of Froth | 53.506 | 28.640 | 21.000 | 21.257 | 24.326 | 70.111 | 218.840 |

## Table 15

### SIZE DISTRIBUTION OF PARTICLES IN FROTH

Test 1-5 Impeller Speed --- 1725 rpm Air Volume --- 3.5 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.081 | 0.070 | 0.051 | 0.087 | 0.240 | 13.187 | 13.716 |
| 178 | 1.187 | 1.022 | 0.686 | 1.000 | 1.827 | 14.433 | 20.155 |
| 126 | 4.337 | 2.780 | 1.757 | 2.112 | 2.500 | 6.503 | 19.989 |
| 89 | 7.246 | 3.574 | 2.148 | 2.251 | 2.427 | 4.255 | 21.901 |
| 60 | 16.045 | 4.753 | 2.485 | 2.162 | 6.003 | 12.040 | 43.488 |
| 39 | 10.857 | 7.453 | 3.599 | 3.302 | 2.629 | 4.537 | 32.377 |
| 27.5 | 8.412 | 4.719 | 2.682 | 2.459 | 1.588 | 3.440 | 23.300 |
| 19.5 | 4.826 | 3.165 | 1.912 | 1.886 | 1.153 | 3.190 | 16.132 |
| 13.8 | 3.017 | 2.175 | 1.386 | 1.450 | 0.217 | 1.987 | 10.232 |
| 9.8 | 0.967 | 0.430 | 0.643 | 0.633 | 0.127 | 0.428 | 3.228 |
| -8 | 4.042 | ----- | 4.632 | 1.141 | 0.385 | 0.447 | 10.647 |
| Sum | 61.017 | 30.141 | 21.981 | 18.483 | 19.096 | 64.447 | 215.165 |
| Original Gms. of Froth | 62.350 | 34.119 | 19.410 | 19.525 | 20.485 | 65.137 | 221.026 |

## Table 16

### Size Distribution of Particles in Froth

Test 2-1 Impeller Speed --- 2048 rpm Air Volume --- 1.0 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.095 | 0.134 | 0.230 | 0.618 | 1.588 | 8.402 | 11.067 |
| 178 | 0.545 | 0.895 | 1.178 | 2.241 | 3.316 | 11.221 | 19.396 |
| 126 | 1.978 | 2.560 | 2.334 | 2.660 | 2.460 | 6.611 | 18.603 |
| 89 | 4.002 | 3.651 | 2.652 | 2.740 | 2.529 | 7.415 | 22.989 |
| 60 | 18.820 | 11.967 | 6.835 | 6.898 | 6.874 | 27.750 | 79.144 |
| 39 | 4.691 | 3.179 | 2.027 | 2.105 | 2.268 | 7.440 | 21.710 |
| 27.5 | 3.210 | 2.130 | 1.392 | 1.340 | 1.523 | 6.625 | 16.220 |
| 19.5 | 2.120 | 1.849 | 1.037 | 0.848 | 1.466 | 5.036 | 12.356 |
| 13.8 | 1.269 | 0.972 | 0.227 | 0.739 | 0.749 | 3.542 | 7.498 |
| 9.8 | 0.707 | 0.622 | 0.264 | 0.212 | 0.233 | 0.926 | 2.964 |
| -8 | 0.445 | 0.430 | 0.130 | 0.183 | 0.150 | 1.064 | 2.402 |
| Sum | 37.882 | 28.389 | 18.306 | 20.584 | 23.156 | 86.033 | 214.349 |
| Original Gms. of Froth | 39.149 | 28.568 | 19.258 | 21.289 | 23.682 | 88.719 | 220.665 |

## Table 17

### SIZE DISTRIBUTION OF PARTICLES IN FROTH

Test 2-2 Impeller Speed --- 2048 rpm Air Volume --- 2.0 liters/min.

| Mean Dia. | Grams of Solids in Froth after | | | | | Gms. Solids | |
|---|---|---|---|---|---|---|---|
| Microns | 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | in Tails | Totals |
| 252 | 0.105 | 0.216 | 0.376 | 1.090 | 2.423 | 6.656 | 10.866 |
| 178 | 0.778 | 1.626 | 1.940 | 3.135 | 3.632 | 7.984 | 19.095 |
| 126 | 2.857 | 4.071 | 2.827 | 2.775 | 2.461 | 4.389 | 19.380 |
| 89 | 5.484 | 5.386 | 3.007 | 2.880 | 2.690 | 4.518 | 23.965 |
| 60 | 22.612 | 14.854 | 7.346 | 7.464 | 7.846 | 15.377 | 75.499 |
| 39 | 6.700 | 4.505 | 1.980 | 2.073 | 2.321 | 5.786 | 23.365 |
| 27.5 | 4.323 | 2.935 | 1.420 | 1.556 | 1.738 | 4.666 | 16.638 |
| 19.5 | 2.976 | 1.982 | 1.071 | 1.245 | 1.540 | 3.277 | 12.091 |
| 13.8 | 2.615 | 1.811 | 0.618 | 0.653 | 0.902 | 2.516 | 9.115 |
| 9.8 | 1.473 | 1.175 | 0.225 | 0.149 | 0.302 | 1.450 | 4.774 |
| -8 | 0.325 | 0.423 | 0.148 | 0.211 | 0.268 | 1.220 | 2.595 |
| Sum | 50.248 | 38.984 | 20.958 | 23.231 | 26.123 | 57.839 | 217.383 |
| Original Gms. of Froth | 50.579 | 39.230 | 21.672 | 24.045 | 26.824 | 59.590 | 221.940 |

## Table 18

### SIZE DISTRIBUTION OF PARTICLES IN FROTH

Test 2-3 Impeller Speed --- 2048 rpm Air Volume --- 2.5 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.074 | 0.209 | 0.452 | 1.157 | 2.251 | 6.862 | 11.005 |
| 178 | 0.738 | 1.657 | 2.507 | 3.160 | 3.290 | 8.095 | 19.447 |
| 126 | 3.278 | 4.090 | 3.586 | 2.629 | 1.935 | 3.992 | 19.510 |
| 89 | 6.731 | 5.079 | 3.751 | 2.621 | 2.021 | 3.680 | 23.883 |
| 60 | 25.896 | 13.282 | 9.285 | 6.860 | 6.031 | 13.271 | 74.625 |
| 39 | 8.337 | 4.890 | 2.646 | 2.300 | 1.595 | 4.188 | 23.956 |
| 27.5 | 5.273 | 3.619 | 1.808 | 1.622 | 1.308 | 3.736 | 17.366 |
| 19.5 | 3.685 | 2.245 | 1.651 | 1.615 | 1.073 | 2.679 | 12.948 |
| 13.8 | 2.663 | 0.902 | 1.252 | 0.871 | 0.863 | 1.504 | 8.055 |
| 9.8 | 0.977 | 0.589 | 0.461 | 0.546 | 0.590 | 0.615 | 3.778 |
| -8 | 0.442 | 0.143 | 0.292 | 0.276 | 0.262 | 0.586 | 2.001 |
| Sum | 58.094 | 36.705 | 27.691 | 23.657 | 21.219 | 49.208 | 216.574 |
| Original Gms. of Froth | 60.100 | 37.658 | 28.036 | 23.931 | 21.348 | 51.557 | 222.630 |

TABLE 19

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 2-4 IMPELLER SPEED --- 2048 RPM AIR VOLUME --- 3.0 LITERS/MIN.

| MEAN DIA. MICRONS | GRAMS OF SOLIDS IN FROTH AFTER | | | | | GMS. SOLIDS IN TAILS | TOTALS |
|---|---|---|---|---|---|---|---|
| | 20 SEC. | 40 SEC. | 60 SEC. | 90 SEC. | 150 SEC. | | |
| 252 | 0.074 | 0.154 | 0.274 | 0.689 | 1.629 | 7.127 | 9.947 |
| 178 | 0.590 | 1.293 | 1.610 | 2.515 | 3.431 | 9.713 | 19.152 |
| 126 | 2.570 | 4.105 | 2.904 | 2.666 | 2.488 | 5.259 | 19.992 |
| 89 | 5.441 | 5.587 | 3.019 | 2.561 | 2.488 | 4.784 | 23.880 |
| 60 | 25.854 | 16.846 | 7.162 | 6.765 | 6.696 | 13.537 | 76.860 |
| 39 | 6.013 | 4.628 | 2.293 | 1.714 | 2.057 | 5.748 | 22.453 |
| 27.5 | 4.538 | 3.270 | 1.500 | 1.507 | 1.634 | 4.290 | 16.739 |
| 19.5 | 3.209 | 2.280 | 1.144 | 1.022 | 1.541 | 3.101 | 12.297 |
| 13.8 | 1.546 | 1.953 | 0.835 | 0.525 | 0.826 | 2.713 | 8.398 |
| 9.8 | 0.900 | 1.252 | 0.506 | 0.240 | 0.430 | 1.383 | 4.711 |
| -8 | 0.238 | 0.683 | 0.492 | 0.278 | 0.316 | 1.069 | 3.076 |
| SUM | 50.973 | 42.051 | 21.739 | 20.482 | 23.536 | 58.724 | 217.505 |
| ORIGINAL GMS. OF FROTH | 52.190 | 42.387 | 22.056 | 21.300 | 24.236 | 60.501 | 222.670 |

TABLE 20

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 2-5 IMPELLER SPEED --- 2048 RPM AIR VOLUME --- 3.5 LITERS/MIN.

| MEAN DIA. MICRONS | GRAMS OF SOLIDS IN FROTH AFTER 20 SEC. | 40 SEC. | 60 SEC. | 90 SEC. | 150 SEC. | GMS. SOLIDS IN TAILS | TOTALS |
|---|---|---|---|---|---|---|---|
| 252 | 0.121 | 0.202 | 0.325 | 0.763 | 1.903 | 6.921 | 10.235 |
| 178 | 0.968 | 1.653 | 1.878 | 2.424 | 3.171 | 8.058 | 18.152 |
| 126 | 3.892 | 4.158 | 2.690 | 2.042 | 1.914 | 3.931 | 18.627 |
| 89 | 7.720 | 5.033 | 2.661 | 2.019 | 1.992 | 3.485 | 22.910 |
| 60 | 32.297 | 14.399 | 6.684 | 5.253 | 6.380 | 12.114 | 77.127 |
| 39 | 8.415 | 4.462 | 2.418 | 2.035 | 1.901 | 3.787 | 23.018 |
| 27.5 | 5.394 | 3.126 | 1.659 | 1.376 | 1.509 | 2.825 | 15.889 |
| 19.5 | 3.526 | 2.279 | 1.492 | 1.154 | 1.418 | 2.019 | 11.888 |
| 13.8 | 2.569 | 1.224 | 1.157 | 0.545 | 0.840 | 1.013 | 7.348 |
| 9.8 | 1.706 | 0.552 | 0.808 | 0.243 | 0.408 | 0.771 | 4.488 |
| -8 | 1.170 | 0.458 | 0.510 | 0.200 | 0.276 | 0.670 | 3.284 |
| SUM | 67.778 | 37.546 | 22.282 | 18.054 | 21.712 | 45.594 | 212.966 |
| ORIGINAL GMS. OF FROTH | 68.115 | 38.987 | 22.960 | 19.043 | 22.314 | 47.144 | 218.563 |

TABLE 21

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 3-1 IMPELLER SPEED --- 1294 RPM AIR VOLUME --- 1.0 LITERS/MIN.

| MEAN DIA. MICRONS | GRAMS OF SOLIDS IN FROTH AFTER 20 SEC. | 40 SEC. | 60 SEC. | 90 SEC. | 150 SEC. | GMS. SOLIDS IN TAILS | TOTALS |
|---|---|---|---|---|---|---|---|
| 252 | 0.088 | 0.120 | 0.172 | 0.367 | 1.101 | 8.613 | 10.461 |
| 178 | 0.756 | 1.065 | 1.311 | 2.054 | 3.395 | 10.736 | 10.317 |
| 126 | 2.601 | 3.207 | 2.716 | 2.722 | 2.657 | 5.544 | 19.447 |
| 89 | 4.631 | 4.457 | 3.064 | 2.731 | 2.697 | 5.704 | 23.284 |
| 60 | 19.440 | 12.903 | 6.957 | 6.972 | 8.709 | 19.974 | 74.955 |
| 39 | 4.319 | 4.220 | 2.990 | 2.532 | 2.786 | 6.307 | 23.154 |
| 27.5 | 2.956 | 2.643 | 1.745 | 1.686 | 2.052 | 4.924 | 16.006 |
| 19.5 | 2.417 | 2.048 | 1.737 | 1.510 | 1.971 | 3.358 | 13.041 |
| 13.8 | 1.453 | 1.169 | 0.983 | 0.889 | 0.929 | 2.743 | 8.166 |
| 9.8 | 0.980 | 0.593 | 0.533 | 0.461 | 0.600 | 1.367 | 4.534 |
| -8 | 0.334 | 0.273 | 0.301 | 0.261 | 0.441 | 1.766 | 3.376 |
| SUM | 39.975 | 32.698 | 22.509 | 22.185 | 27.338 | 71.036 | 215.741 |
| ORIGINAL GMS. OF FROTH | 40.554 | 34.119 | 22.537 | 22.694 | 28.142 | 72.462 | 220.508 |

## Table 22

### Size Distribution of Particles in Froth

Test 3-2 Impeller Speed --- 1294 rpm Air Volume --- 2.0 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.118 | 0.129 | 0.142 | 0.248 | 0.690 | 9.290 | 10.617 |
| 178 | 1.000 | 1.306 | 1.156 | 1.606 | 2.800 | 12.155 | 20.023 |
| 126 | 3.176 | 3.445 | 2.282 | 2.200 | 2.398 | 5.991 | 19.492 |
| 89 | 5.471 | 4.593 | 2.468 | 2.198 | 2.373 | 6.149 | 23.252 |
| 60 | 20.246 | 14.460 | 6.901 | 5.954 | 6.690 | 20.840 | 75.091 |
| 39 | 6.092 | 3.718 | 2.220 | 2.310 | 3.082 | 6.813 | 24.235 |
| 27.5 | 3.415 | 2.568 | 1.539 | 1.548 | 1.981 | 5.022 | 16.073 |
| 19.5 | 2.500 | 2.149 | 1.540 | 1.394 | 1.743 | 3.410 | 12.736 |
| 13.8 | 1.437 | 1.123 | 1.084 | 0.896 | 1.188 | 2.168 | 7.896 |
| 9.8 | 0.685 | 0.782 | 0.465 | 0.239 | 0.625 | 1.028 | 3.824 |
| -8 | 0.480 | 0.368 | 0.233 | 0.210 | 0.272 | 1.041 | 2.604 |
| Sum | 44.620 | 34.641 | 20.030 | 18.803 | 23.842 | 73.907 | 215.843 |
| Original Gms. of Froth | 46.382 | 35.405 | 19.997 | 19.482 | 24.537 | 75.588 | 221.391 |

## Table 23

### Size Distribution of Particles in Froth

Test 3-3 Impeller Speed --- 1294 rpm Air Volume --- 2.5 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.122 | 0.098 | 0.102 | 0.174 | 0.457 | 10.522 | 11.475 |
| 178 | 1.188 | 0.850 | 0.857 | 1.180 | 2.309 | 13.337 | 19.721 |
| 126 | 3.854 | 2.619 | 2.131 | 2.109 | 2.586 | 6.455 | 19.754 |
| 89 | 6.775 | 3.855 | 2.547 | 2.176 | 2.423 | 6.224 | 24.000 |
| 60 | 21.740 | 12.112 | 7.371 | 5.955 | 6.730 | 18.601 | 72.509 |
| 39 | 7.653 | 4.009 | 2.590 | 2.498 | 2.854 | 6.384 | 25.988 |
| 27.5 | 4.230 | 2.671 | 2.085 | 1.663 | 2.041 | 4.357 | 17.047 |
| 19.5 | 2.907 | 2.131 | 1.623 | 1.335 | 1.986 | 2.945 | 12.927 |
| 13.8 | 2.472 | 0.675 | 1.170 | 0.466 | 1.252 | 2.404 | 8.439 |
| 9.8 | 1.492 | 0.392 | 0.228 | 0.197 | 0.730 | 1.398 | 4.437 |
| -8 | 0.618 | 0.437 | 0.232 | 0.205 | 0.412 | 0.956 | 2.860 |
| Sum | 53.051 | 29.849 | 20.936 | 17.958 | 23.780 | 73.583 | 219.157 |
| Original Gms. of Froth | 53.825 | 31.376 | 20.610 | 18.893 | 23.952 | 75.058 | 223.714 |

## Table 24

### Size Distribution of Particles in Froth

Test 3-4 | Impeller Speed --- 1294 RPM | Air Volume --- 3.0 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.110 | 0.097 | 0.101 | 0.199 | 0.528 | 10.587 | 11.622 |
| 178 | 1.106 | 0.904 | 0.927 | 1.431 | 2.576 | 13.545 | 20.489 |
| 126 | 3.651 | 2.821 | 2.316 | 2.411 | 2.588 | 6.392 | 20.179 |
| 89 | 6.700 | 4.117 | 2.720 | 2.454 | 2.505 | 6.092 | 24.588 |
| 60 | 22.550 | 12.150 | 6.660 | 6.066 | 6.907 | 19.186 | 73.519 |
| 39 | 7.904 | 4.209 | 2.928 | 2.418 | 2.366 | 4.933 | 24.758 |
| 27.5 | 4.649 | 2.806 | 1.875 | 1.865 | 1.920 | 3.634 | 16.749 |
| 19.5 | 3.020 | 2.273 | 1.399 | 1.565 | 1.870 | 2.918 | 13.045 |
| 13.8 | 2.640 | 1.317 | 1.151 | 0.492 | 0.968 | 1.420 | 7.988 |
| 9.8 | 1.169 | 0.630 | 0.727 | 0.314 | 0.469 | 0.749 | 4.058 |
| -8 | 0.927 | 0.430 | 0.647 | 0.205 | 0.258 | 0.808 | 3.267 |
| Sum | 54.426 | 31.754 | 21.451 | 19.420 | 22.947 | 70.264 | 220.262 |
| Original Gms. of Froth | 55.478 | 32.979 | 21.592 | 20.395 | 23.504 | 71.765 | 225.713 |

## TABLE 25

## SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 3-5 IMPELLER SPEED --- 1294 RPM AIR VOLUME --- 3.5 LITERS/MIN.

| MEAN DIA. MICRONS | GRAMS OF SOLIDS IN FROTH AFTER 20 SEC. | 40 SEC. | 60 SEC. | 90 SEC. | 150 SEC. | GMS. SOLIDS IN TAILS | TOTALS |
|---|---|---|---|---|---|---|---|
| 252 | 0.130 | 0.125 | 0.110 | 0.180 | 0.414 | 10.437 | 11.396 |
| 178 | 1.315 | 1.192 | 1.000 | 1.318 | 2.272 | 13.262 | 20.359 |
| 126 | 4.338 | 3.298 | 2.181 | 2.083 | 2.268 | 6.044 | 20.212 |
| 89 | 7.837 | 4.520 | 2.455 | 2.050 | 2.150 | 5.568 | 24.580 |
| 60 | 25.610 | 5.060 | 2.284 | 2.224 | 2.202 | 8.141 | 45.521 |
| 39 | 8.824 | 7.748 | 3.256 | 2.467 | 2.685 | 6.522 | 31.502 |
| 27.5 | 5.146 | 4.679 | 2.509 | 2.164 | 2.366 | 5.126 | 21.990 |
| 19.5 | 3.657 | 3.309 | 1.835 | 1.650 | 1.805 | 3.373 | 15.629 |
| 13.8 | 2.768 | 2.224 | 1.238 | 1.162 | 1.311 | 2.113 | 10.816 |
| 9.8 | 0.655 | 1.569 | 0.582 | 0.740 | 0.353 | 0.758 | 4.657 |
| -8 | 0.390 | 4.531 | 2.239 | 1.488 | 2.106 | 2.333 | 13.087 |
| SUM | 60.670 | 38.255 | 19.689 | 17.526 | 19.932 | 63.677 | 219.749 |
| ORIGINAL GMS. OF FROTH | 62.975 | 37.183 | 20.024 | 18.226 | 20.640 | 64.862 | 223.910 |

## TABLE 26

## SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 4-1 IMPELLER SPEED --- 863 RPM AIR VOLUME --- 1.0 LITERS/MIN.

| MEAN DIA. MICRONS | GRAMS OF SOLIDS IN FROTH AFTER | | | | | GMS. SOLIDS IN TAILS | TOTALS |
|---|---|---|---|---|---|---|---|
| | 20 SEC. | 40 SEC. | 60 SEC. | 90 SEC. | 150 SEC. | | |
| 252 | 0.067 | 0.085 | 0.080 | 0.118 | 0.320 | 10.588 | 11.258 |
| 178 | 0.500 | 0.702 | 0.591 | 0.818 | 1.681 | 15.485 | 19.777 |
| 126 | 1.665 | 2.288 | 1.793 | 2.012 | 2.822 | 9.661 | 20.241 |
| 89 | 2.865 | 3.482 | 2.290 | 2.381 | 2.970 | 9.978 | 23.966 |
| 60 | 4.248 | 4.728 | 3.034 | 2.565 | 3.339 | 17.112 | 35.026 |
| 39 | 5.090 | 5.945 | 3.292 | 3.387 | 3.905 | 12.351 | 33.970 |
| 27.5 | 3.239 | 3.842 | 2.512 | 2.614 | 3.186 | 9.895 | 25.288 |
| 19.5 | 2.117 | 2.406 | 1.686 | 1.805 | 2.282 | 6.616 | 16.912 |
| 13.8 | 1.429 | 1.635 | 1.132 | 1.185 | 1.592 | 4.544 | 11.517 |
| 9.8 | 0.660 | 0.350 | 0.380 | 0.483 | 0.931 | 2.237 | 5.041 |
| -8 | 1.400 | 2.392 | 1.583 | 1.656 | 1.692 | 3.718 | 12.441 |
| SUM | 23.280 | 27.855 | 18.373 | 19.024 | 24.720 | 102.185 | 215.437 |
| ORIGINAL GMS. OF FROTH | 24.342 | 28.691 | 18.997 | 19.755 | 25.614 | 104.984 | 222.383 |

TABLE 27

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 4-2 IMPELLER SPEED --- 863 RPM AIR VOLUME --- 2.0 LITERS/MIN.

| MEAN DIA. | GRAMS OF SOLIDS IN FROTH AFTER | | | | | GMS. SOLIDS | |
|---|---|---|---|---|---|---|---|
| MICRONS | 20 SEC. | 40 SEC. | 60 SEC. | 90 SEC. | 150 SEC. | IN TAILS | TOTALS |
| 252 | 0.082 | 0.074 | 0.070 | 0.132 | 0.303 | 10.003 | 10.664 |
| 178 | 0.573 | 0.591 | 0.495 | 0.887 | 1.613 | 15.868 | 20.027 |
| 126 | 1.957 | 1.995 | 1.530 | 2.215 | 2.702 | 9.641 | 20.040 |
| 89 | 3.348 | 3.040 | 2.049 | 2.784 | 2.965 | 10.460 | 24.646 |
| 60 | 5.500 | 4.258 | 2.567 | 2.938 | 3.332 | 15.477 | 34.072 |
| 39 | 5.582 | 4.609 | 2.679 | 3.678 | 3.577 | 12.101 | 32.226 |
| 27.5 | 3.802 | 3.322 | 2.231 | 2.870 | 3.204 | 10.130 | 25.559 |
| 19.5 | 2.433 | 2.180 | 1.482 | 1.974 | 2.283 | 6.591 | 16.943 |
| 13.8 | 1.603 | 1.456 | 1.012 | 1.345 | 1.605 | 4.355 | 11.376 |
| 9.8 | 0.529 | 0.900 | 0.681 | 0.592 | 1.110 | 2.460 | 6.272 |
| -8 | 3.002 | 1.538 | 1.139 | 1.818 | 1.967 | 5.435 | 14.899 |
| SUM | 28.411 | 23.963 | 15.935 | 21.233 | 24.661 | 102.521 | 216.724 |
| ORIGINAL GMS. OF FROTH | 28.471 | 24.974 | 16.550 | 21.950 | 25.307 | 104.335 | 221.587 |

TABLE 28

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 4-3 IMPELLER SPEED --- 863 RPM AIR VOLUME --- 2.5 LITERS/MIN.

| MEAN DIA. MICRONS | GRAMS OF SOLIDS IN FROTH AFTER 20 SEC. | 40 SEC. | 60 SEC. | 90 SEC. | 150 SEC. | GMS. SOLIDS IN TAILS | TOTALS |
|---|---|---|---|---|---|---|---|
| 252 | 0.078 | 0.088 | 0.078 | 0.115 | 0.320 | 9.793 | 10.472 |
| 178 | 0.432 | 0.655 | 0.557 | 0.750 | 1.790 | 15.951 | 20.135 |
| 126 | 1.454 | 2.233 | 1.665 | 1.832 | 3.108 | 9.915 | 20.207 |
| 89 | 2.782 | 3.653 | 2.292 | 2.173 | 3.270 | 10.018 | 24.188 |
| 60 | 4.612 | 5.515 | 2.763 | 2.442 | 3.365 | 14.202 | 32.899 |
| 39 | 4.605 | 5.787 | 3.586 | 2.916 | 4.745 | 12.777 | 34.416 |
| 27.5 | 3.467 | 3.900 | 2.600 | 2.336 | 3.532 | 9.930 | 25.765 |
| 19.5 | 2.192 | 2.524 | 1.738 | 1.616 | 2.535 | 6.491 | 17.096 |
| 13.8 | 1.480 | 1.637 | 1.187 | 1.130 | 1.747 | 4.238 | 11.419 |
| 9.8 | 1.030 | 1.037 | 0.806 | 0.578 | 1.187 | 2.025 | 6.663 |
| -8 | 1.571 | 1.887 | 1.377 | 1.477 | 2.030 | 5.855 | 14.197 |
| SUM | 23.703 | 28.916 | 18.649 | 17.365 | 27.629 | 101.195 | 217.457 |
| ORIGINAL GMS. OF FROTH | 24.332 | 29.847 | 19.139 | 17.871 | 28.428 | 102.863 | 222.480 |

## Table 29

## Size Distribution of Particles in Froth

Test 4-4 — Impeller Speed --- 863 rpm — Air Volume --- 3.0 liters/min.

| Mean Dia. Microns | Grams of Solids in Froth after 20 sec. | 40 sec. | 60 sec. | 90 sec. | 150 sec. | Gms. Solids in Tails | Totals |
|---|---|---|---|---|---|---|---|
| 252 | 0.055 | 0.069 | 0.075 | 0.120 | 0.320 | 9.773 | 10.412 |
| 178 | 0.430 | 0.521 | 0.521 | 0.724 | 1.742 | 15.942 | 19.880 |
| 126 | 1.678 | 1.972 | 1.677 | 1.897 | 3.131 | 10.276 | 20.631 |
| 89 | 3.322 | 3.218 | 2.199 | 2.263 | 3.236 | 9.888 | 24.126 |
| 60 | 5.286 | 5.250 | 2.621 | 2.968 | 4.437 | 15.017 | 35.579 |
| 39 | 6.350 | 4.898 | 3.236 | 2.638 | 3.339 | 11.614 | 32.075 |
| 27.5 | 4.018 | 3.645 | 2.485 | 2.361 | 3.369 | 9.820 | 25.698 |
| 19.5 | 2.541 | 2.356 | 1.626 | 1.630 | 2.359 | 6.479 | 16.991 |
| 13.8 | 1.644 | 1.573 | 1.125 | 1.104 | 1.644 | 4.274 | 11.364 |
| 9.8 | 1.267 | 1.072 | 0.705 | 0.680 | 0.805 | 2.294 | 6.823 |
| -8 | 1.637 | 1.758 | 1.369 | 1.230 | 2.161 | 5.802 | 13.957 |
| Sum | 28.228 | 26.332 | 17.639 | 17.615 | 26.543 | 101.179 | 217.536 |
| Original Gms. of Froth | 29.075 | 27.026 | 18.335 | 18.226 | 27.364 | 102.655 | 222.681 |

TABLE 30

SIZE DISTRIBUTION OF PARTICLES IN FROTH

TEST 4-5 IMPELLER SPEED --- 863 RPM AIR VOLUME --- 3.5 LITERS/MIN.

| MEAN DIA. MICRONS | GRAMS OF SOLIDS IN FROTH AFTER 20 SEC. | 40 SEC. | 60 SEC. | 90 SEC. | 150 SEC. | GMS. SOLIDS IN TAILS | TOTALS |
|---|---|---|---|---|---|---|---|
| 252 | 0.075 | 0.089 | 0.113 | 0.208 | 0.786 | 9.732 | 11.003 |
| 178 | 0.328 | 0.792 | 1.002 | 1.471 | 2.776 | 13.971 | 20.340 |
| 126 | 1.156 | 3.001 | 3.021 | 2.972 | 2.755 | 7.819 | 20.724 |
| 89 | 3.062 | 4.925 | 3.898 | 3.150 | 2.519 | 7.498 | 25.052 |
| 60 | 13.971 | 6.228 | 3.489 | 2.709 | 2.393 | 10.965 | 39.755 |
| 39 | 12.523 | 4.992 | 3.041 | 2.429 | 2.370 | 7.166 | 32.521 |
| 27.5 | 8.409 | 4.466 | 2.590 | 2.274 | 2.411 | 6.010 | 26.160 |
| 19.5 | 4.750 | 3.015 | 1.835 | 1.620 | 1.818 | 4.088 | 17.126 |
| 13.8 | 2.945 | 2.088 | 1.280 | 1.136 | 1.314 | 2.674 | 11.437 |
| 9.8 | 0.562 | 1.307 | 0.802 | 0.549 | 0.890 | 1.514 | 5.624 |
| -8 | 3.867 | 1.724 | 1.660 | 1.435 | 1.608 | 3.125 | 13.419 |
| SUM | 51.648 | 32.627 | 22.731 | 19.953 | 21.640 | 74.562 | 223.161 |
| ORIGINAL GMS. OF FROTH | 52.872 | 33.780 | 22.964 | 20.502 | 22.282 | 75.527 | 227.847 |

FIG. 1 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE. TEST 1-1

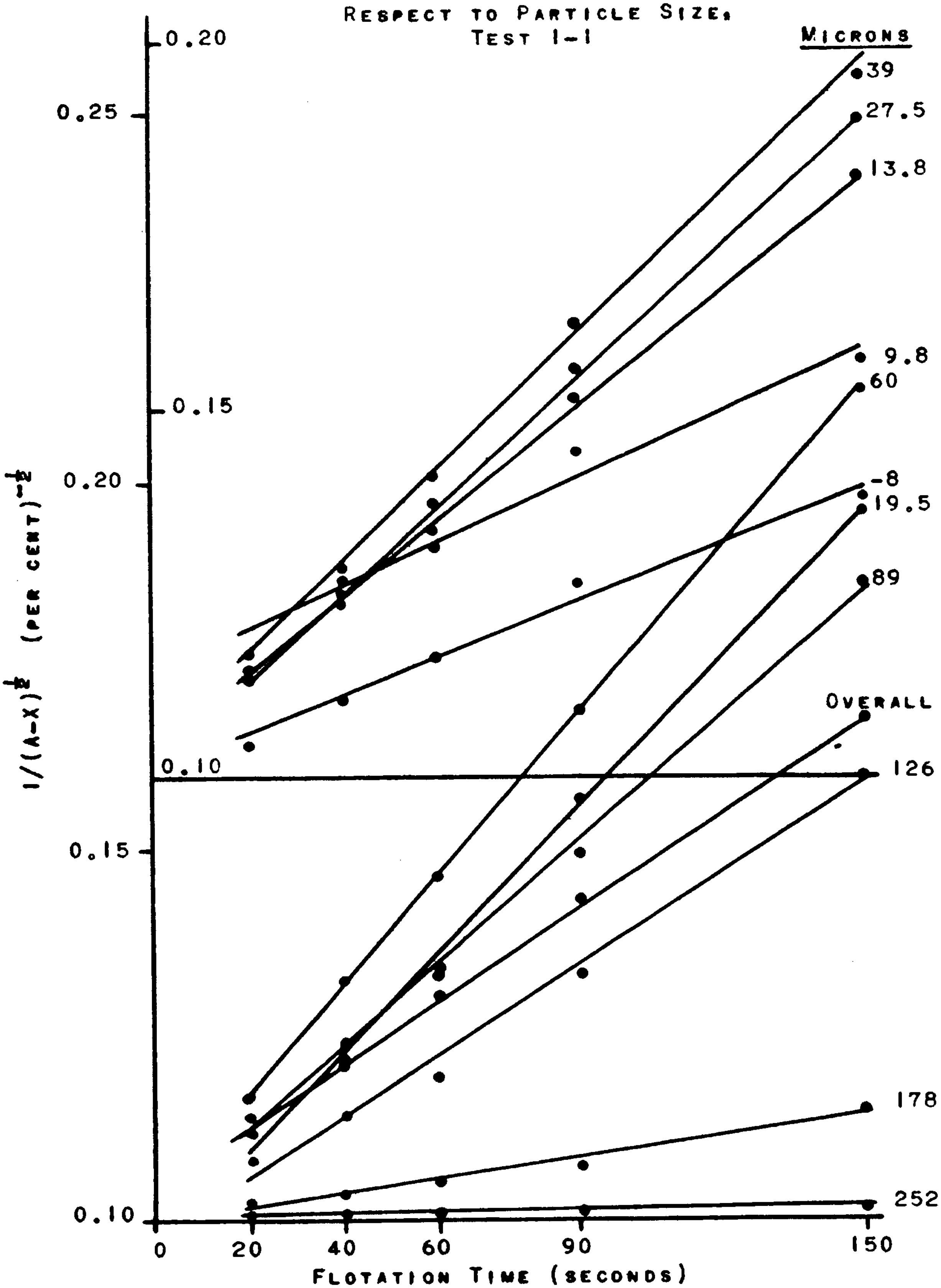


FIG. 2 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 1-2

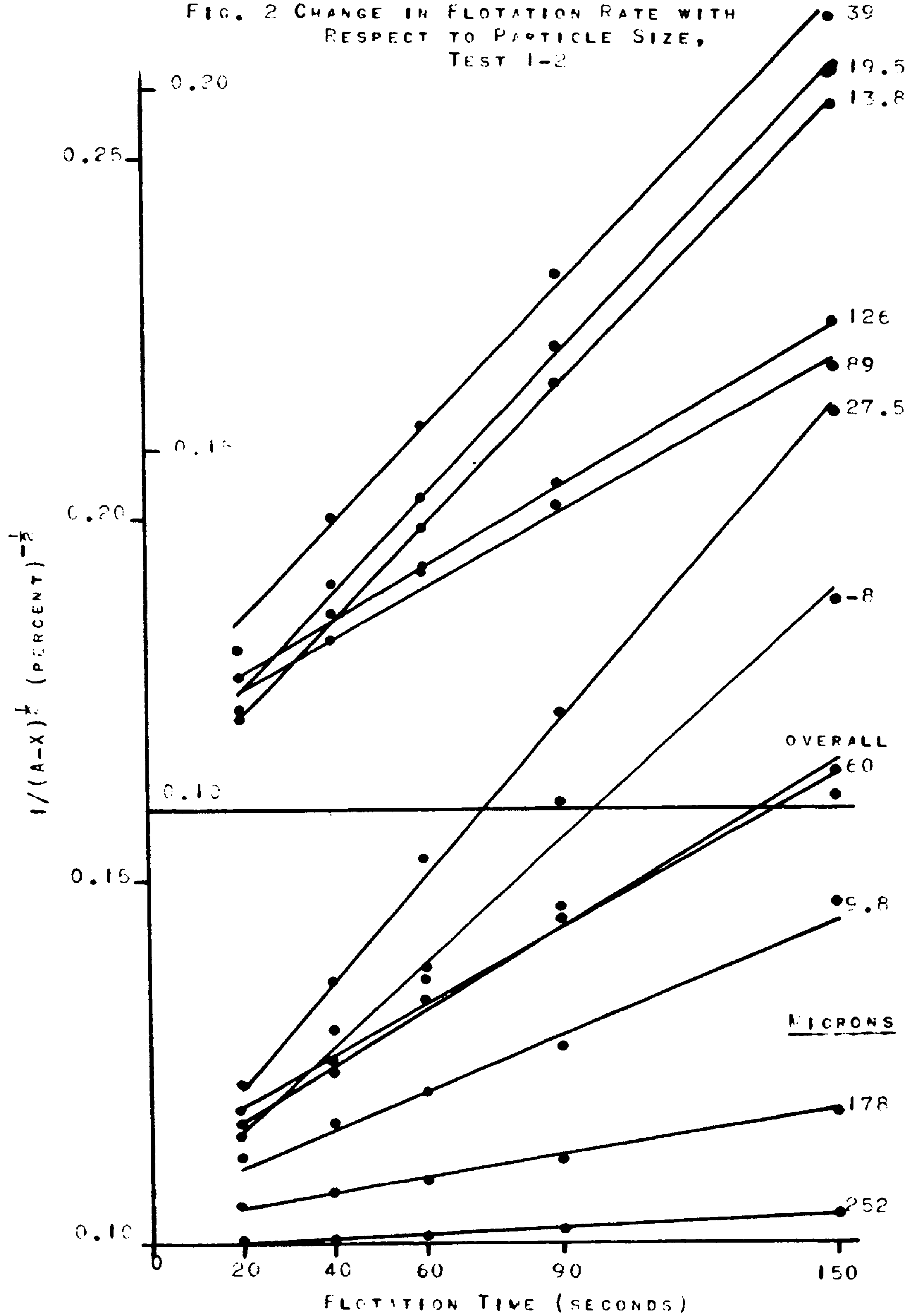


Fig. 3 Change in Flotation Rate with Respect to Particle Size, Test 1-3

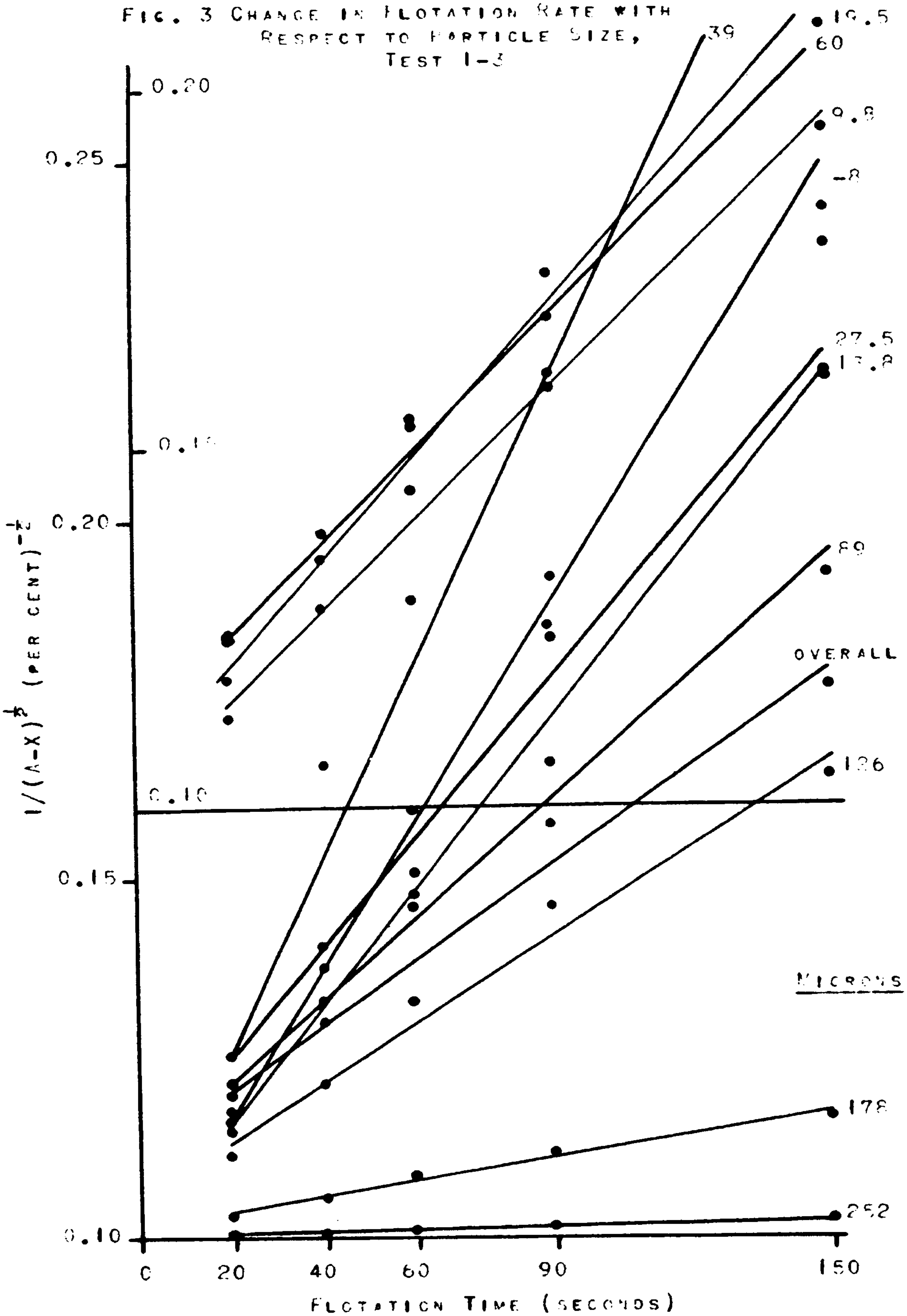


FIG. 4 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 1-4

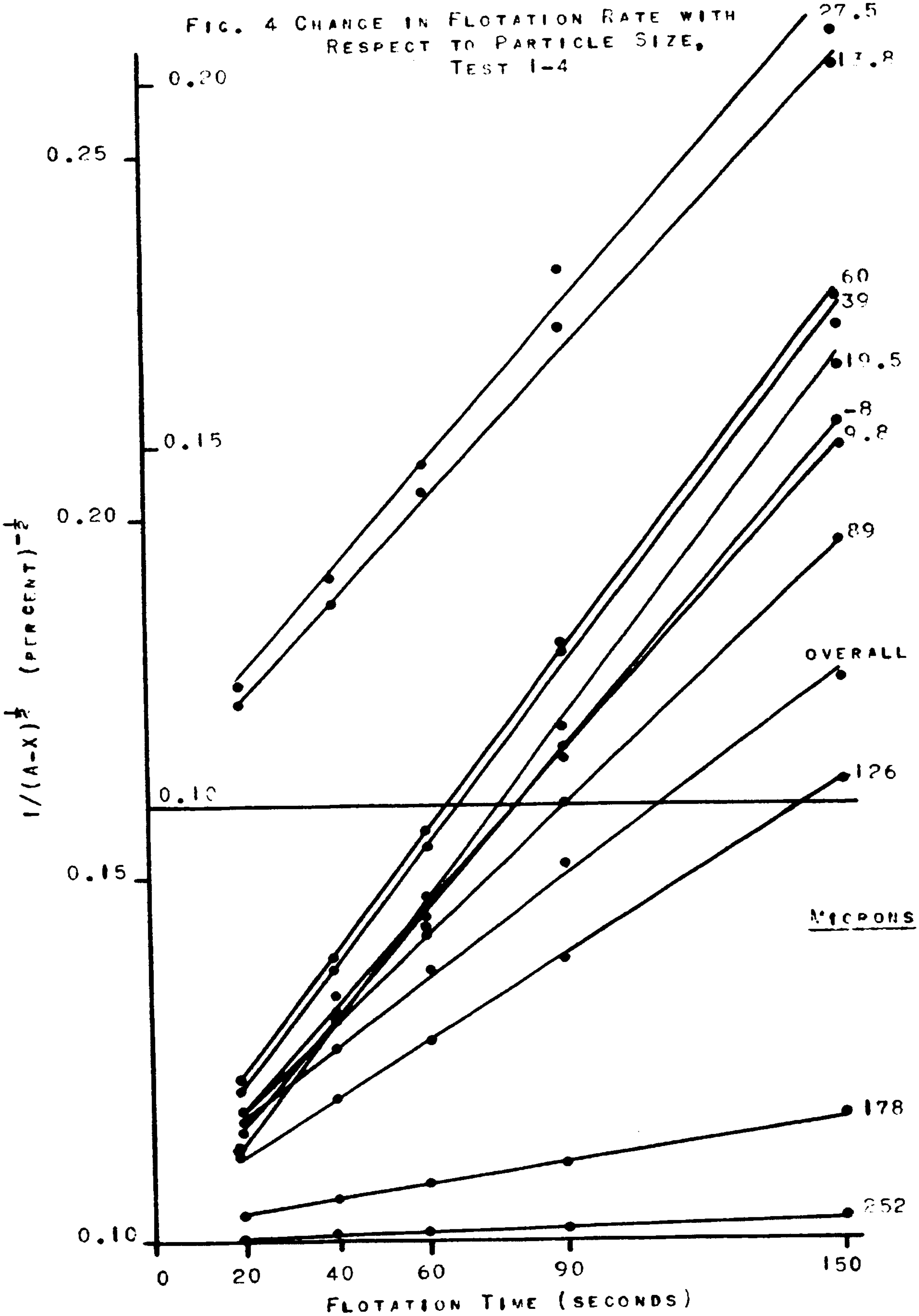


FIG. 5 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 1-5

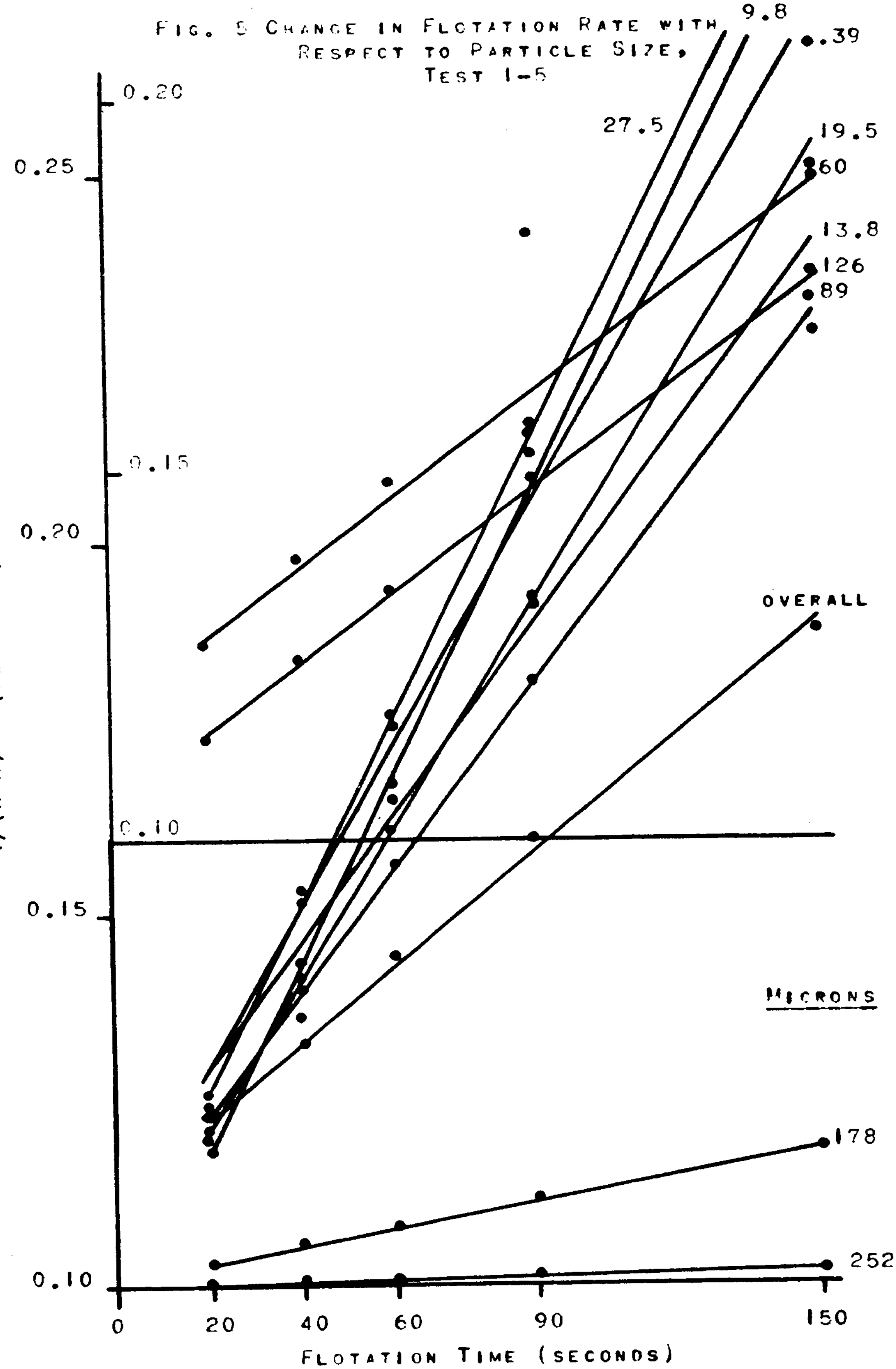
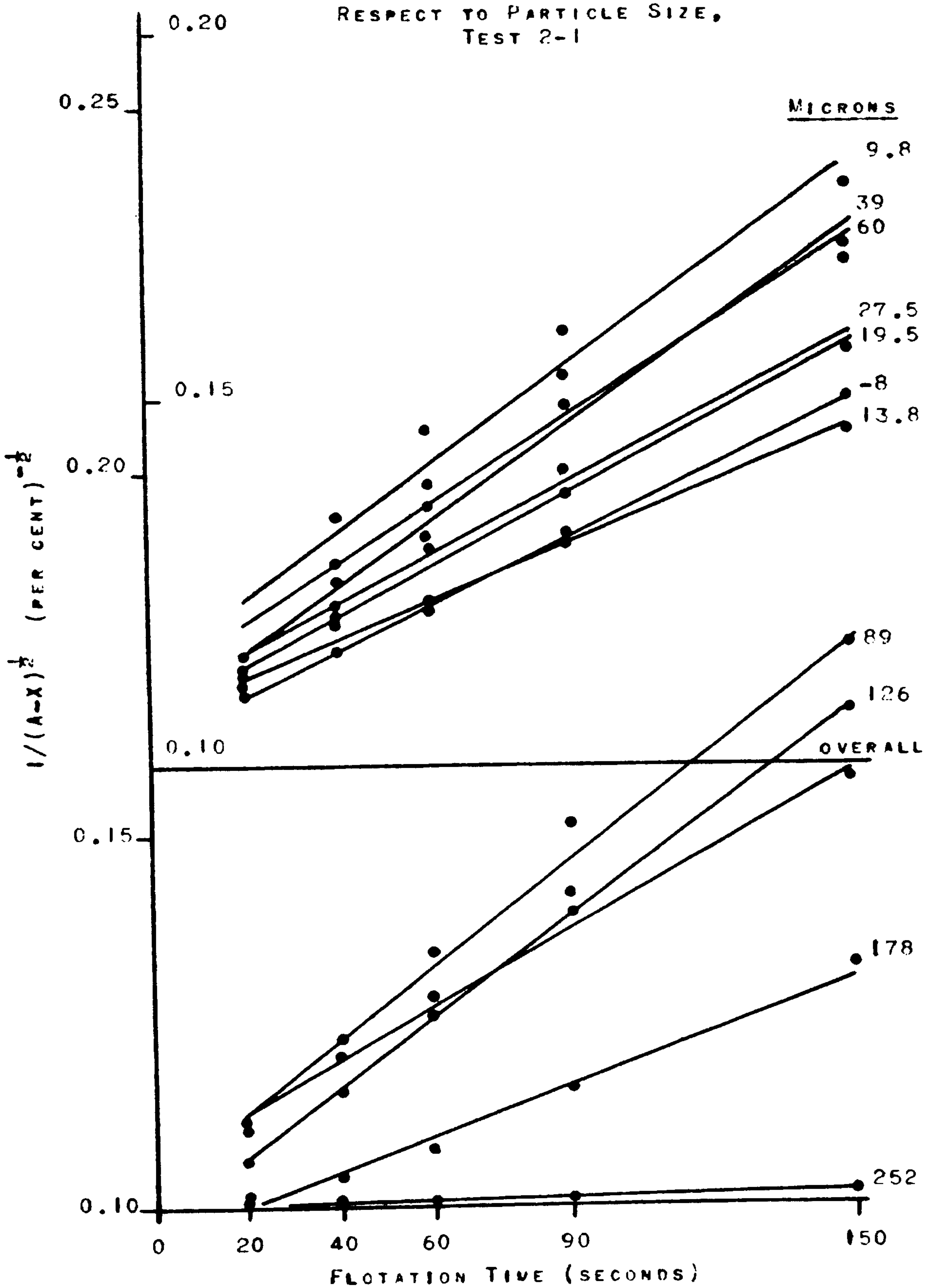


Fig. 6 Change in Flotation Rate with Respect to Particle Size, Test 2-1



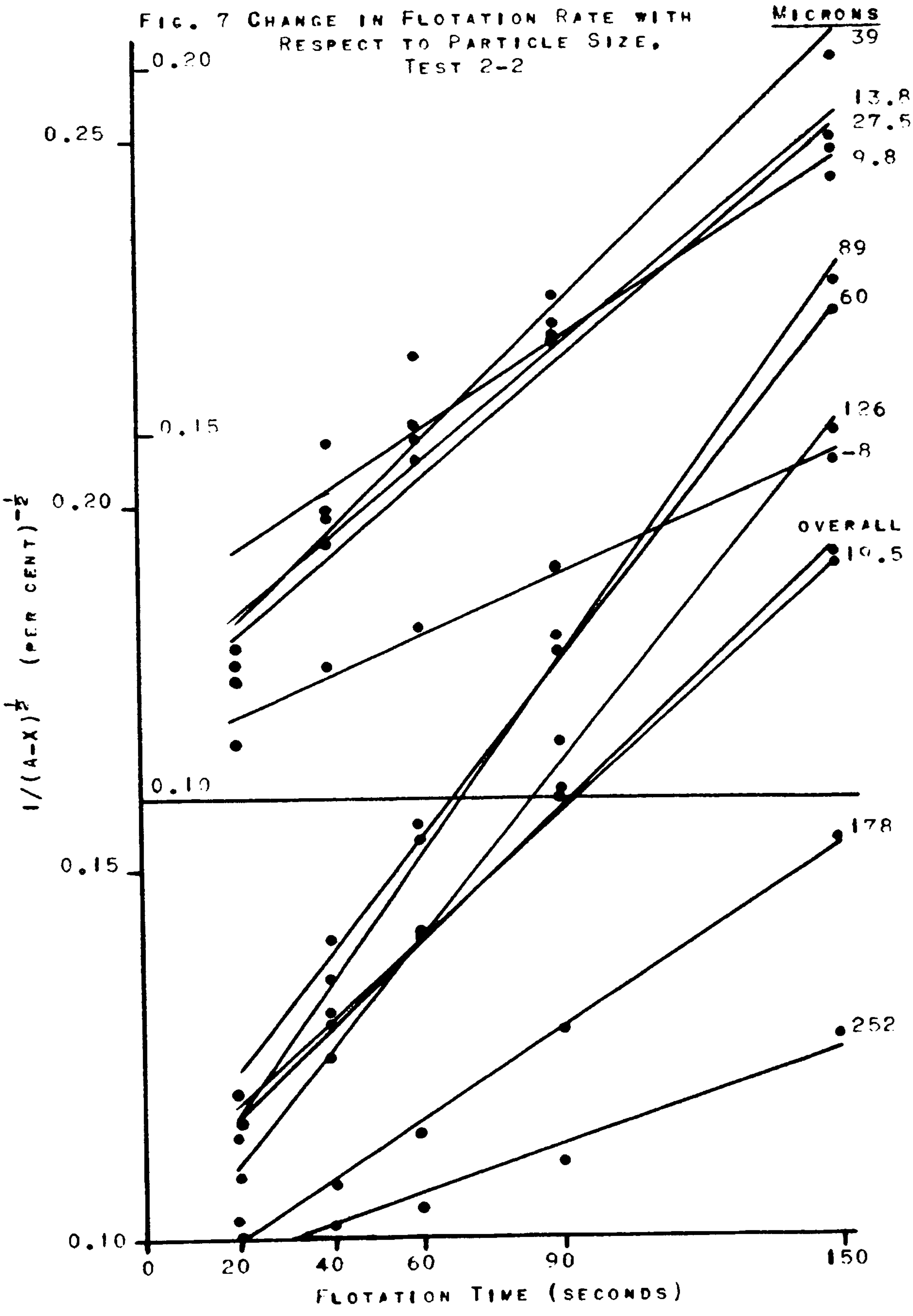


FIG. 7 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 2-2
MICRONS
39
13.8
27.5
9.8
89
60
126
-8
OVERALL
10.5
178
252
0.20
0.15
0.10
0.25
0.20
0.15
0.10
$1/(A-X)^{\frac{1}{2}}$ (PER CENT)$^{-\frac{1}{2}}$
0
20
40
60
90
150
FLOTATION TIME (SECONDS)

FIG. 8 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 2-3

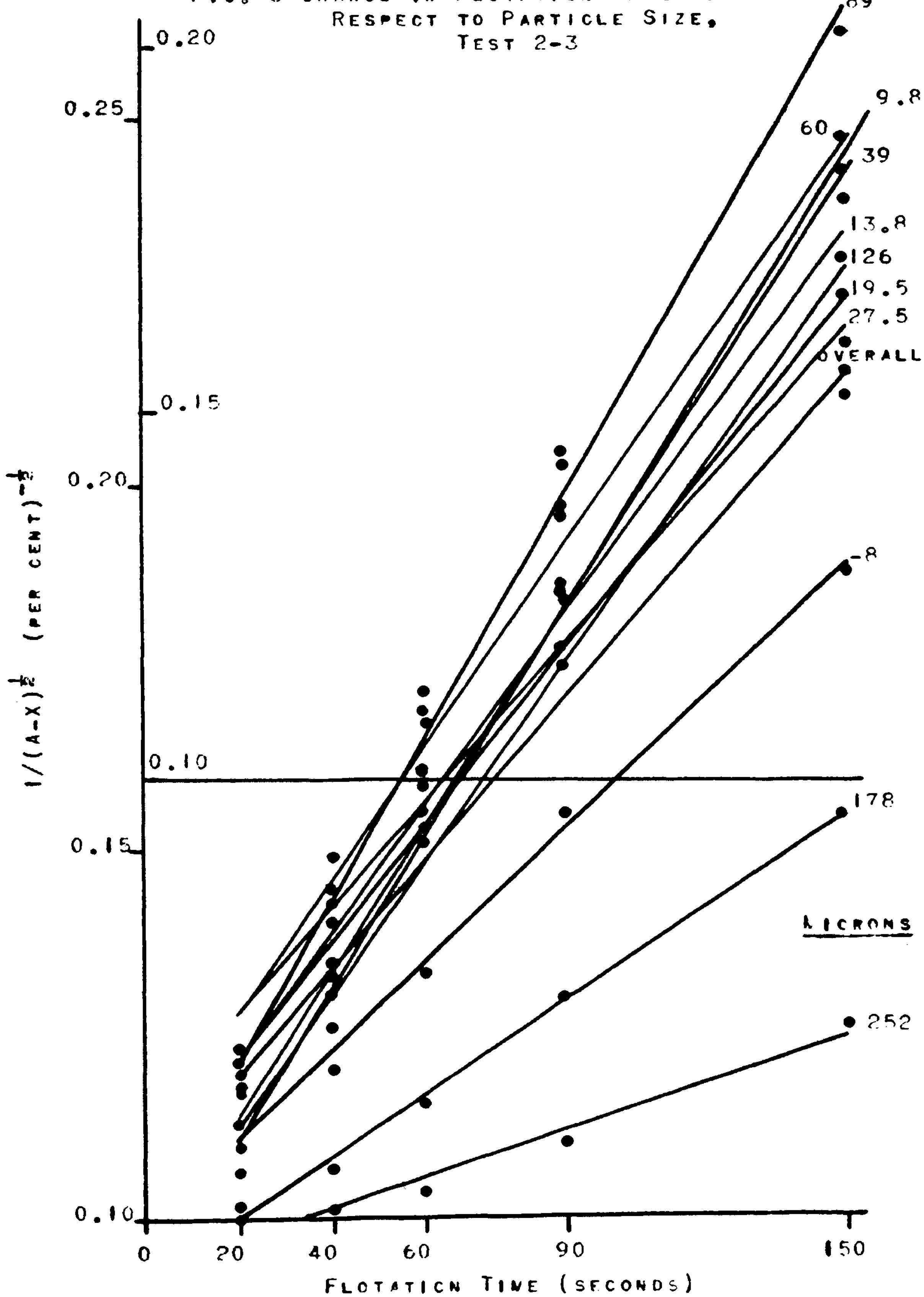
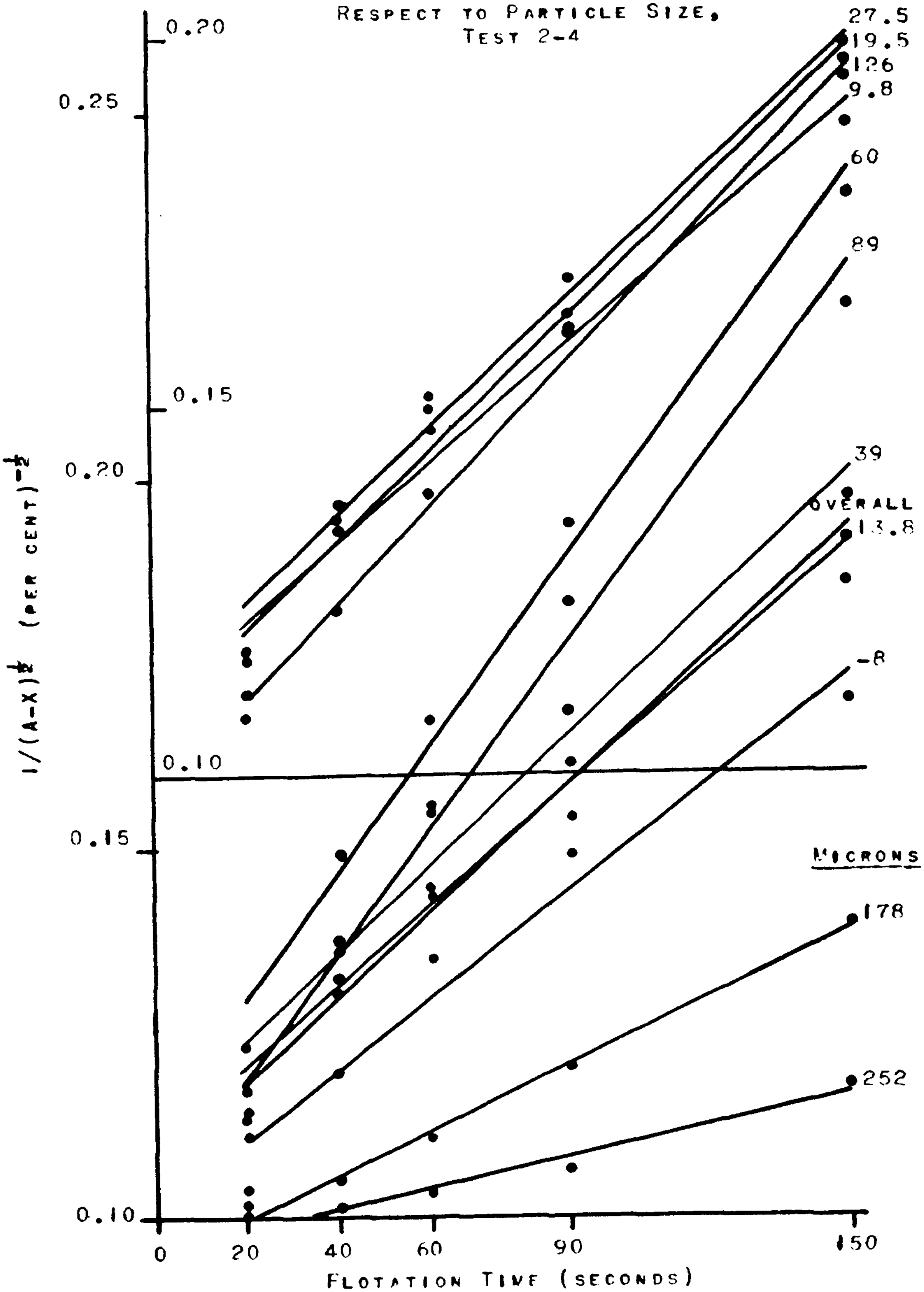


Fig. 9 Change in Flotation Rate with Respect to Particle Size, Test 2-4



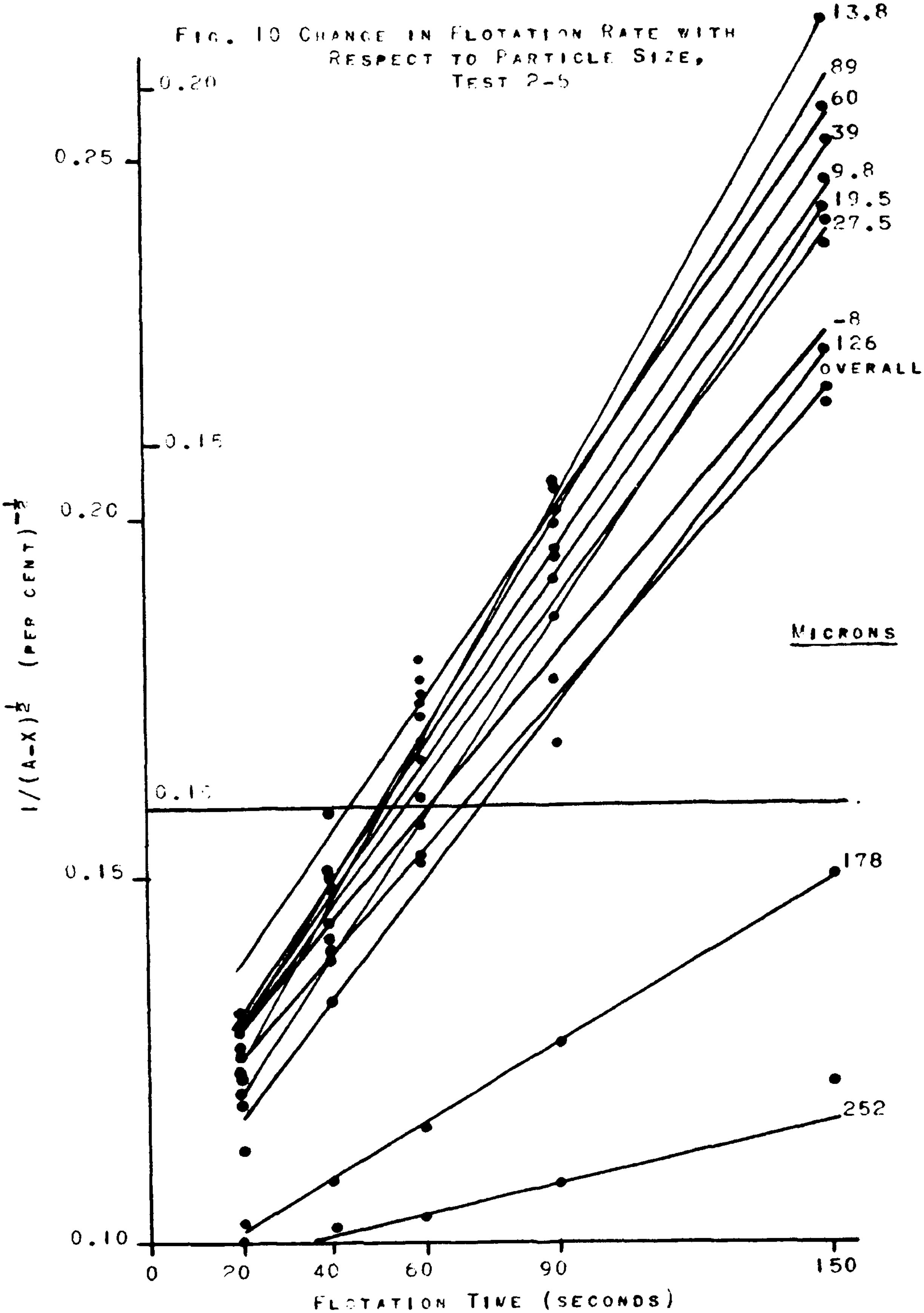



FIG. 10 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 2-5

Fig. 11 Change in Flotation Rate with Respect to Particle Size, Test 3-1

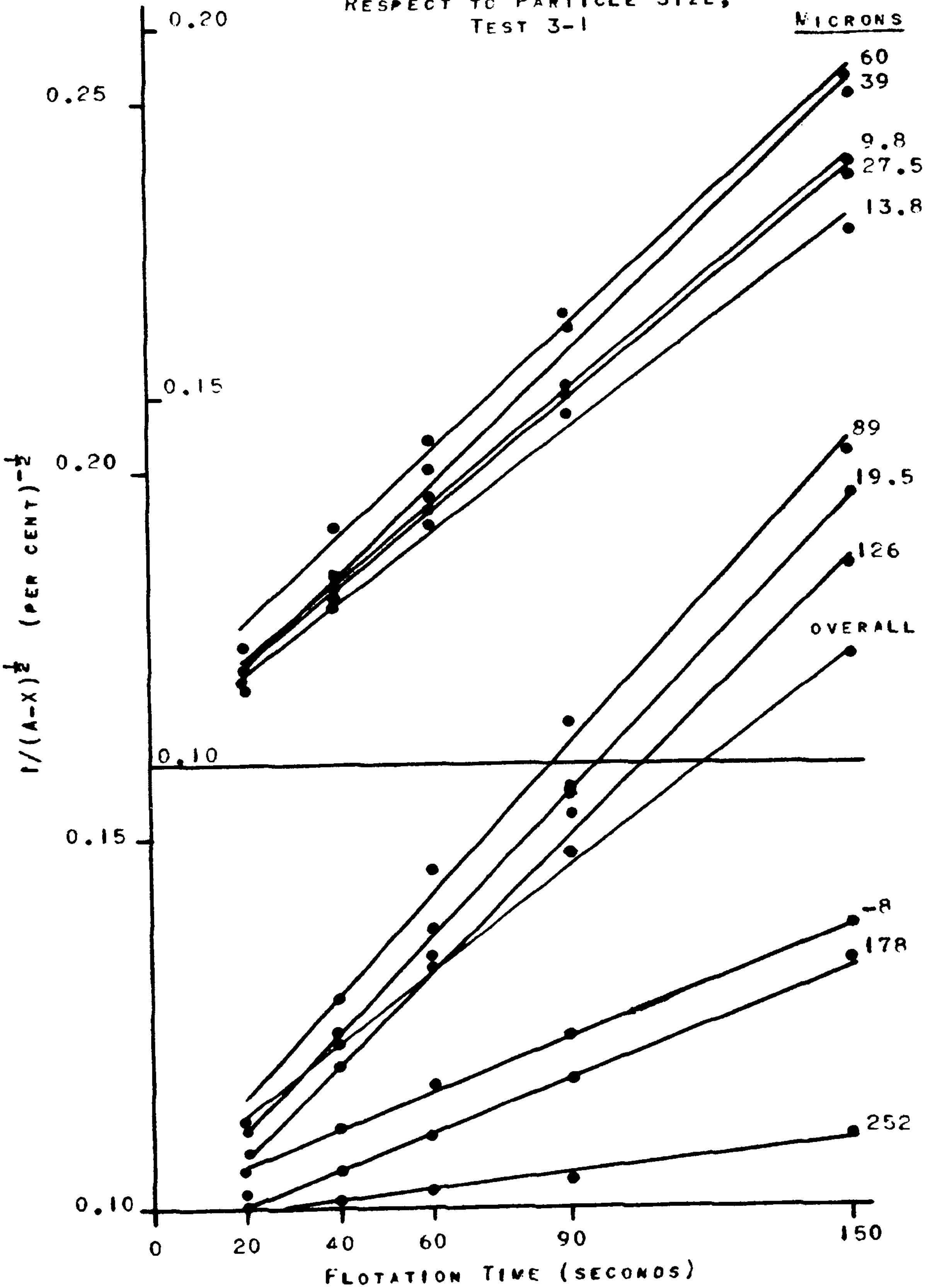


FIG. 12 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 3-2

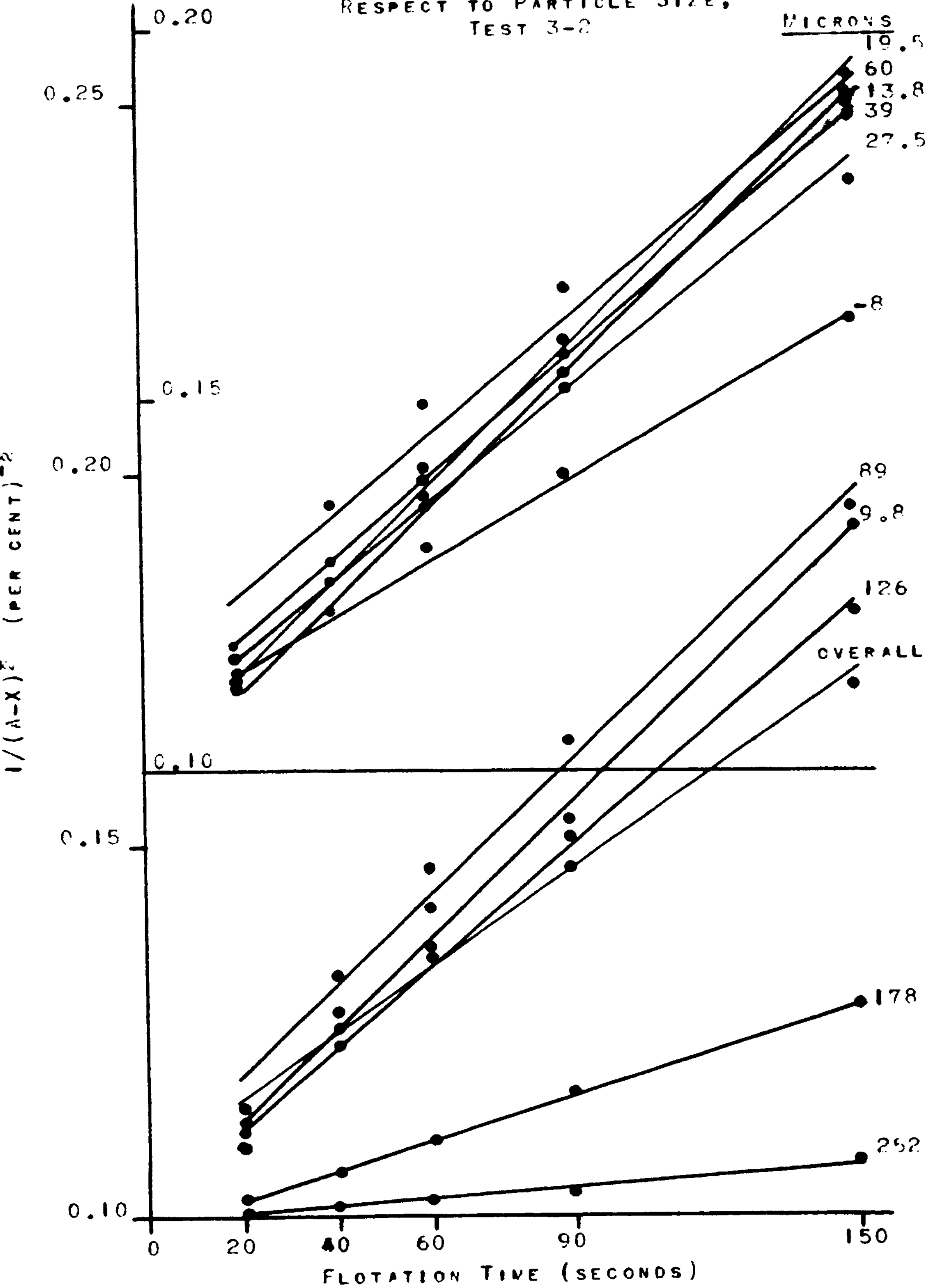


Fig. 13 Change in Flotation Rate with Respect to Particle Size, Test 3-3

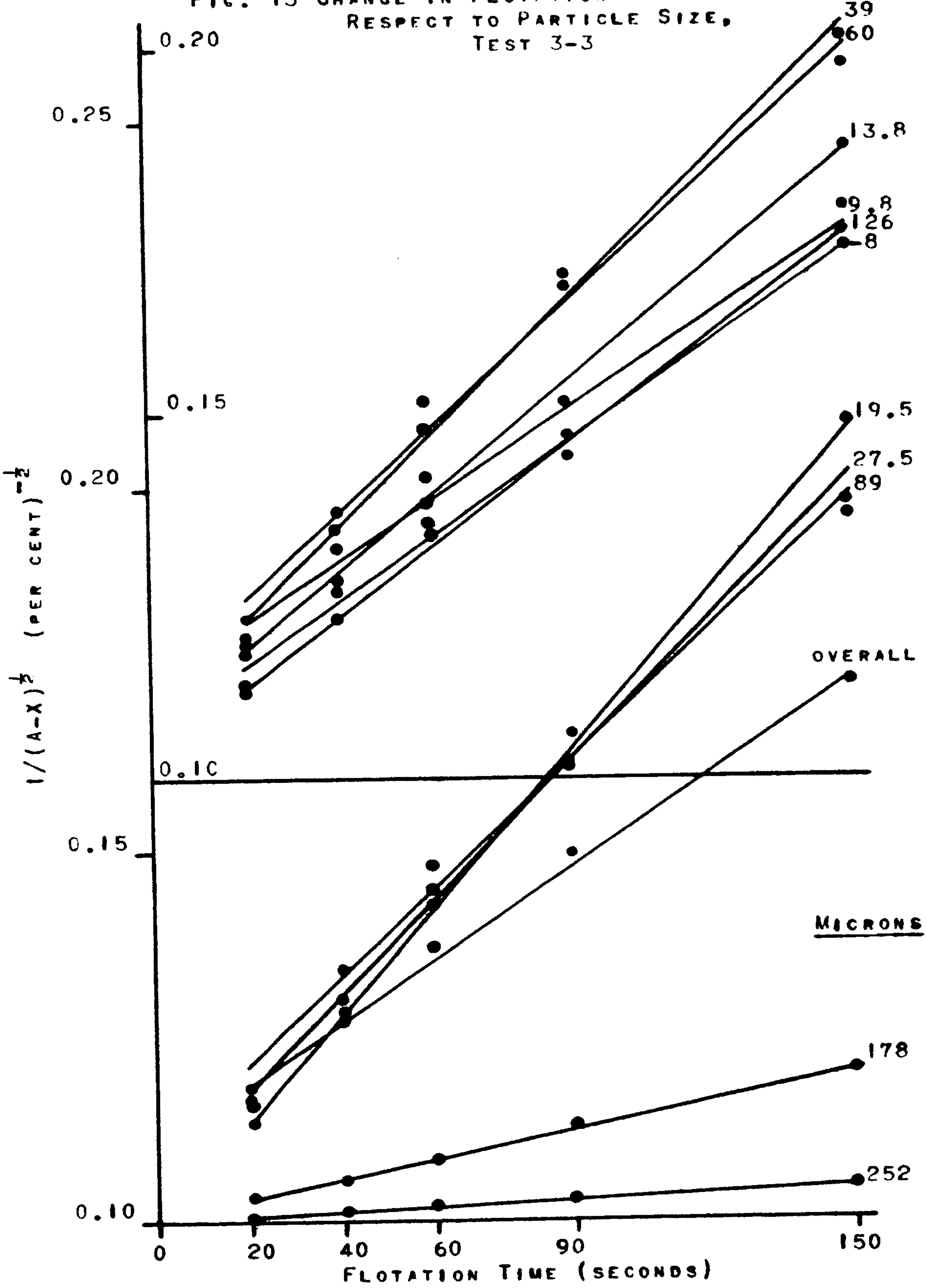
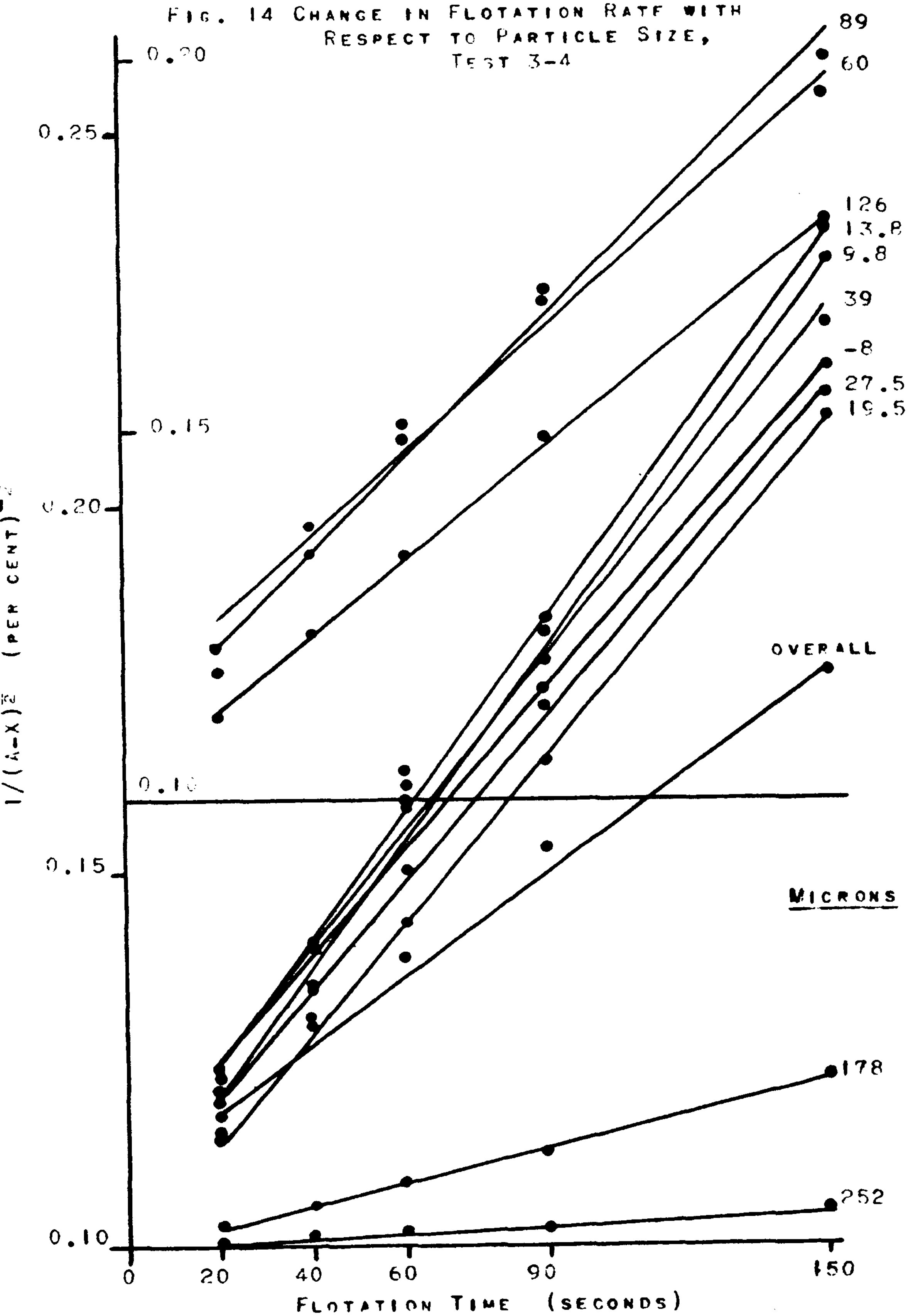


FIG. 14 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 3-4



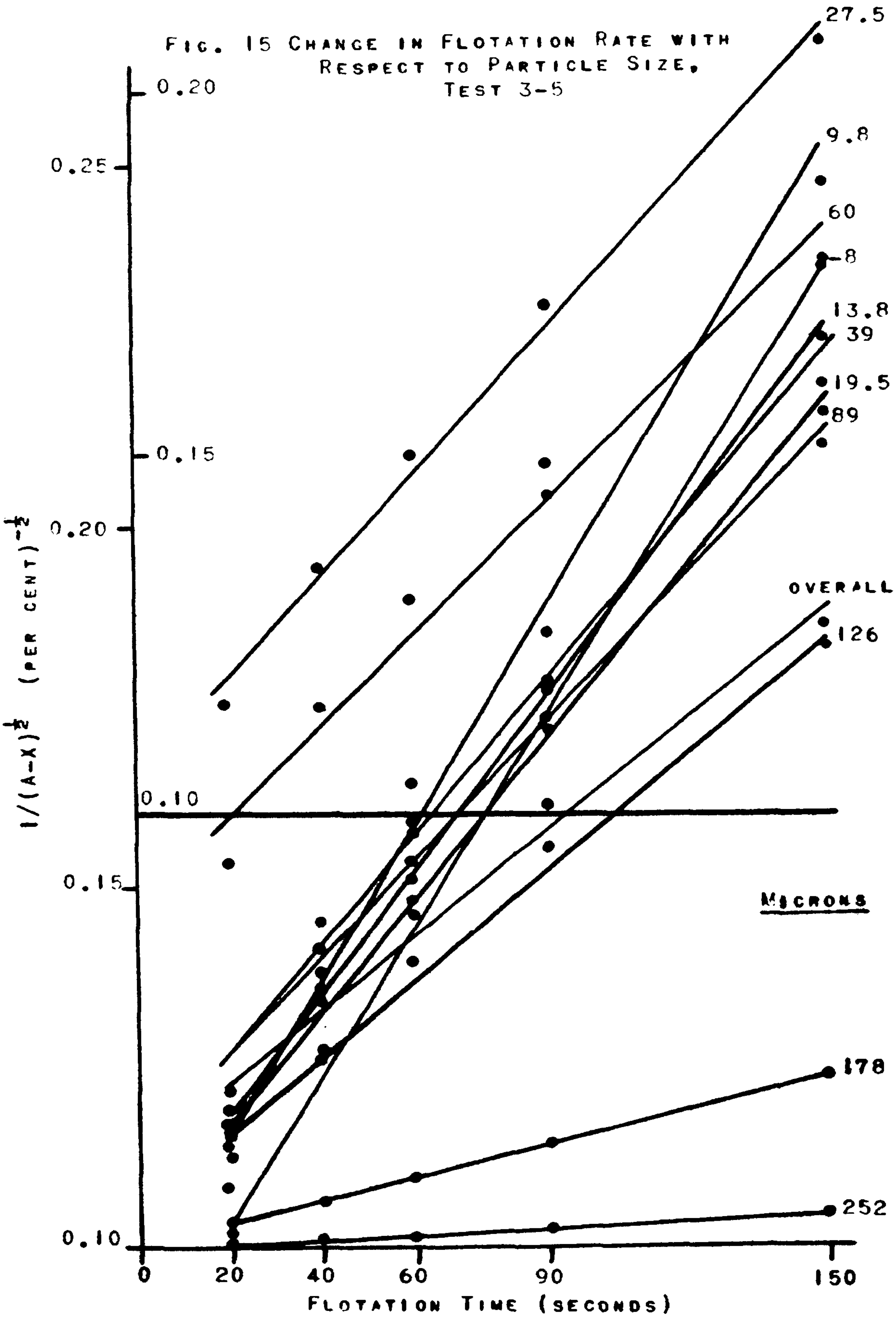


FIG. 15 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 3-5
0.20
0.25
0.15
0.20
0.10
0.15
0.10
$1/(A-X)^{\frac{1}{2}}$ (PER CENT)$^{-\frac{1}{2}}$
27.5
9.8
60
8
13.8
39
19.5
89
OVERALL
126
MICRONS
178
252
0
20
40
60
90
150
FLOTATION TIME (SECONDS)

FIG. 16 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-1

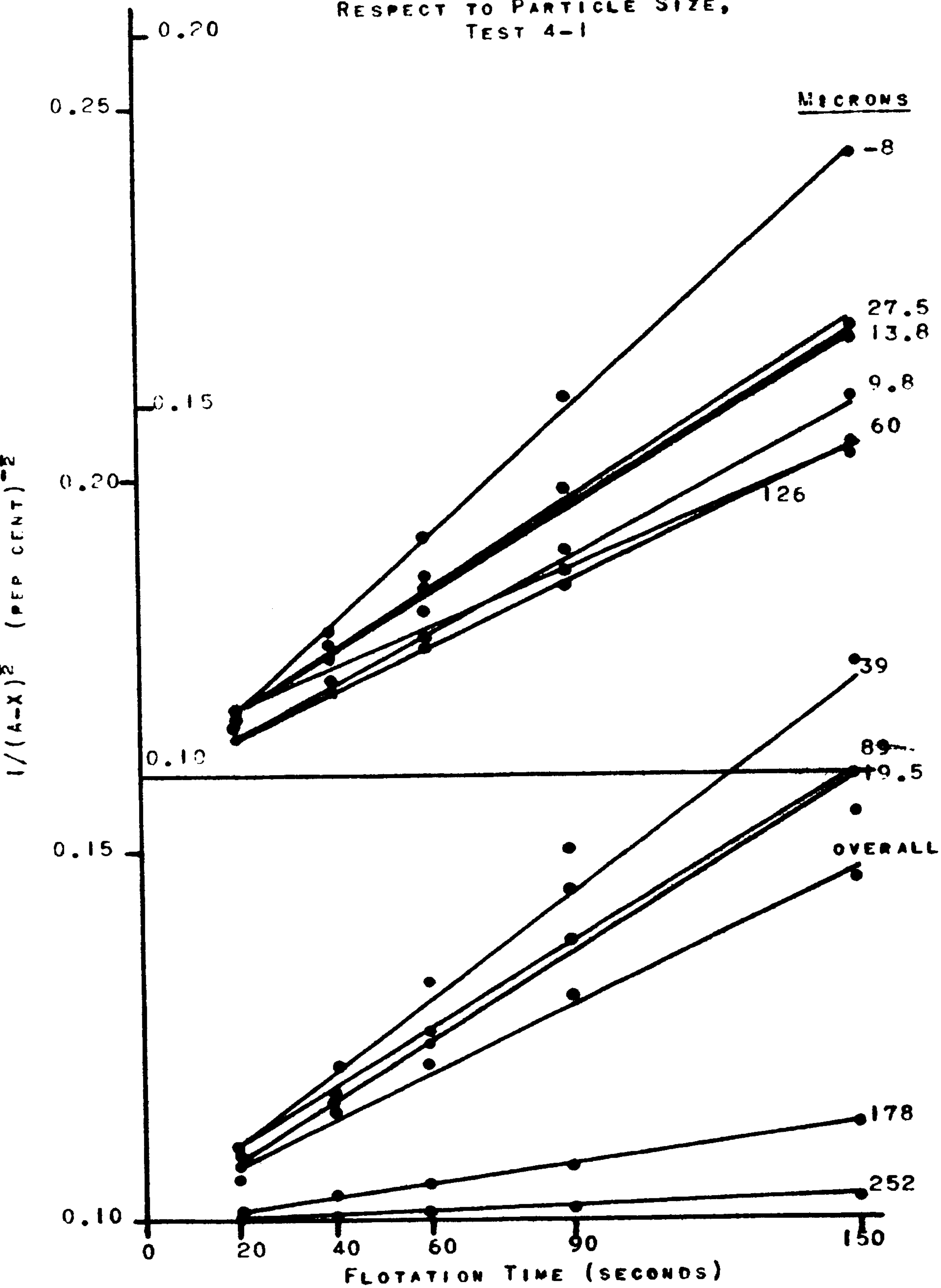


FIG. 17 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-2

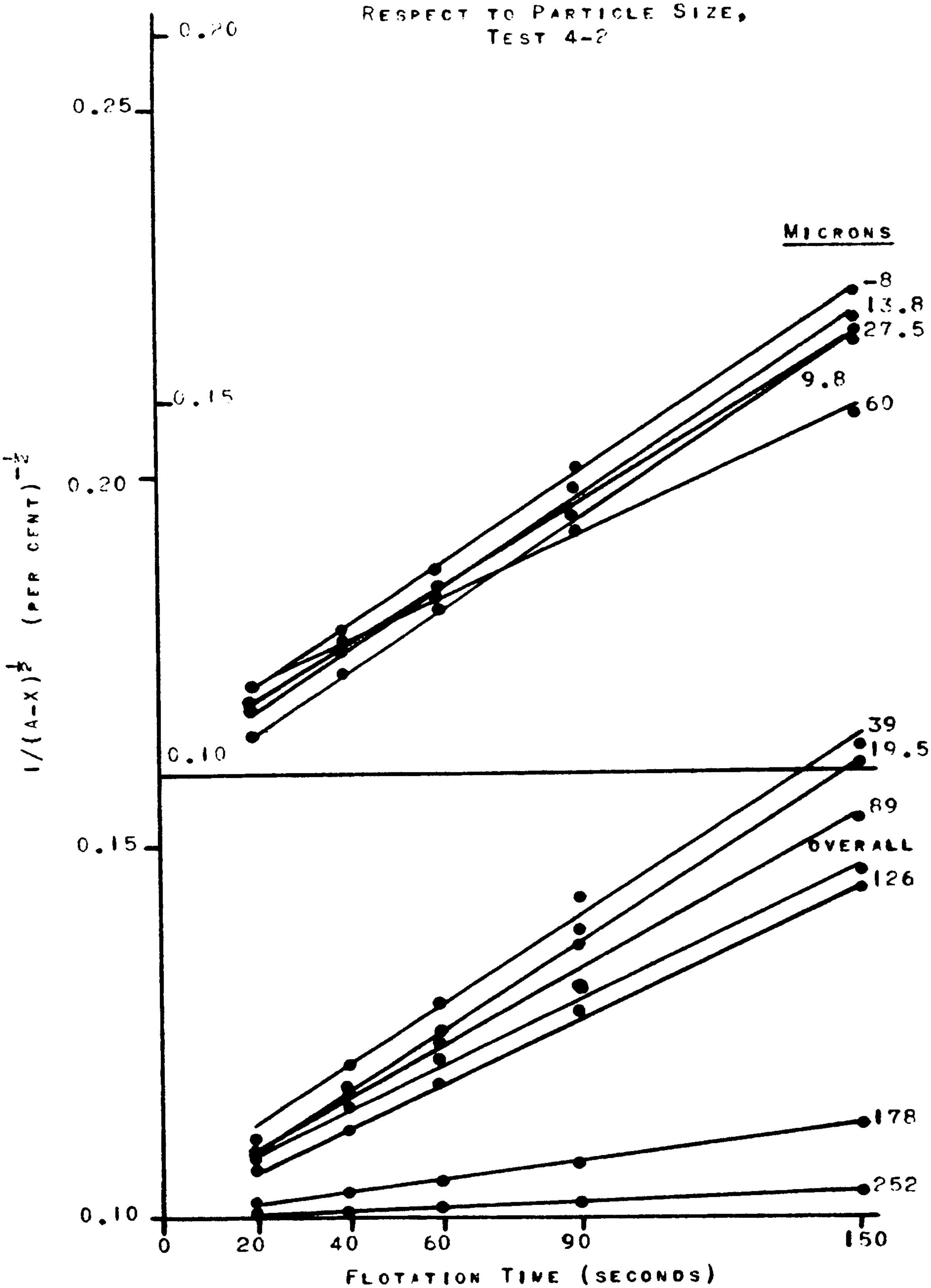


FIG. 18 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-3

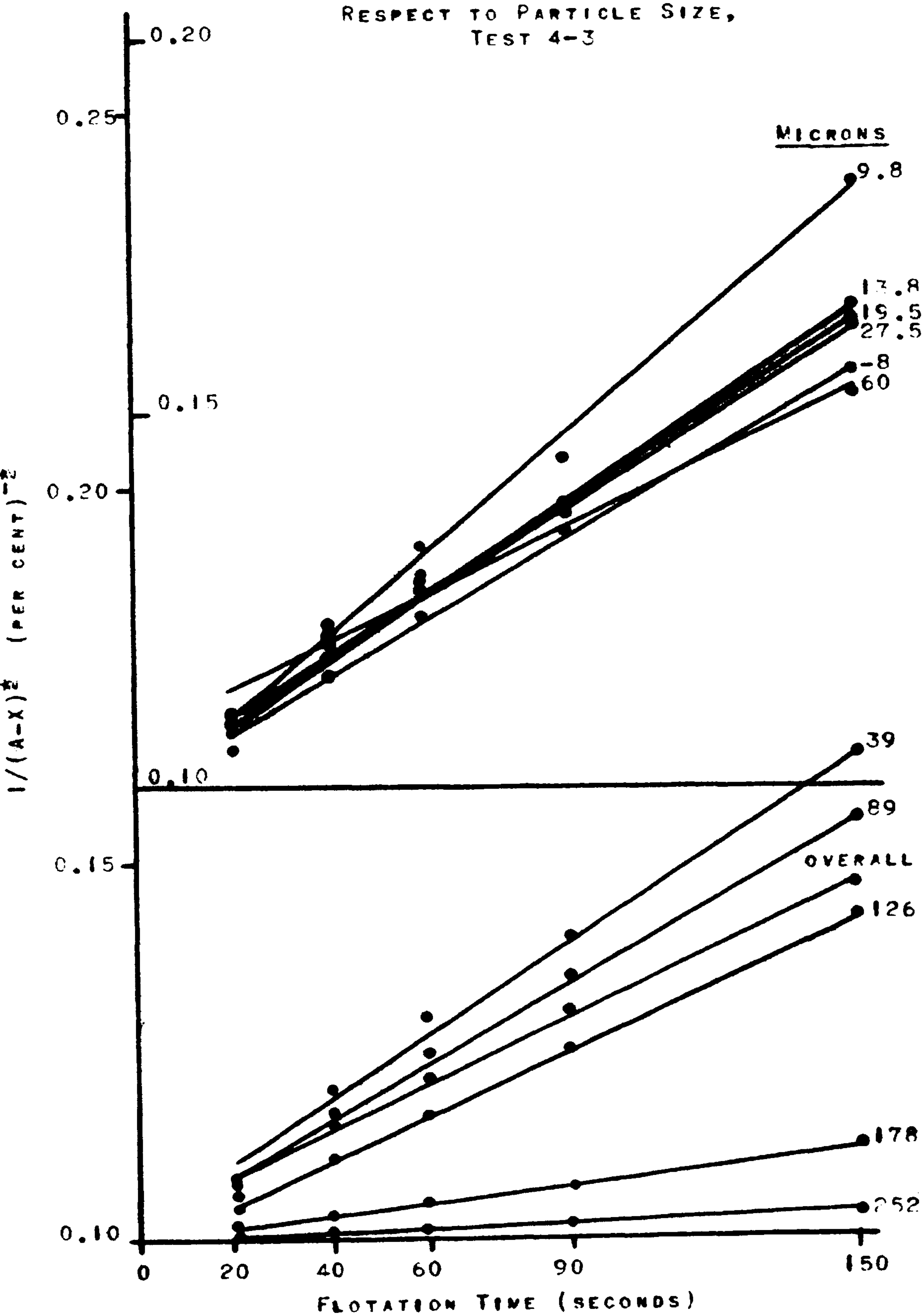
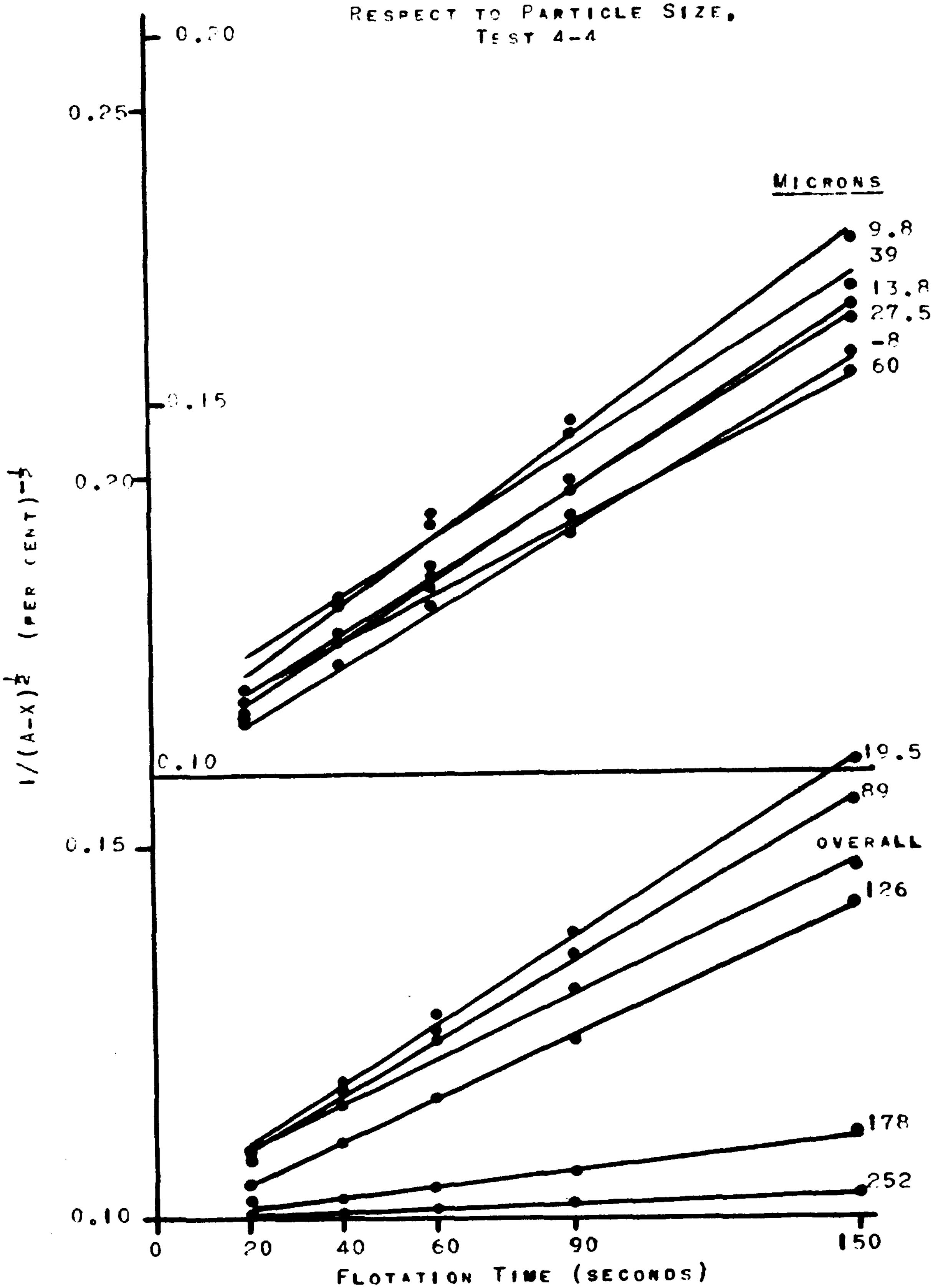


FIG. 19 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-4



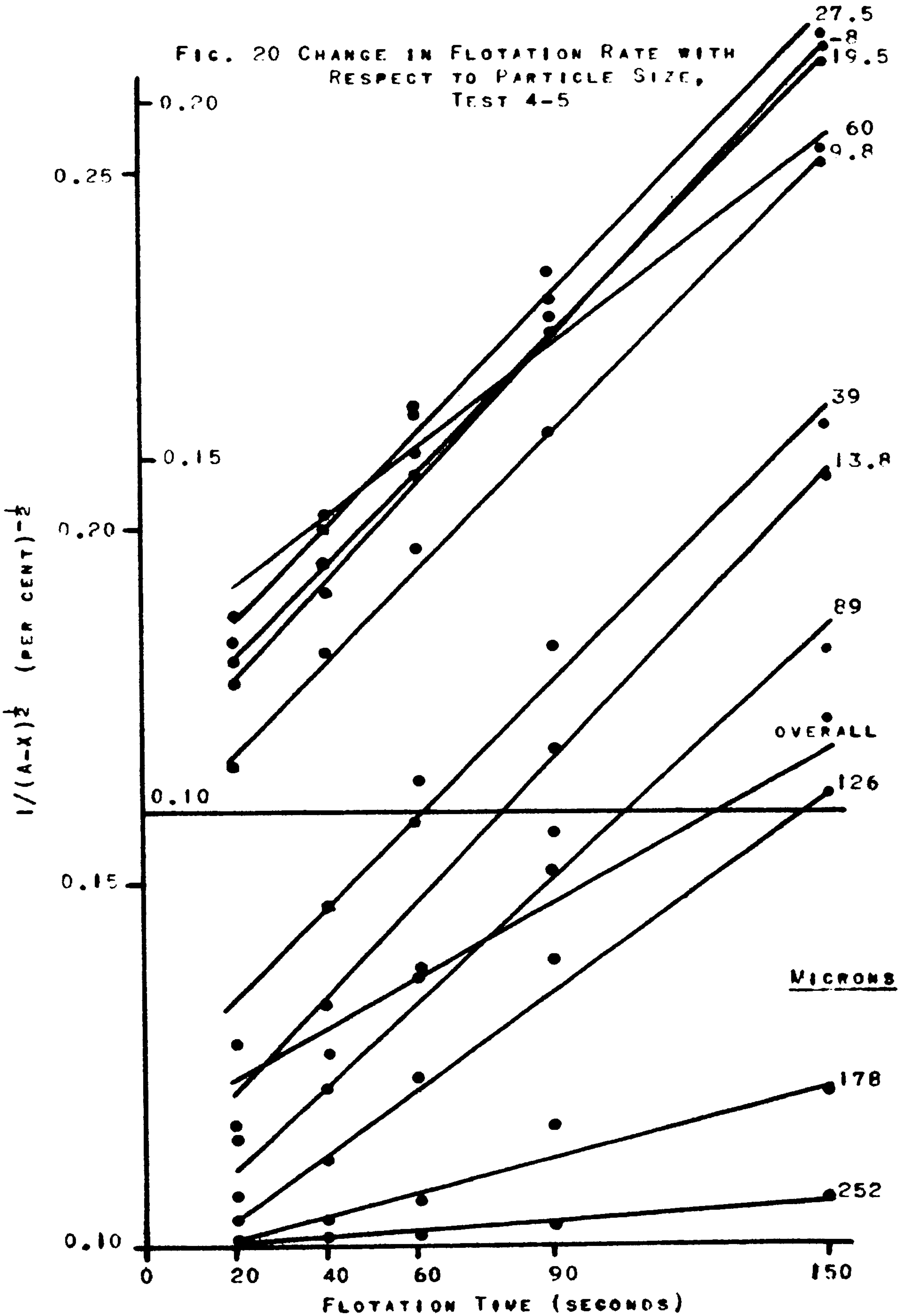


FIG. 20 CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, TEST 4-5
1/(A-X)^½ (PER CENT)^-½
FLOTATION TIME (SECONDS)
0.20
0.25
0.15
0.20
0.10
0.15
0.10
0
20
40
60
90
150
27.5
-8
19.5
60
9.8
39
13.8
89
OVERALL
126
MICRONS
178
252

TABLE 31

CALCULATED FLOTATION RATE CONSTANTS

IMPELLER SPEED --- 863

FLOTATION RATE CONSTANT, K (1/(MIN.)(PER CENT)$^{\frac{1}{2}}$)

| MEAN DIA. | AIR VOLUME (LITERS PER MIN.) | | | | |
|---|---|---|---|---|---|
| MICRONS | 1.0 | 2.0 | 2.5 | 3.0 | 3.5 |
| OVERALL | 0.0358 | 0.0354 | 0.0369 | 0.0361 | 0.0425 |
| 252 | 0.0026 | 0.0027 | 0.0028 | 0.0027 | 0.0056 |
| 178 | 0.0107 | 0.0100 | 0.0102 | 0.0097 | 0.0202 |
| 126 | 0.0369 | 0.0360 | 0.0356 | 0.0461 | 0.0677 |
| 89 | 0.0470 | 0.0423 | 0.0442 | 0.0444 | 0.0704 |
| 60 | 0.0323 | 0.0354 | 0.0391 | 0.0406 | 0.0589 |
| 39 | 0.0514 | 0.0487 | 0.0508 | 0.0490 | 0.0773 |
| 27.5 | 0.0480 | 0.0465 | 0.0484 | 0.0477 | 0.0798 |
| 19.5 | 0.0484 | 0.0491 | 0.0500 | 0.0487 | 0.0789 |
| 13.8 | 0.0477 | 0.0505 | 0.0518 | 0.0501 | 0.0826 |
| 9.8 | 0.0409 | 0.0501 | 0.0653 | 0.0561 | 0.0786 |
| -8 | 0.0706 | 0.0501 | 0.0460 | 0.0445 | 0.0825 |

IMPELLER SPEED --- 1294

FLOTATION RATE CONSTANT, K (1/(MIN.)(PER CENT)$^{\frac{1}{2}}$)

| MEAN DIA. | AIR VOLUME (LITERS PER MIN.) | | | | |
|---|---|---|---|---|---|
| MICRONS | 1.0 | 2.0 | 2.5 | 3.0 | 3.5 |
| OVERALL | 0.0580 | 0.0526 | 0.0516 | 0.0448 | 0.0608 |
| 252 | 0.0092 | 0.0059 | 0.0036 | 0.0040 | 0.0036 |
| 178 | 0.0301 | 0.0237 | 0.0160 | 0.0188 | 0.0188 |
| 126 | 0.0744 | 0.0650 | 0.0581 | 0.0616 | 0.0638 |
| 89 | 0.0826 | 0.0720 | 0.0713 | 0.0765 | 0.0800 |
| 60 | 0.0700 | 0.0646 | 0.0703 | 0.0679 | 0.0755 |
| 39 | 0.0738 | 0.0663 | 0.0755 | 0.0945 | 0.0901 |
| 27.5 | 0.0634 | 0.0600 | 0.0756 | 0.0893 | 0.0839 |
| 19.5 | 0.0797 | 0.0749 | 0.0878 | 0.0941 | 0.0917 |
| 13.8 | 0.0573 | 0.0744 | 0.0630 | 0.105 | 0.101 |
| 9.8 | 0.0638 | 0.0731 | 0.0496 | 0.105 | 0.129 |
| -8 | 0.0303 | 0.0448 | 0.0531 | 0.0768 | 0.122 |

TABLE 32

CALCULATED FLOTATION RATE CONSTANTS

IMPELLER SPEED --- 1725 RPM

FLOTATION RATE CONSTANT, K $(1/(\text{MIN.})(\text{PER CENT})^{\frac{1}{2}})$

| MEAN DIA. MICRONS | AIR VOLUME (LITERS PER MIN.) 1.0 | 2.0 | 2.5 | 3.0 | 3.5 |
|---|---|---|---|---|---|
| OVERALL | 0.0519 | 0.0458 | 0.0547 | 0.0565 | 0.0624 |
| 252 | 0.0014 | 0.0035 | 0.0018 | 0.0024 | 0.0016 |
| 178 | 0.0116 | 0.0118 | 0.0130 | 0.0127 | 0.0138 |
| 126 | 0.0491 | 0.0444 | 0.0491 | 0.0472 | 0.0571 |
| 89 | 0.0675 | 0.0424 | 0.0686 | 0.0721 | 0.101 |
| 60 | 0.0884 | 0.0465 | 0.0383 | 0.101 | 0.0567 |
| 39 | 0.0737 | 0.0797 | 0.164 | 0.0928 | 0.132 |
| 27.5 | 0.0712 | 0.0878 | 0.0917 | 0.0868 | 0.127 |
| 19.5 | 0.0802 | 0.0802 | 0.0851 | 0.104 | 0.112 |
| 13.8 | 0.0622 | 0.0776 | 0.0972 | 0.0825 | 0.103 |
| 9.8 | 0.0350 | 0.0361 | 0.0753 | 0.0870 | 0.155 |
| -8 | 0.0311 | 0.0724 | 0.143 | 0.0902 | 0.340 |

IMPELLER SPEED --- 2048

FLOTATION RATE CONSTANT, K $(1/(\text{MIN.})(\text{PER CENT})^{\frac{1}{2}})$

| MEAN DIA. MICRONS | AIR VOLUME (LITERS PER MIN.) 1.0 | 2.0 | 2.5 | 3.0 | 3.5 |
|---|---|---|---|---|---|
| OVERALL | 0.0432 | 0.0721 | 0.0878 | 0.0698 | 0.0859 |
| 252 | 0.0148 | 0.0259 | 0.0251 | 0.0168 | 0.0198 |
| 178 | 0.0301 | 0.0498 | 0.0505 | 0.0367 | 0.0445 |
| 126 | 0.0579 | 0.0945 | 0.109 | 0.0811 | 0.0964 |
| 89 | 0.0610 | 0.107 | 0.133 | 0.101 | 0.121 |
| 60 | 0.0494 | 0.0970 | 0.109 | 0.104 | 0.108 |
| 39 | 0.0525 | 0.0738 | 0.105 | 0.0712 | 0.110 |
| 27.5 | 0.0404 | 0.0649 | 0.0865 | 0.0719 | 0.102 |
| 19.5 | 0.0411 | 0.0704 | 0.0950 | 0.0741 | 0.113 |
| 13.8 | 0.0320 | 0.0627 | 0.104 | 0.0564 | 0.134 |
| 9.8 | 0.0560 | 0.0514 | 0.123 | 0.0656 | 0.106 |
| -8 | 0.0340 | 0.0342 | 0.0719 | 0.0588 | 0.0888 |

Fig. 21 Variation in Flotation Rate with Respect to Particle Size, Air Volume Constant (1.0 liters per min.)

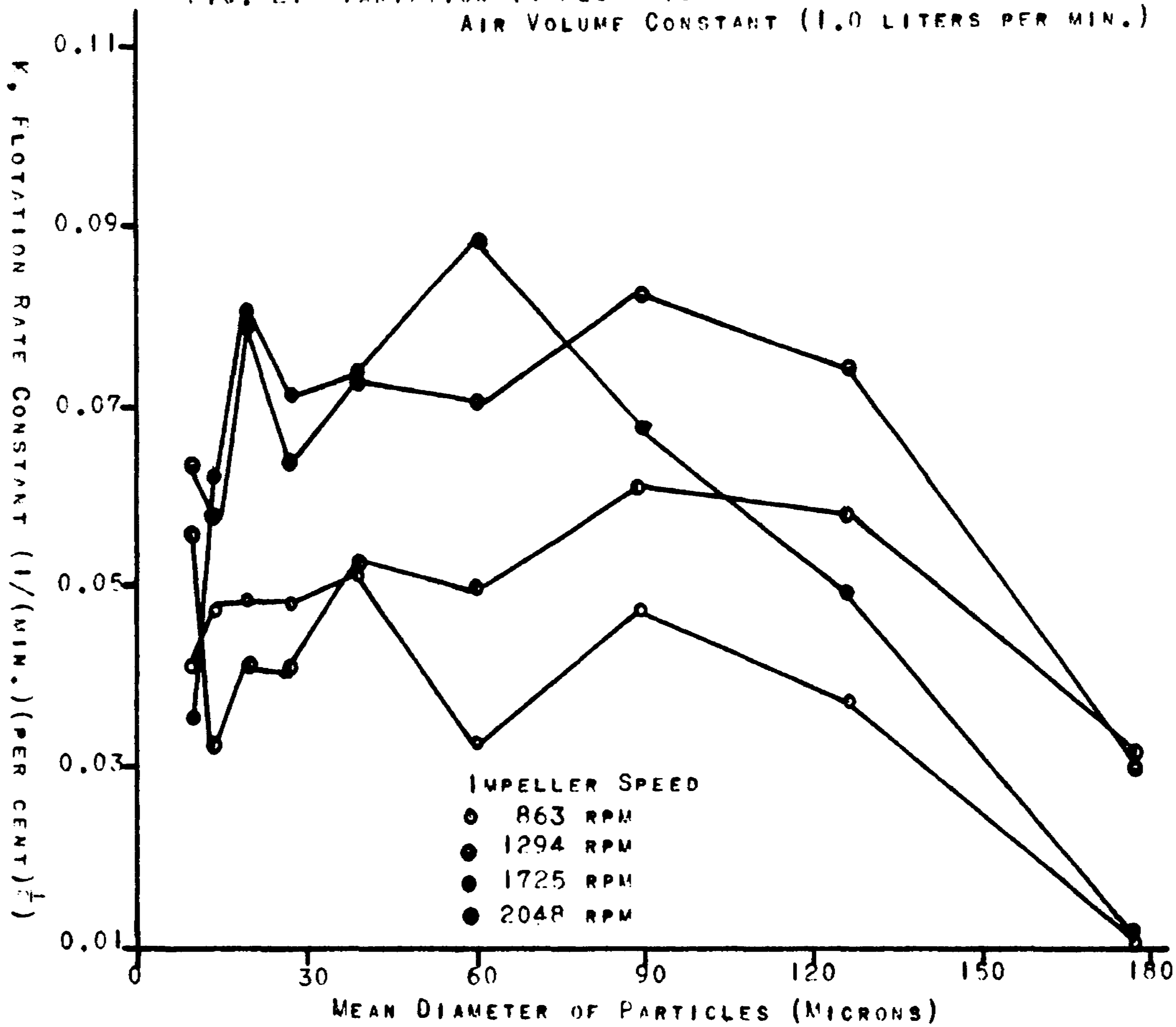


Fig. 22 Variation in Flotation Rate with Respect to Particle Size, Air Volume Constant (2.0 liters/min.)

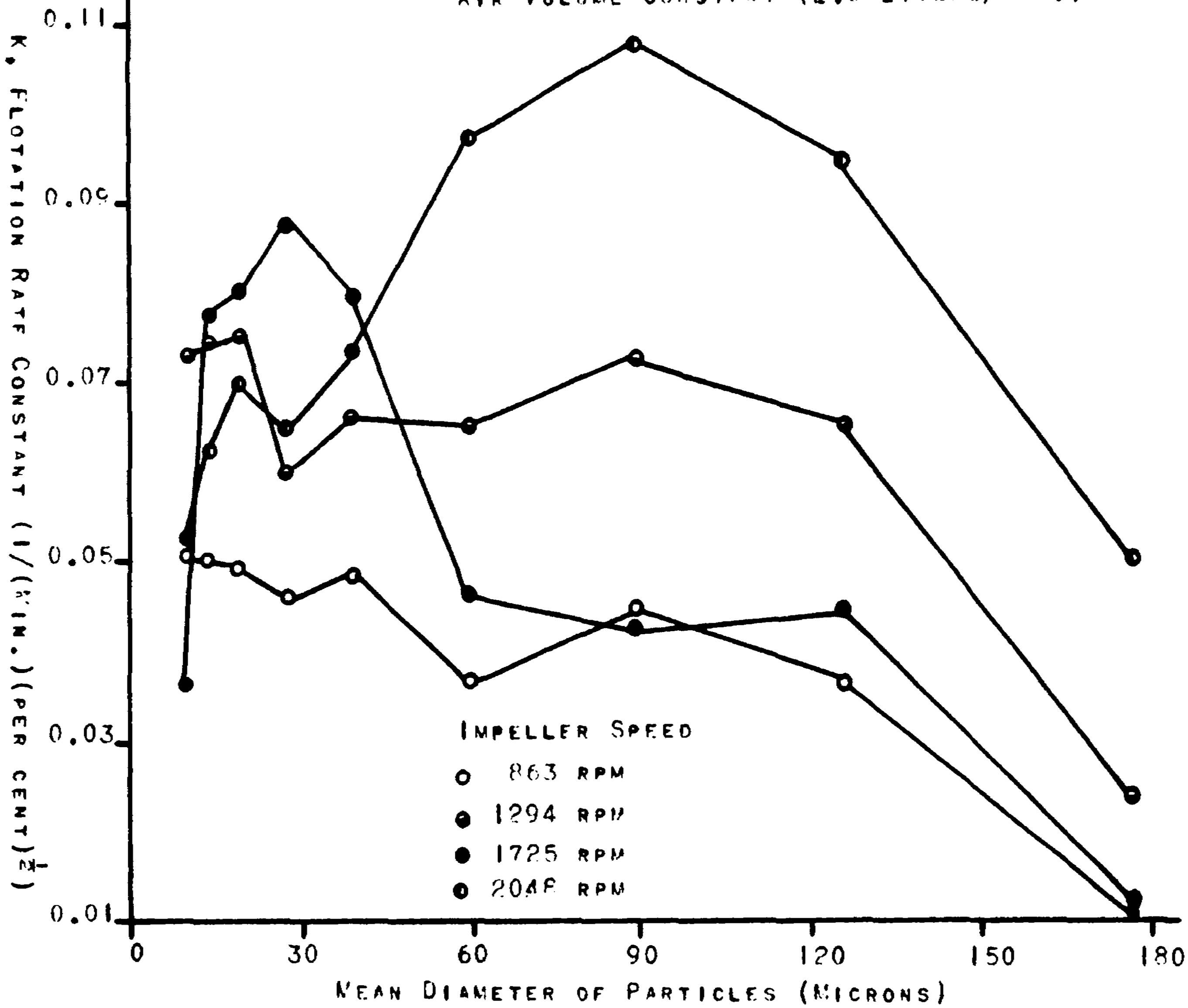


FIG. 23 VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, AIR VOLUME CONSTANT (3.0 LITERS PER MIN.)

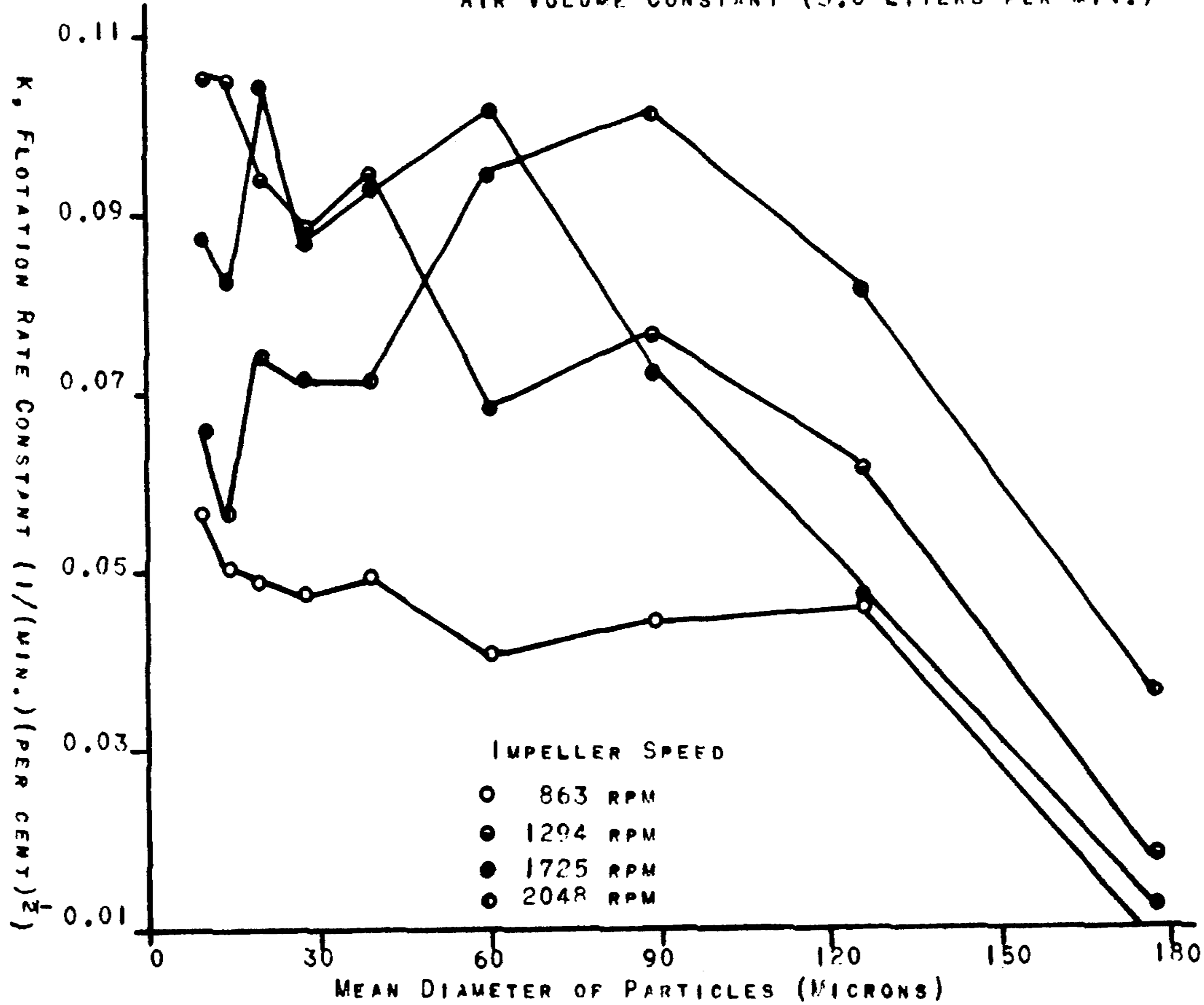


FIG. 24 VARIATION IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE, IMPELLER SPEED CONSTANT (863 RPM)

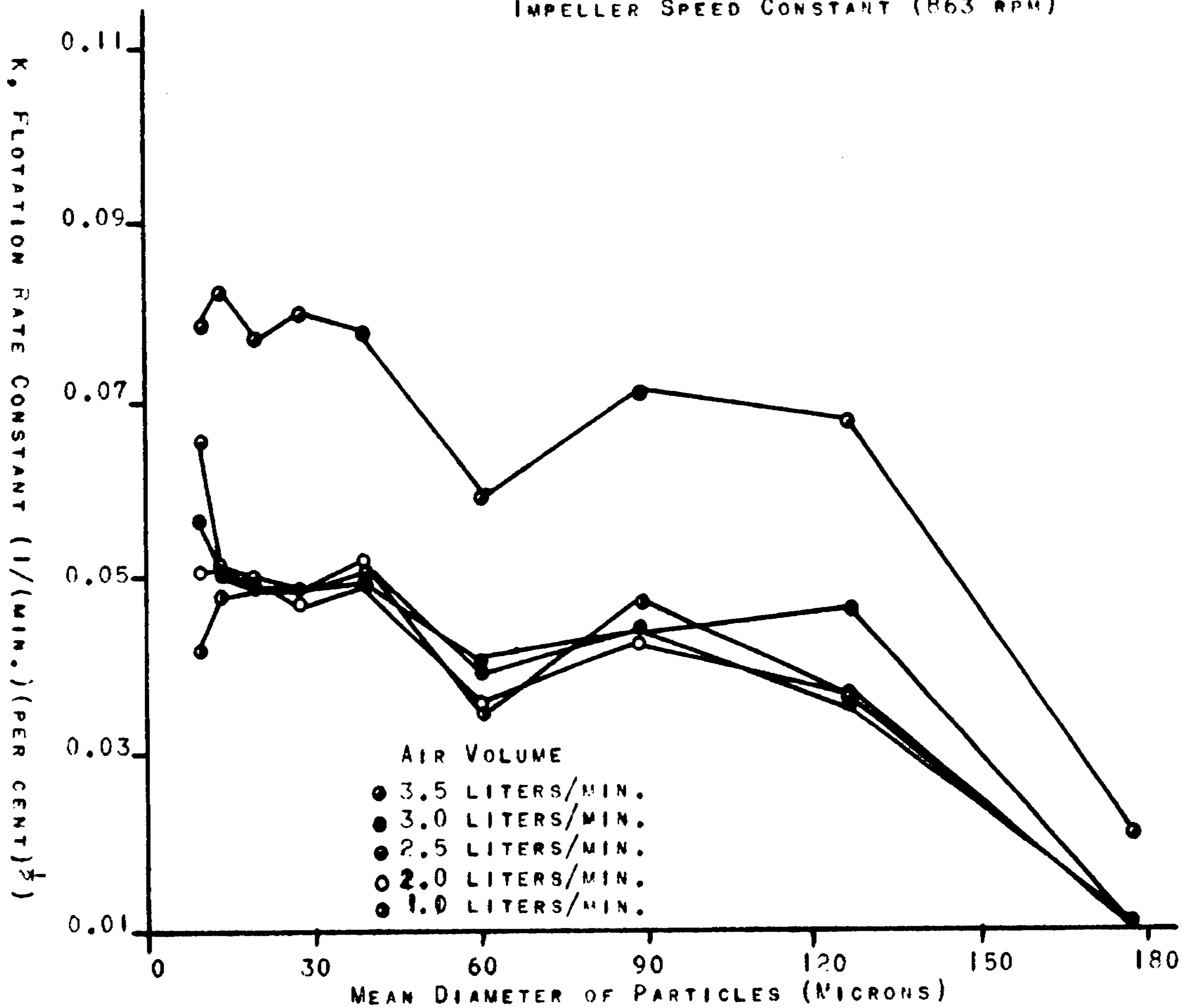


Fig. 25 Variation in Flotation Rate with Respect to Particle Size, Impeller Speed Constant (1294 rpm)

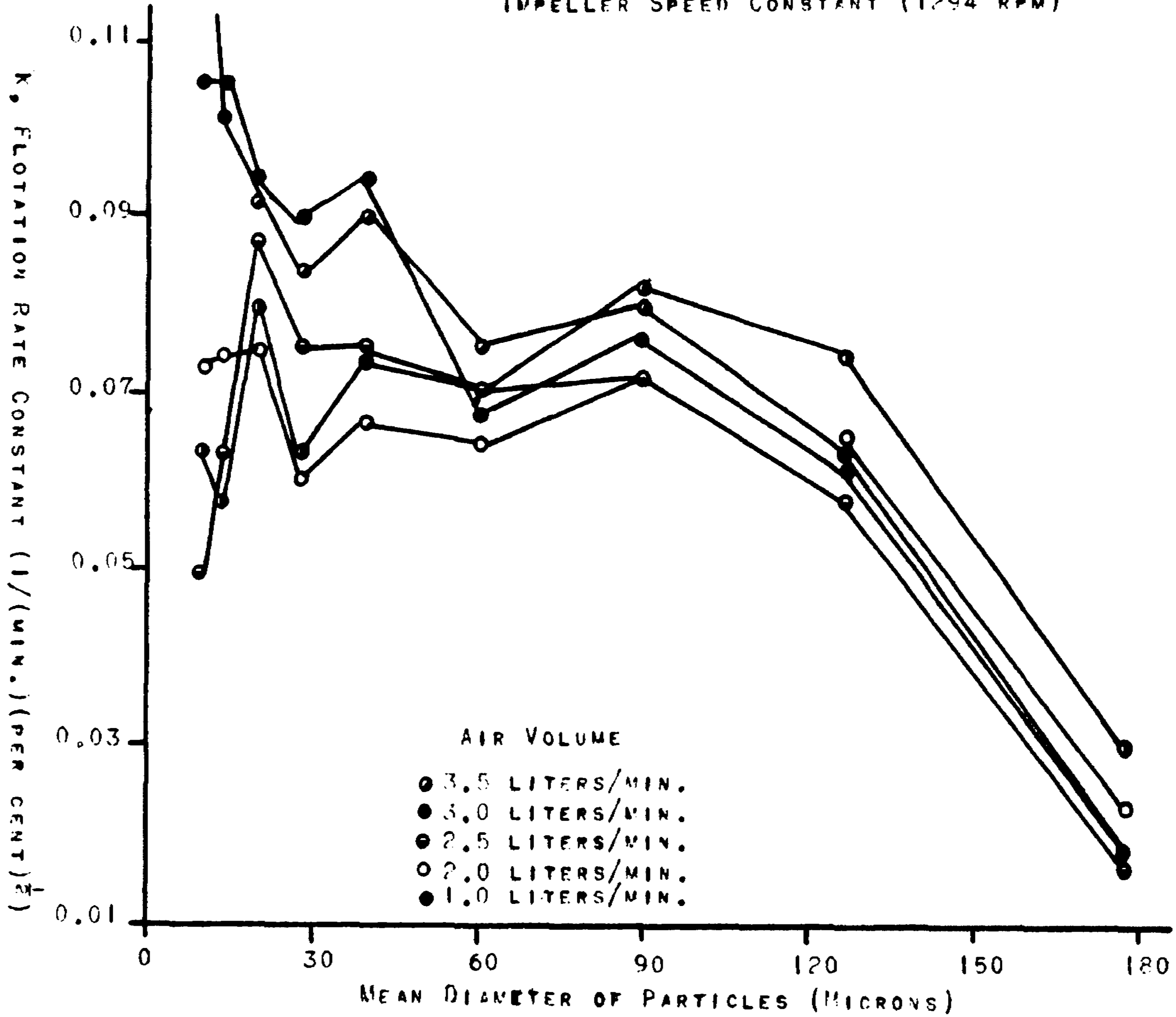
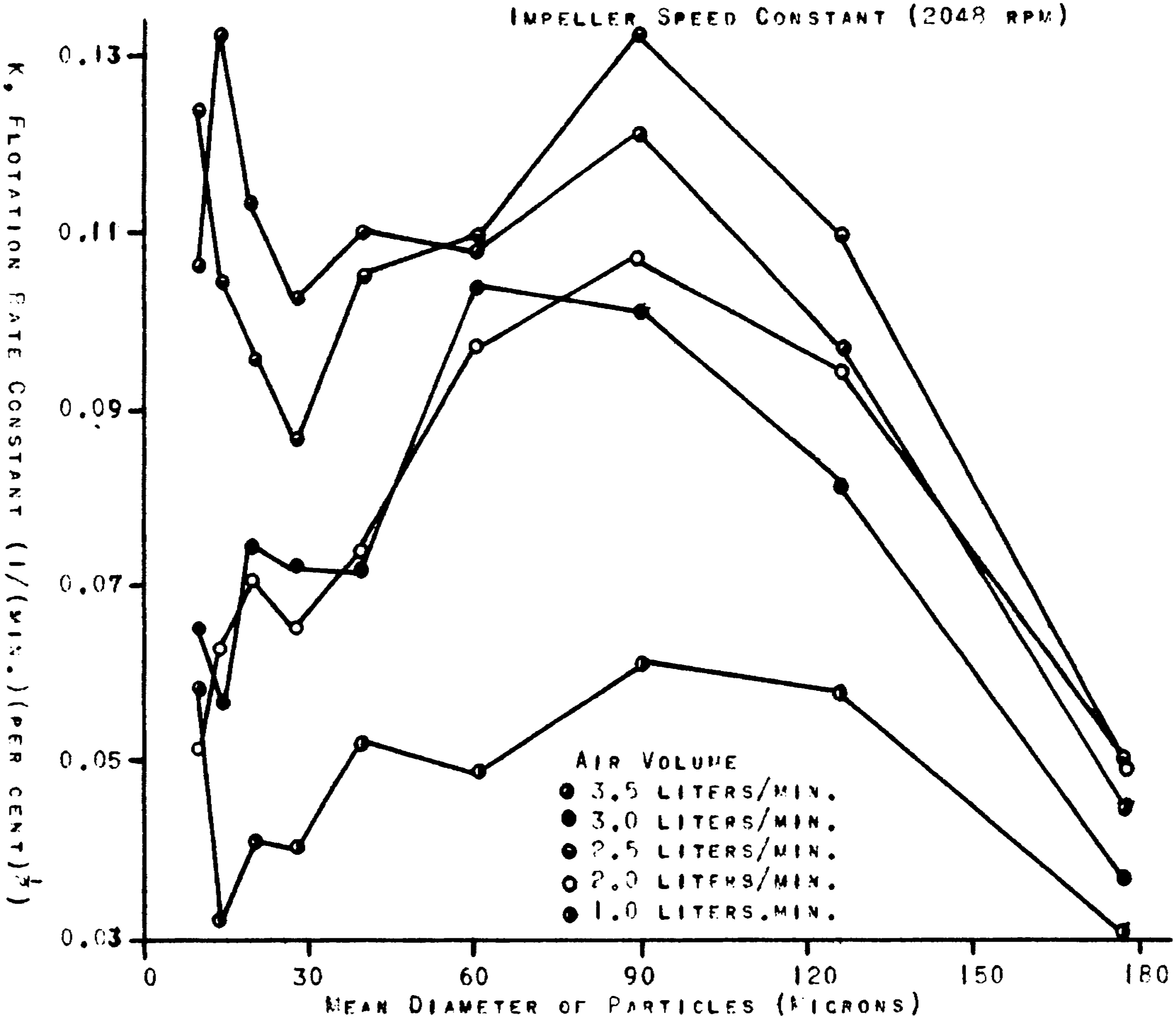


Fig. 26 Variation in Flotation Rate with Respect to Particle Size, Impeller Speed Constant (2048 rpm)



## DISCUSSION OF RESULTS

Two of the variables that affect the flotation rate were considered in the investigation. These variables were impeller speed and volume of air entering the flotation cell per unit time.

Morris(14) found that the flotation rate increases

(14) Morris, T. M., op. cit.

as the particle size increases until a maximum rate is reached. The maximum rate occured in the 50 to 60 micron range for copper and pyrite. After the maximum rate was reached, the flotation rate decreased with an increase in particle size.

Kidd and Wall(15) floated various size fractions of

(15) Kidd, R. L., and Wall, W. L., Effect of particle size on flotation of sphalerite: Mining and Metallurgy, vol. 14, pp. 421-422, 1933.

sphalerite and plotted cumulative recovery as a function of cumulative flotation time for each size fraction. The greatest recovery was attained for the 74 to 104 micron size fraction, and the recovery decreased as the particle size increased or decreased from the optimum size. The validity of the Kidd and Wall tests on the elutricated fractions are questionable. The elutriated fractions were subjected to gum arabic, which was used for a dispersing agent, and they failed to clean the sphalerite particles before they were floated. The rate of flotation of these size fractions would be expected to be retarded since they were coated with a depressant.

Results from flotation tests using a batch cell and collecting galena concentrate made by Gaudin, Groh, and Henderson[16] indicate that the largest size, 20 mesh,

(16) Gaudin, A. M., Groh, J. O., and Henderson, H. B., Effect of particle size on flotation: Am. Inst. Min. Met. Eng. T. P. 414, 1930.

floated fastest and the flotation rate decreased as the particle size decreased. These results are contrary to the results obtained by Morris and Kidd and Wall as previously discussed.

Gaudin, Schuhmann, and Schlechten[17] found that the

(17) Gaudin, A. M., Schuhmann, R., Jr., and Schlechten, A. W., The effect of size on the behavior of galena particles: Jour. of Physical and Colloid Chem., vol. 46, pp. 902-910, 1942.

specific flotation rate of galena increased as the particle size increased. They used particle sizes of less than 40 microns in diameter. The specific flotation rate of any size fraction is defined as the grams of that size fraction floated per minute divided by the grams of that size fraction in the cell. They conducted their experiments using a steady state flotation cell.

A graph of the flotation rate constant versus the mean diameter of the particles indicates that the flotation

RATE INCREASES AS THE PARTICLE SIZE INCREASES UNTIL A MAXIMUM FLOTATION RATE IS REACHED BETWEEN 60 AND 89 MICRONS. THIS RELATIONSHIP WAS SEEN TO EXIST FOR IMPELLER SPEEDS OF 1725 AND 2048 REVOLUTIONS PER MINUTE AS SHOWN IN FIGURES 21, 22, AND 23. AT SLOWER SPEEDS OF 863 AND 1294 REVOLUTIONS PER MINUTE THE FLOTATION RATE REMAINED FAIRLY CONSTANT OR DECREASED AS THE PARTICLE SIZE INCREASED. THIS IS ALSO SHOWN IN FIGURES 21, 22, AND 23. AS THE PARTICLE SIZE INCREASED BEYOND THE 60 TO 89 MICRON RANGE THE FLOTATION RATE DECREASED. THIS CONDITION EXISTED FOR EACH OF THE FOUR SPEEDS.

FIRST LET US CONSIDER WHAT HAPPENS WHEN THE IMPELLER SPEED VARIES AND THE AIR VOLUME REMAINS CONSTANT. THERE ARE TWO FACTORS INVOLVED IN REMOVING THE VALUABLE MINERALS FROM THE FLOTATION CELL IN THE FORM OF FROTH. FIRST THE SOLID AND BUBBLE MUST UNITE, AND SECOND, THE BUBBLE SOLID AGGREGATE MUST BE CAPABLE OF REACHING THE SURFACE WITHOUT BEING DISRUPTED.

BASED ON THE COLLISION THEORY OF BUBBLE PARTICLE UNION, SUTHERLAND'S [18] ANALYSIS PREDICTS THAT THE

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(18) SUTHERLAND, K. L., KINETICS OF THE FLOTATION PROCESS: JOUR. OF PHYSICAL AND COLLOID CHEM., VOL. 52, PP. 394-425, 1948.

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FLOTATION RATE CONSTANT WOULD INCREASE AS THE PARTICLE SIZE INCREASES UNTIL THE MAXIMUM PARTICLE SIZE FLOATABLE IS REACHED. THE FLOTATION RATE BEING DIRECTLY PROPORTIONAL TO THE DIAMETER OF THE PARTICLE.

Morris[19] measured the forces acting between a

(19) Morris, T. M. Measurement of equilibrium forces between an air bubble and an attached solid in water: Am. Inst. Min. Met. Eng. Trans., vol. 187, pp. 91-96, 1950.

bubble and particle under static conditions. He found the probability of the bubble particle system being capable of withstanding the disruptive forces present in the flotation cell was greater for any given bubble the smaller the size of the attached particle. Therefore, the greater would be the probability of the particle bubble aggregate reaching the surface and being removed.

Now consider the ascending portion of the flotation rate versus particle size curve for impeller speeds of 1725 and 2048 revolutions per minute. At the faster speed more work is put into the system and it would be expected that more bubbles would be produced, since work is required to overcome the surface energy existing between the air water interface. Since the air volume is constant for both speeds and there would be a greater number of bubbles present at the higher speed, the size of the bubbles produced at the higher speed would be expected to be smaller in size. According to Sutherland's analysis the ascending curve would be expected, but why should the smaller sizes float slower for the higher speed and faster at the slower speed. The velocity of the particles and bubbles increase with an increase in impeller speed and it becomes more difficult for the smaller particles to unite with a bubble. The inertia of the small particles is insufficient in many instances to allow them to penetrate the film formed by the laminar flow of fluid around the bubble and form a bubble particle aggregate. The small particles that are capable of uniting with a bubble have a greater chance of reaching the surface than the larger bubble.

As the particle size increases to the optimum size, the probability of a bubble particle aggregate reaching the surface decreases. However, the probability of a bubble and particle uniting increases since the inertia of the particle increases with the particle size. The flotation rate would be expected to increase with particle size as is indicated by the experimental results.

At slower impeller speeds of 863 and 1294 revolutions per minute the flotation rate remains fairly constant or decreases as the particle size increases. At these slower impeller speeds the disruptive forces within the cell are less than at higher speeds, and the film formed by the laminar flow of fluid around the bubble does not offer as much resistance to penetration by a moving particle. Although the inertia of the particles has decreased, it is sufficient to permit the particles and bubbles to unite. The probability of the larger particles, because of their inertia, of uniting with bubbles is

GREATER THAN THE SMALL PARTICLES, BUT THE PROBABILITY OF THE SMALL PARTICLES OF REACHING THE SURFACE ATTACHED TO A BUBBLE IS GREATER THAN THE LARGER PARTICLES. THEREFORE, AT THE SLOWER IMPELLER SPEEDS THE FLOTATION RATE MAY BE EXPECTED TO REMAIN FAIRLY CONSTANT OR DECREASE AS THE PARTICLE SIZE INCREASES AS WAS INDICATED BY THE RESULTS.

AS THE PARTICLE SIZE INCREASED FROM THE OPTIMUM SIZE OF 60 TO 89 MICRONS, THE FLOTATION RATE WAS FOUND TO DECREASE. THE DECREASE IN RATE WAS FOUND TO BE MORE RAPID AT HIGHER IMPELLER SPEEDS. THE PROBABILITY OF BUBBLE PARTICLE ATTACHMENT INCREASES WITH AN INCREASE IN PARTICLE SIZE AS BEFORE, BUT THE PROBABILITY OF THE BUBBLE PARTICLE AGGREGATE REACHING THE SURFACE DECREASES. THE LATER ACTION IS PREDOMINANT FOR THE LARGER PARTICLE SIZES. THE FLOTATION RATE OF THE LARGER PARTICLES WAS FOUND TO DECREASE MORE RAPIDLY AT HIGHER IMPELLER SPEEDS WHICH IS IN ACCORDANCE WITH THE REASONING SINCE THE DISRUPTIVE FORCES INCREASE WITH AN INCREASE IN IMPELLER SPEED. ALTHOUTH THE INERTIA OF THE PARTICLES INCREASE WITH SPEED, THE DISRUPTIVE FORCES OVERCOME THIS APPARENT ADVANTAGE SINCE IT IS MORE DIFFICULT FOR A LARGE PARTICLE TO REMAIN ATTACHED TO A BUBBLE THAN A SMALL PARTICLE.

THE VALUES OF K APPEAR TO BE LOW AS SHOWN IN FIGURE 22 FOR THE 60 AND 89 MICRON SIZE FRACTIONS AT AN IMPELLER SPEED OF 1725 REVOLUTIONS PER MINUTE. THIS MAY BE accounted for by referring to Figure 2. The three-halves order rate equation does not fit the data very well for these two size fractions, and there is a drift in the K value as the flotation time increases. These two K values should be greater. Similarly the K value for the 60 micron size fraction at an impeller speed of 1294 revolutions per minute should be greater as seen in Figure 23. This K value drifts with an increase in time as may be observed in Figure 14.

From Figures 21, 22, and 23 it can be seen that with an air volume of 1.0 liter per minute the flotation rate decreases from the maximum rate as the particle size becomes larger or smaller for all of the impeller speeds studied. This relationship remains the same at impeller speeds of 1725 and 2048 revolutions per minute as the air volume increased from 1.0 to 3.5 liters per minute. This is shown in Figures 22 and 23 and holds for air volumes of 2.5 and 3.5 liters per minute. At the slower impeller speeds of 863 and 1294 revolutions per minute the flotation rate increases with a decrease in particle size as the air volume increases which is shown in Figures 22 and 23. This trend also exists at air volumes of 2.5 and 3.5 liters per minute. In order to attain the optimum flotation conditions it is necessary to consider the effect of a variation in air volume on the impeller speed which has been illustrated.

THE VARIATION OF THE FLOTATION RATE CAUSED BY A CHANGE IN THE AIR VOLUME WHEN THE IMPELLER SPEED IS CONSTANT WILL NOW BE CONSIDERED. AT THE SLOWEST IMPELLER SPEED OF 863 REVOLUTIONS PER MINUTE A CHANGE IN AIR VOLUME DID NOT NOTICEABLY CHANGE THE FLOTATION RATE WITH RESPECT TO PARTICLE SIZE UNTIL THE AIR VOLUME WAS 3.5 LITERS PER MINUTE. THIS MAY BE OBSERVED FROM FIGURE 24. THE REASON FOR THE SUDDEN CHANGE IN FLOTATION RATE AT THIS AIR VOLUME IS DIFFICULT TO DETERMINE. IN ORDER TO ANALYZE THIS SITUATION IT WOULD BE NECESSARY TO OBTAIN AT LEAST ONE MORE SET OF DATA TO DETERMINE IF COMPARABLE RESULTS WOULD BE OBTAINED.

WHEN THE IMPELLER SPEED WAS INCREASED TO 1294 REVOLUTIONS PER MINUTE, THE CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE WAS SMALL AS THE PARTICLE SIZE DECREASED UNTIL REACHING 60 MICRONS. AS THE PARTICLE SIZE DECREASED FURTHER, THE FLOTATION RATE INCREASED AS THE AIR VOLUME INCREASED FOR EACH SIZE FRACTION. AS THE PARTICLE SIZE DECREASED THE FLOTATION RATE FOR EACH SIZE FRACTION INCREASED MORE RAPIDLY AS THE AIR VOLUME INCREASED.

AT THE SLOWER OF THE TWO IMPELLER SPEEDS, 863 AND 1294 REVOLUTIONS PER MINUTE, THE WORK PUT INTO THE SYSTEM APPEARS TO BE INSUFFICIENT TO UTILIZE THE ADDITIONAL VOLUME OF AIR ADDED TO THE FLOTATION CELL. CONSEQUENTLY THE ADVANTAGE TO BE GAINED FROM HAVING MORE AIR BUBBLES IN THE CELL IS ELIMINATED SINCE TWO MUCH WORK IS REQUIRED

TO CREATE THE ADDITIONAL BUBBLES. WHEN THE IMPELLER SPEED HAS BEEN INCREASED TO 1294 REVOLUTIONS PER MINUTE, MORE WORK HAS BEEN PUT INTO THE SYSTEM AND MORE BUBBLES RESULT IN THE CELL AS THE AIR VOLUME IN INCREASED. THE FLOTATION RATES OF THE SMALLEST SIZE PARTICLES ARE THE FIRST TO INDICATE AN INCREASE WITH AN INCREASE IN THE AIR VOLUME. THIS MAY BE EXPECTED SINCE THE SMALLEST PARTICLES HAVE THE GREATEST PROBABILITY OF REACHING THE SURFACE AS A BUBBLE PARTICLE AGGREGATE. ALSO THE INERTIA OF THE SMALLEST PARTICLES IN OF SUFFICIENT MAGNITUDE TO PENETRATE THE FILM FORMED BY THE LAMINAR FLOW OF FLUID AROUND THE BUBBLE AND UNITE WITH THE BUBBLE AT THIS IMPELLER SPEED.

WITH AN INCREASE IN IMPELLER SPEED TO 1725 AND 2048 REVOLUTIONS PER MINUTE THE NUMBER OF BUBBLES FORMED INCREASES AS THE AIR VOLUME INCREASES. THIS IS POSSIBLE SINCE THERE HAS BEEN AN INCREASE IN THE AMOUNT OF WORK PUT INTO THE SYSTEM. WITH MORE BUBBLES PRESENT THE FLOTATION RATES OF THE VARIOUS SIZED PARTICLES INCREASED FOR A GIVEN SPEED. HAVING MORE BUBBLES IN THE CELL, THERE EXISTED A GREATER PROBABILITY OF BUBBLE PARTICLE UNION WHICH PRODUCED AN INCREASE IN FLOTATION RATE WITH AN INCREASE IN AIR VOLUME. FIGURE 26 INDICATES THE CHANGE IN FLOTATION RATE WITH RESPECT TO PARTICLE SIZE WITH A CHANGE IN AIR VOLUME AT AN IMPELLER SPEED OF 2048 REVOLUTIONS PER MINUTE. IN THIS FIGURE THE RESULTS FROM THE TEST MADE HAVING AN AIR VOLUME OF 2.5 LITERS PER minute are not in accordance with the reasoning. By observing the results shown in Figure 8, it can be seen that the data obtained in this test does not fit the three-halves order rate equation very well. This is a possible explanation of why these results are not in agreement with the general trend. In any case, the results of this test are questionable. At impeller speeds of 1725 and 2048 revolutions per minute the flotation rate was a maximum for the size range of 74 to 104 microns as the air volume was increased from 1.0 to 3.5 liters per minute. The flotation rate decreased as the particle size increased or decreased from the optimum size range.

At present the general practice is to operate all of the flotation cells in a bank of cells at the same impeller speed and air volume. The results of the investigation indicate, that with a knowledge of the effect of impeller speed and air volume on the flotation rate of each size fraction of the ore, the mill operator would have a valuable tool for controlling the recovery per unit time. The following example shows how this could be accomplished for refloating the pyrite-pyrrhotite consentrates used in the experimental work. Figure 23 shows that the flotation rate of each size fraction increases as the particle size decreases when the impeller speed was 1294 revolutions per minute. In Figure 22 it

CAN BE SEEN THAT THE FLOTATION RATE IS A MAXIMUM FOR THE SIZE FRACTION OF 89 MICRONS AND DECREASES AS THE PARTICLE SIZE INCREASES OR DECREASES FOR AN IMPELLER SPEED OF 2048 REVOLUTIONS PER MINUTE. BY KNOWING THE SIZE DISTRIBUTION OF THE FLOTATION FEED AND THE NUMBER OF FLOTATION CELLS REQUIRED FOR THE OPERATION, THE IMPELLER SPEED AND AIR VOLUME COMBINATIONS FOR EACH CELL COULD BE DETERMINED IN ORDER TO INCREASE THE RECOVERY PER UNIT TIME. THAT IS, IF THE SIZE DISTRIBUTION OF THE FEED WAS 50 PER CENT MINUS 89 MICRONS AND 50 PER CENT 89 TO 178 MICRONS AND FOUR CELLS WERE REQUIRED, AN INCREASE IN THE RECOVERY PER UNIT TIME COULD BE ATTAINED BY OPERATING TWO CELLS AT AN IMPELLER SPEED OF 1294 REVOLUTIONS PER MINUTE AND AN AIR VOLUME OF 3.0 LITERS PER MINUTE. THE OTHER TWO CELLS WOULD BE OPERATED AT AN IMPELLER SPEED OF 2048 REVOLUTIONS PER MINUTE AND AN AIR VOLUME OF 2.0 LITERS PER MINUTE. AN ARRANGEMENT OF THIS NATURE WOULD ALLOW THE MINUS 89 MICRONS MATERIAL TO BE FLOATED FASTER IN THE CELLS OPERATED AT A SLOWER IMPELLER SPEED, AND THE 89 TO 178 MICRON MATERIAL WOULD FLOAT FASTER IN THE CELLS OPERATING AT A FASTER IMPELLER SPEED. OTHER FACTORS SUCH AS POWER AND MAINTENANCE WOULD HAVE TO BE CONSIDERED IN DETERMINING THE MOST ECONOMICAL COMBINATIONS OF THE IMPELLER SPEED AND AIR VOLUME FOR EACH CELL NECESSARY TO INCREASE THE RECOVERY PER UNIT TIME. HOWEVER, THE RESULTS INDICATE THAT VARIATIONS CAN BE MADE IN THE AIR VOLUME AND IMPELLER SPEED TO INCREASE THE RECOVERY PER UNIT TIME.

## SUMMARY OF CONCLUSIONS

1. At all of the impeller speeds studied and an air volume of 1.0 liter per minute the flotation rate was found to decrease from the maximum rate as the particle size decreased or increased from the size having the maximum rate.
2. Using impeller speeds of 863 and 1294 revolutions per minute and air volumes of 2.0, 2.5, 3.0, and 3.5 liters per minute the flotation rate was found to increase as the particle size decreased.
3. Using impeller speeds of 1725 and 2048 revolutions per minute and air volumes of 2.0, 2.5, 3.0, and 3.5 liters per minute the flotation rate was found to decrease from the maximum rate as the particle size decreased or increased from the size having the maximum flotation rate.
4. Using an impeller speed of 863 revolutions per minute a change in air volume did not noticeably change the flotation rate with respect to particle size.
5. Using an impeller speed of 1294 revolutions per minute a change in air volume produced a small change in the flotation rate for particles of 60 microns or greater. For particles less than 60 microns the flotation rate increased with an increase in air volume.

6. Using impeller speeds of 1725 and 2048 revolutions per minute the flotation rate of the various size fractions increased with an increase in air volume.
7. With a knowledge of the effect of impeller speed and air volume on the flotation rate constant with respect to particle size, the impeller speed and air volume of each flotation cell in a bank of cells could be controlled in order to increase the recovery per unit time for a given ore.

## Table 33

### Calculated Data for Test I-I

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 19.78 | 80.22 | 0.1116 | 22.75 | 77.25 | 0.1138 | 19.84 | 80.16 | 0.1117 |
| 40 | 12.62 | 67.60 | 0.1216 | 12.47 | 64.78 | 0.1242 | 11.44 | 68.72 | 0.1206 |
| 60 | 8.60 | 59.00 | 0.1302 | 8.14 | 56.64 | 0.1329 | 12.58 | 56.14 | 0.1335 |
| 90 | 10.66 | 48.34 | 0.1439 | 12.10 | 44.54 | 0.1498 | 15.67 | 40.47 | 0.1572 |
| 150 | 12.90 | 35.44 | 0.1680 | 15.90 | 28.64 | 0.1868 | 14.48 | 25.99 | 0.1962 |
| | 252 Microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 0.54 | 99.46 | 0.1003 | 26.05 | 73.95 | 0.1163 | 24.19 | 75.81 | 0.1149 |
| 40 | 0.36 | 99.10 | 0.1005 | 16.71 | 57.24 | 0.1322 | 10.56 | 65.25 | 0.1238 |
| 60 | 0.25 | 98.85 | 0.1006 | 10.41 | 46.83 | 0.1461 | 10.33 | 54.92 | 0.1368 |
| 90 | 0.54 | 98.31 | 0.1009 | 11.79 | 35.04 | 0.1689 | 11.50 | 43.42 | 0.1518 |
| 150 | 1.87 | 96.44 | 0.1018 | 11.89 | 23.15 | 0.2123 | 12.04 | 31.38 | 0.1818 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 4.02 | 95.89 | 0.1021 | 24.61 | 75.39 | 0.1152 | 26.41 | 73.59 | 0.1166 |
| 40 | 2.72 | 93.26 | 0.1036 | 14.88 | 60.51 | 0.1286 | 11.92 | 61.67 | 0.1273 |
| 60 | 1.84 | 91.42 | 0.1046 | 10.28 | 50.23 | 0.1411 | 7.26 | 54.51 | 0.1310 |
| 90 | 4.35 | 87.07 | 0.1072 | 12.03 | 38.20 | 0.1618 | 6.40 | 48.01 | 0.1443 |
| 150 | 11.04 | 76.03 | 0.1147 | 10.85 | 27.35 | 0.1949 | 7.20 | 40.81 | 0.1565 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 14.15 | 85.85 | 0.1079 | 21.69 | 78.31 | 0.1130 | 8.02 | 91.98 | 0.1043 |
| 40 | 8.87 | 76.98 | 0.1140 | 14.28 | 64.03 | 0.1250 | 9.48 | 82.50 | 0.1101 |
| 60 | 6.47 | 70.51 | 0.1191 | 8.24 | 55.79 | 0.1339 | 8.65 | 73.85 | 0.1164 |
| 90 | 12.58 | 57.93 | 0.1331 | 14.47 | 41.32 | 0.1556 | 11.18 | 62.67 | 0.1263 |
| 150 | 19.03 | 38.90 | 0.1603 | 13.47 | 27.85 | 0.1895 | 9.92 | 52.75 | 0.1377 |

## Table 34

### Calculated Data for Test 1-2

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 Microns | | | 19.5 Microns | | |
| 20 | 23.46 | 76.54 | 0.1143 | 23.03 | 76.97 | 0.1140 | 23.39 | 76.61 | 0.1142 |
| 40 | 13.05 | 63.49 | 0.1255 | 11.96 | 65.01 | 0.1240 | 17.25 | 59.36 | 0.1315 |
| 60 | 7.51 | 55.98 | 0.1337 | 7.25 | 57.76 | 0.1333 | 10.74 | 48.62 | 0.1434 |
| 90 | 8.58 | 47.40 | 0.1452 | 8.69 | 49.07 | 0.1428 | 11.52 | 37.10 | 0.1642 |
| 150 | 10.67 | 36.73 | 0.1650 | 10.50 | 38.57 | 0.1610 | 12.67 | 24.43 | 0.2023 |
| | 252 Microns | | | 60 Microns | | | 13.8 Microns | | |
| 20 | 0.82 | 99.18 | 0.1004 | 26.64 | 73.36 | 0.1168 | 21.36 | 78.64 | 0.1128 |
| 40 | 0.76 | 98.42 | 0.1008 | 14.12 | 59.24 | 0.1299 | 16.29 | 62.35 | 0.1266 |
| 60 | 0.50 | 97.92 | 0.1011 | 6.89 | 52.35 | 0.1382 | 10.84 | 51.51 | 0.1393 |
| 90 | 1.12 | 96.80 | 0.1016 | 5.96 | 46.39 | 0.1468 | 11.92 | 39.59 | 0.1589 |
| 150 | 4.67 | 92.13 | 0.1042 | 8.22 | 38.17 | 0.1618 | 13.88 | 25.71 | 0.1972 |
| | 178 Microns | | | 39 Microns | | | 9.8 Microns | | |
| 20 | 9.98 | 90.02 | 0.1054 | 32.87 | 67.13 | 0.1221 | 9.69 | 90.31 | 0.1052 |
| 40 | 3.25 | 86.76 | 0.1073 | 16.43 | 50.70 | 0.1404 | 17.93 | 72.38 | 0.1166 |
| 60 | 1.88 | 84.89 | 0.1085 | 8.19 | 42.51 | 0.1534 | 3.89 | 68.49 | 0.1208 |
| 90 | 4.04 | 80.85 | 0.1112 | 9.53 | 32.98 | 0.1741 | 6.33 | 62.16 | 0.1268 |
| 150 | 9.29 | 71.56 | 0.1182 | 10.31 | 22.67 | 0.2100 | 15.80 | 46.36 | 0.1469 |
| | 126 Microns | | | 27.5 Microns | | | -8 Microns | | |
| 20 | 28.78 | 71.22 | 0.1185 | 28.50 | 71.50 | 0.1183 | 20.35 | 79.65 | 0.1120 |
| 40 | 9.62 | 61.60 | 0.1274 | 17.53 | 53.97 | 0.1361 | 14.55 | 65.10 | 0.1239 |
| 60 | 5.45 | 56.15 | 0.1335 | 10.24 | 43.73 | 0.1535 | 12.06 | 53.04 | 0.1373 |
| 90 | 8.66 | 47.49 | 0.1451 | 10.55 | 33.18 | 0.1736 | 14.52 | 38.52 | 0.1611 |
| 150 | 11.66 | 35.83 | 0.1671 | 11.49 | 21.69 | 0.2147 | 10.54 | 27.98 | 0.1890 |

## TABLE 35

### CALCULATED DATA FOR TEST 1-3

| TIME (SEC.) | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | OVERALL | | | 89 MICRONS | | | 19.5 MICRONS | | |
| 20 | 25.04 | 74.96 | 0.1155 | 27.43 | 72.57 | 0.1174 | 25.10 | 74.90 | 0.1156 |
| 40 | 16.02 | 58.94 | 0.1303 | 15.76 | 56.81 | 0.1327 | 19.47 | 55.43 | 0.1343 |
| 60 | 10.14 | 48.80 | 0.1431 | 11.07 | 45.74 | 0.1479 | 12.11 | 43.32 | 0.1519 |
| 90 | 8.45 | 40.35 | 0.1574 | 9.60 | 36.14 | 0.1663 | 10.45 | 32.87 | 0.1744 |
| 150 | 8.19 | 32.16 | 0.1763 | 9.15 | 26.99 | 0.1925 | 9.92 | 22.95 | 0.2087 |
| | 252 MICRONS | | | 60 MICRONS | | | 13.8 MICRONS | | |
| 20 | 0.53 | 99.47 | 0.1003 | 34.05 | 65.95 | 0.1231 | 23.75 | 76.25 | 0.1145 |
| 40 | 0.44 | 99.03 | 0.1005 | 13.89 | 52.06 | 0.1386 | 19.25 | 57.00 | 0.1325 |
| 60 | 0.70 | 98.33 | 0.1008 | 9.82 | 42.24 | 0.1539 | 12.74 | 44.26 | 0.1503 |
| 90 | 1.06 | 97.27 | 0.1014 | 6.79 | 35.45 | 0.1680 | 11.72 | 32.54 | 0.1753 |
| 150 | 1.58 | 95.69 | 0.1022 | 4.07 | 31.38 | 0.1785 | 11.89 | 20.65 | 0.2201 |
| | 178 MICRONS | | | 39 MICRONS | | | 9.8 MICRONS | | |
| 20 | 5.29 | 94.71 | 0.1028 | 36.40 | 63.60 | 0.1254 | 20.37 | 79.63 | 0.1121 |
| 40 | 4.70 | 90.01 | 0.1054 | 25.14 | 38.46 | 0.1662 | 18.43 | 61.20 | 0.1278 |
| 60 | 4.78 | 85.23 | 0.1083 | 10.48 | 27.98 | 0.1890 | 13.17 | 48.03 | 0.1443 |
| 90 | 5.49 | 79.74 | 0.1120 | 7.17 | 20.81 | 0.2192 | 9.31 | 38.72 | 0.1606 |
| 150 | 6.25 | 73.49 | 0.1167 | 8.51 | 12.30 | 0.2851 | 12.42 | 26.30 | 0.1950 |
| | 126 MICRONS | | | 27.5 MICRONS | | | -8 MICRONS | | |
| 20 | 18.15 | 81.85 | 0.1105 | 30.17 | 69.83 | 0.1197 | 23.24 | 76.76 | 0.1141 |
| 40 | 13.63 | 68.22 | 0.1211 | 19.00 | 50.83 | 0.1403 | 23.52 | 53.24 | 0.1370 |
| 60 | 11.50 | 56.72 | 0.1328 | 11.62 | 39.21 | 0.1597 | 14.04 | 39.20 | 0.1597 |
| 90 | 9.97 | 46.75 | 0.1462 | 9.68 | 29.53 | 0.1840 | 12.15 | 27.05 | 0.1923 |
| 150 | 9.59 | 37.16 | 0.1640 | 8.92 | 20.61 | 0.2203 | 10.16 | 16.89 | 0.2433 |

## Table 36

### Calculated Data for Test 1-4

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 24.45 | 75.55 | 0.1151 | 27.48 | 72.52 | 0.1175 | 23.93 | 76.07 | 0.1147 |
| 40 | 13.09 | 62.46 | 0.1265 | 13.09 | 59.43 | 0.1314 | 17.43 | 58.64 | 0.1306 |
| 60 | 9.60 | 52.86 | 0.1375 | 9.88 | 49.55 | 0.1421 | 9.28 | 49.36 | 0.1423 |
| 90 | 9.71 | 43.15 | 0.1522 | 10.48 | 39.07 | 0.1600 | 15.03 | 34.33 | 0.1707 |
| 150 | 11.11 | 32.04 | 0.1767 | 13.15 | 25.92 | 0.1964 | 13.92 | 20.41 | 0.2263 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 0.73 | 99.27 | 0.1004 | 32.56 | 67.44 | 0.1218 | 22.17 | 77.83 | 0.1134 |
| 40 | 0.41 | 98.86 | 0.1006 | 15.31 | 52.13 | 0.1385 | 16.98 | 60.85 | 0.1282 |
| 60 | 0.33 | 98.53 | 0.1007 | 11.48 | 40.65 | 0.1568 | 12.49 | 48.36 | 0.1438 |
| 90 | 0.51 | 98.02 | 0.1010 | 10.54 | 30.11 | 0.1822 | 12.42 | 35.94 | 0.1668 |
| 150 | 1.82 | 96.20 | 0.1030 | 11.30 | 18.81 | 0.2306 | 11.55 | 24.39 | 0.2025 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 7.26 | 92.74 | 0.1038 | 29.22 | 70.78 | 0.1203 | 21.15 | 78.85 | 0.1126 |
| 40 | 3.69 | 89.05 | 0.1060 | 17.37 | 53.41 | 0.1368 | 23.58 | 55.27 | 0.1345 |
| 60 | 2.84 | 86.21 | 0.1077 | 11.31 | 42.10 | 0.1541 | 9.11 | 46.16 | 0.1472 |
| 90 | 4.36 | 81.85 | 0.1105 | 11.89 | 30.21 | 0.1820 | 9.62 | 36.54 | 0.1654 |
| 150 | 9.84 | 72.01 | 0.1178 | 9.54 | 20.67 | 0.2200 | 13.92 | 22.62 | 0.2102 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 20.06 | 79.94 | 0.1118 | 25.42 | 74.58 | 0.1158 | 24.25 | 75.75 | 0.1149 |
| 40 | 10.14 | 69.80 | 0.1197 | 16.80 | 57.78 | 0.1316 | 17.71 | 58.04 | 0.1313 |
| 60 | 7.61 | 62.19 | 0.1272 | 11.97 | 45.81 | 0.1478 | 10.04 | 48.00 | 0.1443 |
| 90 | 9.82 | 52.37 | 0.1382 | 11.90 | 33.91 | 0.1747 | 12.58 | 35.42 | 0.1680 |
| 150 | 14.81 | 37.56 | 0.1632 | 11.01 | 22.90 | 0.2090 | 13.39 | 22.03 | 0.2130 |

TABLE 37

CALCULATED DATA FOR TEST I-5

| TIME (SEC.) | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | OVERALL | | | 89 MICRONS | | | 19.5 MICRONS | | |
| 20 | 28.21 | 71.79 | 0.1180 | 33.08 | 66.92 | 0.1222 | 29.92 | 70.08 | 0.1195 |
| 40 | 15.44 | 56.35 | 0.1350 | 16.32 | 50.60 | 0.1406 | 19.62 | 50.46 | 0.1408 |
| 60 | 8.78 | 47.57 | 0.1450 | 9.81 | 40.79 | 0.1566 | 11.85 | 38.61 | 0.1609 |
| 90 | 8.83 | 38.74 | 0.1607 | 10.28 | 30.51 | 0.1810 | 11.69 | 26.92 | 0.1928 |
| 150 | 9.27 | 29.47 | 0.1877 | 11.08 | 19.43 | 0.2321 | 7.15 | 19.77 | 0.2249 |
| | 252 MICRONS | | | 60 MICRONS | | | 13.8 MICRONS | | |
| 20 | 0.59 | 99.41 | 0.1003 | 36.90 | 63.10 | 0.1259 | 29.49 | 70.51 | 0.1191 |
| 40 | 0.51 | 98.90 | 0.1006 | 10.93 | 52.17 | 0.1384 | 21.26 | 49.25 | 0.1425 |
| 60 | 0.37 | 98.53 | 0.1007 | 5.71 | 46.46 | 0.1489 | 13.54 | 35.71 | 0.1673 |
| 90 | 0.63 | 97.90 | 0.1011 | 4.97 | 41.49 | 0.1553 | 14.17 | 21.54 | 0.2155 |
| 150 | 1.76 | 96.14 | 0.1020 | 13.81 | 27.68 | 0.1901 | 2.12 | 19.42 | 0.2269 |
| | 178 MICRONS | | | 39 MICRONS | | | 9.8 MICRONS | | |
| 20 | 5.89 | 94.11 | 0.1031 | 33.53 | 66.47 | 0.1227 | 29.96 | 70.04 | 0.1195 |
| 40 | 5.07 | 89.04 | 0.1060 | 23.02 | 43.45 | 0.1517 | 13.32 | 56.72 | 0.1328 |
| 60 | 3.40 | 85.64 | 0.1081 | 11.12 | 32.33 | 0.1759 | 19.92 | 36.80 | 0.1649 |
| 90 | 4.96 | 80.68 | 0.1113 | 10.20 | 22.13 | 0.2126 | 19.61 | 17.19 | 0.2412 |
| 150 | 9.07 | 71.61 | 0.1182 | 8.12 | 14.01 | 0.2672 | 3.93 | 13.26 | 0.2746 |
| | 126 MICRONS | | | 27.5 MICRONS | | | -8 MICRONS | | |
| 20 | 21.70 | 78.30 | 0.1130 | 36.10 | 63.90 | 0.1251 | 37.96 | 62.04 | 0.1270 |
| 40 | 13.91 | 64.39 | 0.1246 | 20.25 | 43.65 | 0.1537 | ----- | ----- | ------ |
| 60 | 8.79 | 55.60 | 0.1341 | 11.51 | 32.14 | 0.1764 | 43.50 | 18.54 | 0.2322 |
| 90 | 10.56 | 45.04 | 0.1490 | 10.55 | 21.59 | 0.2152 | 10.72 | 9.82 | 0.3577 |
| 150 | 12.51 | 32.53 | 0.1753 | 6.82 | 14.77 | 0.2602 | 3.62 | 4.20 | 0.4880 |

TABLE 38

CALCULATED DATA FOR TEST 2-1

| TIME (SEC.) | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | OVERALL | | | 89 MICRONS | | | 19.5 MICRONS | | |
| 20 | 17.74 | 82.26 | 0.1103 | 17.41 | 82.59 | 0.1100 | 17.15 | 82.85 | 0.1099 |
| 40 | 12.95 | 69.31 | 0.1201 | 15.88 | 66.71 | 0.1224 | 14.97 | 67.88 | 0.1214 |
| 60 | 8.73 | 60.58 | 0.1285 | 11.54 | 55.17 | 0.1346 | 8.39 | 59.49 | 0.1314 |
| 90 | 9.65 | 50.93 | 0.1401 | 11.92 | 43.25 | 0.1521 | 6.86 | 52.63 | 0.1378 |
| 150 | 10.73 | 40.20 | 0.1577 | 11.00 | 32.25 | 0.1761 | 11.87 | 40.76 | 0.1566 |
| | 252 MICRONS | | | 60 MICRONS | | | 13.8 MICRONS | | |
| 20 | 0.86 | 99.14 | 1.1004 | 23.78 | 76.22 | 0.1145 | 16.92 | 83.08 | 0.1097 |
| 40 | 1.21 | 97.93 | 0.1011 | 15.12 | 61.10 | 0.1279 | 12.96 | 70.12 | 0.1194 |
| 60 | 2.08 | 95.85 | 0.1021 | 8.64 | 52.46 | 0.1381 | 3.03 | 67.09 | 0.1221 |
| 90 | 5.58 | 90.27 | 0.1053 | 8.72 | 43.74 | 0.1535 | 9.86 | 57.23 | 0.1322 |
| 150 | 14.35 | 75.92 | 0.1161 | 8.68 | 35.06 | 0.1689 | 9.99 | 47.24 | 0.1455 |
| | 178 MICRONS | | | 39 MICRONS | | | 9.8 MICRONS | | |
| 20 | 2.81 | 97.19 | 0.1014 | 21.61 | 78.39 | 0.1129 | 23.85 | 76.15 | 0.1146 |
| 40 | 4.62 | 92.57 | 0.1039 | 14.64 | 63.75 | 0.1253 | 20.99 | 55.16 | 0.1346 |
| 60 | 6.07 | 86.50 | 0.1075 | 9.34 | 54.41 | 0.1356 | 8.91 | 46.25 | 0.1470 |
| 90 | 11.55 | 74.95 | 0.1155 | 9.69 | 44.72 | 0.1495 | 7.15 | 39.10 | 0.1599 |
| 150 | 17.10 | 57.85 | 0.1332 | 10.45 | 34.27 | 0.1708 | 7.86 | 31.24 | 0.1789 |
| | 126 MICRONS | | | 27.5 MICRONS | | | -8 MICRONS | | |
| 20 | 10.63 | 89.37 | 0.1058 | 19.79 | 80.21 | 0.1117 | 18.63 | 81.47 | 0.1108 |
| 40 | 13.76 | 75.61 | 0.1150 | 13.13 | 67.08 | 0.1221 | 17.90 | 63.57 | 0.1254 |
| 60 | 12.55 | 63.06 | 0.1259 | 8.58 | 58.50 | 0.1307 | 5.41 | 58.16 | 0.1311 |
| 90 | 14.30 | 48.76 | 0.1432 | 8.26 | 50.24 | 0.1411 | 7.62 | 50.54 | 0.1407 |
| 150 | 13.22 | 35.54 | 0.1677 | 9.39 | 40.85 | 0.1565 | 6.25 | 44.29 | 0.1503 |

TABLE 39

CALCULATED DATA FOR TEST 2-2

| TIME (SEC.) | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | OVERALL | | | 89 MICRONS | | | 19.5 MICRONS | | |
| 20 | 22.79 | 77.21 | 0.1138 | 22.88 | 77.12 | 0.1139 | 24.61 | 75.39 | 0.1152 |
| 40 | 17.68 | 59.53 | 0.1296 | 22.48 | 54.64 | 0.1353 | 16.39 | 59.00 | 0.1302 |
| 60 | 9.76 | 49.77 | 0.1417 | 12.55 | 42.09 | 0.1541 | 8.86 | 50.14 | 0.1412 |
| 90 | 10.83 | 38.94 | 0.1603 | 12.02 | 30.07 | 0.1823 | 10.30 | 39.84 | 0.1610 |
| 150 | 12.09 | 26.85 | 0.1930 | 11.22 | 18.85 | 0.2303 | 12.74 | 27.10 | 0.1921 |
| | 252 MICRONS | | | 60 MICRONS | | | 13.8 MICRONS | | |
| 20 | 0.97 | 99.03 | 0.1005 | 29.95 | 70.05 | 0.1195 | 28.69 | 71.31 | 0.1184 |
| 40 | 1.99 | 97.04 | 0.1015 | 19.67 | 50.38 | 0.1409 | 19.87 | 51.44 | 0.1394 |
| 60 | 3.46 | 93.58 | 0.1034 | 9.73 | 40.65 | 0.1568 | 6.78 | 44.66 | 0.1496 |
| 90 | 10.03 | 83.55 | 0.1094 | 9.89 | 30.76 | 0.1803 | 7.16 | 37.50 | 0.1633 |
| 150 | 22.30 | 61.25 | 0.1278 | 10.39 | 20.37 | 0.2266 | 9.90 | 27.60 | 0.1903 |
| | 178 MICRONS | | | 39 MICRONS | | | 9.8 MICRONS | | |
| 20 | 4.07 | 95.93 | 0.1021 | 28.68 | 71.32 | 0.1184 | 30.86 | 69.14 | 0.1203 |
| 40 | 8.52 | 87.41 | 0.1070 | 19.28 | 52.04 | 0.1386 | 24.61 | 44.53 | 0.1499 |
| 60 | 10.16 | 77.25 | 0.1138 | 8.48 | 43.56 | 0.1515 | 4.71 | 39.82 | 0.1610 |
| 90 | 16.42 | 60.83 | 0.1282 | 8.87 | 34.69 | 0.1698 | 3.12 | 36.70 | 0.1651 |
| 150 | 19.02 | 41.81 | 0.1547 | 9.93 | 24.76 | 0.2010 | 6.33 | 30.37 | 0.1848 |
| | 126 MICRONS | | | 27.5 MICRONS | | | -8 MICRONS | | |
| 20 | 14.74 | 85.26 | 0.1083 | 25.98 | 74.02 | 0.1162 | 12.53 | 87.47 | 0.1069 |
| 40 | 21.01 | 64.25 | 0.1248 | 17.64 | 56.38 | 0.1350 | 16.30 | 71.17 | 0.1185 |
| 60 | 14.59 | 49.66 | 0.1419 | 8.54 | 47.84 | 0.1467 | 5.70 | 65.47 | 0.1236 |
| 90 | 14.32 | 35.34 | 0.1682 | 9.35 | 38.49 | 0.1638 | 8.13 | 57.34 | 0.1321 |
| 150 | 12.70 | 22.64 | 0.2102 | 10.45 | 28.04 | 0.1889 | 10.33 | 47.01 | 0.1459 |

## Table 40

### CALCULATED DATA FOR TEST 2-3

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 27.00 | 73.00 | 0.1170 | 28.18 | 71.82 | 0.1180 | 28.46 | 71.54 | 0.1182 |
| 40 | 16.91 | 56.09 | 0.1335 | 21.27 | 50.54 | 0.1407 | 17.34 | 54.20 | 0.1358 |
| 60 | 12.59 | 43.50 | 0.1516 | 15.71 | 34.84 | 0.1694 | 12.75 | 41.45 | 0.1553 |
| 90 | 10.75 | 32.75 | 0.1747 | 10.97 | 23.87 | 0.2047 | 12.47 | 28.98 | 0.1858 |
| 150 | 9.59 | 23.16 | 0.2122 | 8.46 | 15.41 | 0.2614 | 8.29 | 20.69 | 0.2198 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 0.67 | 99.33 | 0.1003 | 34.70 | 65.30 | 0.1237 | 33.06 | 66.94 | 0.1222 |
| 40 | 1.90 | 97.43 | 0.1013 | 17.80 | 47.50 | 0.1451 | 11.20 | 55.74 | 0.1339 |
| 60 | 4.11 | 93.32 | 0.1035 | 12.44 | 35.06 | 0.1689 | 15.54 | 40.20 | 0.1577 |
| 90 | 10.51 | 82.81 | 0.1099 | 9.19 | 25.87 | 0.1966 | 10.81 | 29.39 | 0.1879 |
| 150 | 20.46 | 62.35 | 0.1266 | 8.08 | 17.79 | 0.2428 | 10.72 | 18.67 | 0.2314 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 3.80 | 96.20 | 0.1020 | 34.80 | 65.20 | 0.1238 | 25.86 | 74.14 | 0.1161 |
| 40 | 8.52 | 87.68 | 0.1068 | 20.41 | 44.79 | 0.1494 | 15.59 | 58.55 | 0.1307 |
| 60 | 12.89 | 74.79 | 0.1156 | 11.05 | 33.74 | 0.1721 | 12.20 | 46.35 | 0.1491 |
| 90 | 16.25 | 58.54 | 0.1307 | 9.60 | 24.14 | 0.2035 | 14.45 | 31.90 | 0.1771 |
| 150 | 16.92 | 41.62 | 0.1550 | 6.66 | 17.48 | 0.2392 | 15.62 | 16.28 | 0.2478 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 16.80 | 83.20 | 0.1096 | 30.36 | 69.64 | 0.1198 | 22.09 | 77.91 | 0.1133 |
| 40 | 20.96 | 62.24 | 0.1268 | 20.84 | 48.80 | 0.1431 | 7.15 | 70.76 | 0.1203 |
| 60 | 18.38 | 43.86 | 0.1533 | 10.41 | 38.39 | 0.1614 | 14.59 | 56.17 | 0.1334 |
| 90 | 13.48 | 30.38 | 0.1848 | 9.34 | 29.05 | 0.1855 | 13.79 | 42.38 | 0.1560 |
| 150 | 9.92 | 20.46 | 0.2261 | 7.53 | 21.52 | 0.2156 | 13.09 | 29.29 | 0.1883 |

TABLE 41

CALCULATED DATA FOR TEST 2-4

| TIME (SEC.) | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | OVERALL | | | 89 MICRONS | | | 19.5 MICRONS | | |
| 20 | 23.44 | 76.56 | 0.1143 | 22.78 | 77.22 | 0.1138 | 26.10 | 73.90 | 0.1163 |
| 40 | 19.04 | 57.52 | 0.1319 | 23.40 | 53.82 | 0.1363 | 18.54 | 55.36 | 0.1344 |
| 60 | 9.91 | 47.61 | 0.1449 | 12.64 | 41.18 | 0.1558 | 9.30 | 46.06 | 0.1473 |
| 90 | 9.56 | 38.05 | 0.1621 | 10.73 | 30.45 | 0.1846 | 8.31 | 37.75 | 0.1628 |
| 150 | 10.88 | 27.17 | 0.1919 | 10.42 | 20.03 | 0.2235 | 12.53 | 25.22 | 0.1991 |
| | 252 MICRONS | | | 60 MICRONS | | | 13.8 MICRONS | | |
| 20 | 0.74 | 99.26 | 0.1004 | 33.64 | 66.36 | 0.1228 | 18.41 | 81.59 | 0.1107 |
| 40 | 1.55 | 97.71 | 0.1012 | 21.92 | 44.44 | 0.1500 | 23.26 | 58.33 | 0.1309 |
| 60 | 2.75 | 94.96 | 0.1026 | 9.32 | 35.12 | 0.1687 | 9.94 | 48.39 | 0.1438 |
| 90 | 6.93 | 88.03 | 0.1066 | 8.80 | 26.32 | 0.1949 | 6.25 | 42.14 | 0.1540 |
| 150 | 16.38 | 71.65 | 0.1181 | 8.71 | 17.61 | 0.2383 | 9.84 | 32.30 | 0.1760 |
| | 178 MICRONS | | | 39 MICRONS | | | 9.8 MICRONS | | |
| 20 | 3.08 | 96.92 | 0.1016 | 26.78 | 73.22 | 0.1169 | 19.10 | 80.90 | 0.1112 |
| 40 | 6.75 | 90.17 | 0.1053 | 20.61 | 52.61 | 0.1379 | 26.58 | 54.32 | 0.1357 |
| 60 | 8.41 | 81.76 | 0.1106 | 10.21 | 42.40 | 0.1560 | 10.74 | 43.58 | 0.1515 |
| 90 | 13.13 | 68.63 | 0.1207 | 7.64 | 34.76 | 0.1696 | 5.09 | 38.49 | 0.1612 |
| 150 | 17.91 | 50.72 | 0.1404 | 9.16 | 25.60 | 0.1976 | 9.13 | 29.36 | 0.1880 |
| | 126 MICRONS | | | 27.5 MICRONS | | | -8 MICRONS | | |
| 20 | 12.86 | 87.14 | 0.1071 | 27.11 | 72.89 | 0.1171 | 7.71 | 92.26 | 0.1041 |
| 40 | 20.53 | 66.61 | 0.1225 | 19.54 | 53.35 | 0.1369 | 22.20 | 70.06 | 0.1195 |
| 60 | 14.53 | 52.08 | 0.1386 | 8.96 | 44.39 | 0.1501 | 16.00 | 54.06 | 0.1360 |
| 90 | 13.34 | 38.74 | 0.1607 | 9.00 | 35.39 | 0.1681 | 9.04 | 45.02 | 0.1490 |
| 150 | 12.44 | 26.30 | 0.1950 | 9.76 | 25.63 | 0.1975 | 10.27 | 34.75 | 0.1696 |

## Table 42

## CALCULATED DATA FOR TEST 2-5

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 31.16 | 68.84 | 0.1205 | 33.70 | 66.30 | 0.1228 | 29.66 | 70.34 | 0.1192 |
| 40 | 17.84 | 51.00 | 0.1400 | 21.97 | 44.33 | 0.1502 | 19.17 | 51.17 | 0.1398 |
| 60 | 10.50 | 40.50 | 0.1571 | 11.62 | 32.71 | 0.1749 | 12.55 | 38.62 | 0.1609 |
| 90 | 8.71 | 31.79 | 0.1774 | 8.81 | 23.90 | 0.2045 | 9.71 | 28.91 | 0.1860 |
| 150 | 10.21 | 21.58 | 0.2153 | 8.69 | 15.21 | 0.2564 | 11.93 | 16.98 | 0.2427 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 1.18 | 98.82 | 0.1006 | 41.88 | 58.12 | 0.1312 | 34.96 | 65.04 | 0.1240 |
| 40 | 1.97 | 96.85 | 0.1016 | 18.67 | 39.45 | 0.1592 | 16.66 | 48.38 | 0.1438 |
| 60 | 3.18 | 93.67 | 0.1033 | 8.67 | 30.78 | 0.1802 | 15.74 | 32.64 | 0.1750 |
| 90 | 7.46 | 86.21 | 0.1077 | 6.81 | 23.97 | 0.2042 | 7.42 | 25.22 | 0.1991 |
| 150 | 18.59 | 67.62 | 0.1216 | 8.27 | 15.70 | 0.2524 | 11.43 | 13.79 | 0.2693 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 5.33 | 94.67 | 0.1028 | 36.56 | 63.44 | 0.1255 | 38.01 | 61.99 | 0.1270 |
| 40 | 9.11 | 85.56 | 0.1081 | 19.38 | 44.06 | 0.1506 | 12.30 | 49.69 | 0.1419 |
| 60 | 10.35 | 75.21 | 0.1153 | 10.51 | 33.55 | 0.1727 | 18.00 | 31.69 | 0.1777 |
| 90 | 13.35 | 61.86 | 0.1271 | 8.84 | 24.71 | 0.2012 | 5.42 | 26.27 | 0.1951 |
| 150 | 17.47 | 44.39 | 0.1501 | 8.26 | 16.45 | 0.2465 | 9.09 | 17.18 | 0.2413 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 20.90 | 79.10 | 0.1124 | 33.95 | 66.05 | 0.1230 | 35.63 | 64.37 | 0.1246 |
| 40 | 22.32 | 56.78 | 0.1327 | 19.67 | 46.38 | 0.1490 | 13.95 | 50.42 | 0.1408 |
| 60 | 14.44 | 42.34 | 0.1537 | 10.44 | 35.94 | 0.1668 | 15.53 | 34.89 | 0.1693 |
| 90 | 10.96 | 31.38 | 0.1785 | 8.66 | 27.28 | 0.1915 | 6.09 | 28.80 | 0.1863 |
| 150 | 10.28 | 21.10 | 0.2177 | 9.50 | 17.78 | 0.2371 | 8.40 | 20.40 | 0.2214 |

TABLE 43

CALCULATED DATA FOR TEST 3-1

| TIME (SEC.) | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % REC. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | OVERALL | | | 89 MICRONS | | | 19.5 MICRONS | | |
| 20 | 18.39 | 81.61 | 0.1107 | 19.89 | 80.11 | 0.1117 | 18.53 | 81.47 | 0.1108 |
| 40 | 15.47 | 66.14 | 0.1230 | 19.14 | 60.97 | 0.1281 | 15.71 | 65.76 | 0.1233 |
| 60 | 10.22 | 55.92 | 0.1337 | 13.16 | 47.81 | 0.1468 | 13.32 | 52.44 | 0.1381 |
| 90 | 10.29 | 45.63 | 0.1480 | 11.73 | 36.08 | 0.1665 | 11.58 | 40.86 | 0.1564 |
| 150 | 12.76 | 32.87 | 0.1744 | 11.58 | 24.50 | 0.2020 | 15.11 | 25.75 | 0.1971 |
| | 252 MICRONS | | | 60 MICRONS | | | 13.8 MICRONS | | |
| 20 | 0.84 | 99.16 | 0.1004 | 25.94 | 74.06 | 0.1162 | 17.79 | 82.21 | 0.1103 |
| 40 | 1.15 | 98.01 | 0.1010 | 17.21 | 56.85 | 0.1326 | 14.31 | 67.90 | 0.1214 |
| 60 | 1.64 | 96.37 | 0.1019 | 9.28 | 47.57 | 0.1450 | 12.04 | 55.86 | 0.1338 |
| 90 | 3.51 | 92.86 | 0.1038 | 9.30 | 38.27 | 0.1617 | 10.89 | 44.97 | 0.1491 |
| 150 | 10.52 | 82.34 | 0.1102 | 11.62 | 26.65 | 0.1937 | 11.38 | 33.59 | 0.1725 |
| | 178 MICRONS | | | 39 MICRONS | | | 9.8 MICRONS | | |
| 20 | 3.91 | 96.09 | 0.1020 | 18.65 | 81.35 | 0.1109 | 21.61 | 78.39 | 0.1129 |
| 40 | 5.51 | 90.58 | 0.1051 | 18.23 | 63.12 | 0.1259 | 13.08 | 65.31 | 0.1237 |
| 60 | 6.79 | 83.79 | 0.1092 | 12.91 | 50.21 | 0.1411 | 11.76 | 53.55 | 0.1366 |
| 90 | 10.63 | 73.16 | 0.1169 | 10.94 | 39.27 | 0.1596 | 10.17 | 43.38 | 0.1518 |
| 150 | 17.58 | 55.58 | 0.1341 | 12.03 | 27.24 | 0.1916 | 13.23 | 30.15 | 0.1821 |
| | 126 MICRONS | | | 27.5 MICRONS | | | -8 MICRONS | | |
| 20 | 13.37 | 86.63 | 0.1074 | 18.47 | 81.53 | 0.1108 | 9.89 | 90.11 | 0.1053 |
| 40 | 16.49 | 70.14 | 0.1194 | 16.51 | 65.02 | 0.1240 | 8.09 | 82.02 | 0.1104 |
| 60 | 13.97 | 56.17 | 0.1334 | 10.90 | 54.12 | 0.1359 | 8.92 | 73.10 | 0.1170 |
| 90 | 14.00 | 42.17 | 0.1540 | 10.53 | 43.59 | 0.1515 | 7.73 | 65.37 | 0.1237 |
| 150 | 13.66 | 28.51 | 0.1873 | 12.82 | 30.77 | 0.1803 | 13.06 | 52.31 | 0.1383 |

## Table 44

### CALCULATED DATA FOR TEST 3-2

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 20.95 | 79.05 | 0.1125 | 23.53 | 76.47 | 0.1144 | 19.63 | 80.37 | 0.1115 |
| 40 | 15.99 | 63.06 | 0.1259 | 19.75 | 56.72 | 0.1328 | 16.87 | 63.50 | 0.1255 |
| 60 | 9.03 | 54.03 | 0.1360 | 10.61 | 46.11 | 0.1473 | 12.09 | 51.41 | 0.1395 |
| 90 | 8.80 | 45.23 | 0.1487 | 9.45 | 36.66 | 0.1651 | 10.95 | 40.46 | 0.1572 |
| 150 | 11.08 | 34.15 | 0.1711 | 10.21 | 26.45 | 0.1944 | 13.69 | 26.77 | 0.1933 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 1.11 | 98.89 | 0.1006 | 26.96 | 73.04 | 0.1170 | 18.30 | 81.80 | 0.1106 |
| 40 | 1.22 | 97.67 | 0.1012 | 19.26 | 53.78 | 0.1364 | 14.22 | 67.58 | 0.1216 |
| 60 | 1.34 | 96.33 | 0.1019 | 9.19 | 44.59 | 0.1497 | 13.73 | 53.85 | 0.1363 |
| 90 | 2.33 | 94.00 | 0.1031 | 7.93 | 36.66 | 0.1651 | 11.35 | 42.50 | 0.1534 |
| 150 | 6.50 | 87.50 | 0.1069 | 8.91 | 27.75 | 0.1898 | 15.04 | 27.46 | 0.1908 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 4.99 | 95.01 | 0.1026 | 25.14 | 74.86 | 0.1156 | 17.91 | 82.09 | 0.1104 |
| 40 | 6.52 | 88.49 | 0.1063 | 15.34 | 59.52 | 0.1296 | 20.45 | 61.64 | 0.1274 |
| 60 | 5.77 | 82.72 | 0.1100 | 9.16 | 50.36 | 0.1409 | 12.16 | 49.48 | 0.1422 |
| 90 | 8.02 | 74.70 | 0.1157 | 9.53 | 40.83 | 0.1565 | 6.25 | 43.23 | 0.1521 |
| 150 | 13.99 | 60.71 | 0.1283 | 12.72 | 28.11 | 0.1886 | 16.35 | 26.88 | 0.1929 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 16.29 | 83.71 | 0.1093 | 21.25 | 78.75 | 0.1127 | 18.43 | 81.57 | 0.1107 |
| 40 | 17.67 | 66.04 | 0.1231 | 15.98 | 62.77 | 0.1262 | 14.13 | 67.44 | 0.1218 |
| 60 | 11.71 | 54.33 | 0.1357 | 9.58 | 53.19 | 0.1371 | 8.95 | 58.49 | 0.1308 |
| 90 | 11.29 | 43.04 | 0.1524 | 9.63 | 43.56 | 0.1515 | 8.06 | 50.43 | 0.1408 |
| 150 | 12.30 | 30.74 | 0.1804 | 12.32 | 31.24 | 0.1787 | 10.45 | 39.98 | 0.1607 |

## Table 45

### Calculated Data for Test 3-3

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 24.06 | 75.94 | 0.1161 | 28.23 | 71.77 | 0.1180 | 22.49 | 77.51 | 0.1136 |
| 40 | 14.03 | 61.91 | 0.1271 | 16.06 | 55.71 | 0.1340 | 16.48 | 61.03 | 0.1280 |
| 60 | 9.21 | 52.70 | 0.1378 | 10.61 | 45.10 | 0.1489 | 12.56 | 48.47 | 0.1436 |
| 90 | 8.44 | 44.26 | 0.1503 | 9.07 | 36.03 | 0.1666 | 10.33 | 38.14 | 0.1619 |
| 150 | 10.71 | 33.55 | 0.1727 | 10.10 | 25.93 | 0.1964 | 15.36 | 22.78 | 0.2095 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 1.06 | 98.94 | 0.1005 | 29.98 | 70.02 | 0.1195 | 29.29 | 70.71 | 0.1189 |
| 40 | 0.85 | 98.09 | 0.1010 | 16.71 | 53.31 | 0.1370 | 8.00 | 62.71 | 0.1263 |
| 60 | 0.89 | 97.20 | 0.1014 | 10.17 | 43.14 | 0.1523 | 13.86 | 48.85 | 0.1431 |
| 90 | 1.52 | 95.68 | 0.1022 | 8.21 | 34.93 | 0.1692 | 5.52 | 43.33 | 0.1519 |
| 150 | 3.98 | 91.70 | 0.1044 | 9.28 | 25.65 | 0.1974 | 14.84 | 28.49 | 0.1873 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 6.02 | 93.98 | 0.1032 | 29.45 | 70.55 | 0.1191 | 33.63 | 66.37 | 0.1227 |
| 40 | 4.31 | 89.67 | 0.1056 | 15.43 | 55.12 | 0.1347 | 8.83 | 57.54 | 0.1318 |
| 60 | 4.35 | 85.32 | 0.1083 | 9.97 | 45.15 | 0.1488 | 5.14 | 52.40 | 0.1381 |
| 90 | 5.98 | 79.34 | 0.1135 | 9.61 | 35.54 | 0.1677 | 4.44 | 47.96 | 0.1444 |
| 150 | 11.71 | 67.63 | 0.1201 | 10.98 | 24.56 | 0.2018 | 16.45 | 31.51 | 0.1782 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 19.51 | 80.49 | 0.1115 | 24.81 | 75.19 | 0.1153 | 21.61 | 78.39 | 0.1129 |
| 40 | 13.26 | 67.23 | 0.1220 | 15.67 | 59.52 | 0.1296 | 15.28 | 63.11 | 0.1269 |
| 60 | 10.79 | 56.44 | 0.1349 | 12.23 | 47.29 | 0.1454 | 8.11 | 55.00 | 0.1348 |
| 90 | 10.68 | 45.76 | 0.1478 | 9.76 | 37.53 | 0.1632 | 7.17 | 47.83 | 0.1446 |
| 150 | 13.09 | 32.67 | 0.1749 | 11.97 | 25.56 | 0.1978 | 14.40 | 33.43 | 0.1730 |

## Table 46

### Calculated Data for Test 3-4

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 24.58 | 75.42 | 0.1151 | 27.25 | 72.75 | 0.1172 | 23.15 | 76.85 | 0.1141 |
| 40 | 14.61 | 60.81 | 0.1282 | 16.74 | 56.01 | 0.1336 | 17.42 | 59.43 | 0.1297 |
| 60 | 9.57 | 51.24 | 0.1397 | 11.06 | 44.95 | 0.1492 | 10.72 | 48.71 | 0.1433 |
| 90 | 9.04 | 42.20 | 0.1539 | 9.98 | 34.97 | 0.1691 | 12.00 | 36.71 | 0.1650 |
| 150 | 10.41 | 31.79 | 0.1774 | 10.19 | 24.78 | 0.2009 | 14.34 | 22.37 | 0.2114 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 0.95 | 99.05 | 0.1005 | 30.67 | 69.33 | 0.1201 | 33.05 | 66.95 | 0.1222 |
| 40 | 0.83 | 98.22 | 0.1009 | 16.53 | 52.80 | 0.1376 | 16.49 | 50.46 | 0.1408 |
| 60 | 0.87 | 97.35 | 0.1013 | 9.06 | 43.74 | 0.1512 | 14.41 | 37.05 | 0.1643 |
| 90 | 1.71 | 95.64 | 0.1022 | 8.25 | 35.49 | 0.1679 | 6.16 | 29.89 | 0.1829 |
| 150 | 4.54 | 91.10 | 0.1048 | 9.39 | 26.10 | 0.1957 | 12.12 | 17.77 | 0.2372 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 5.40 | 94.60 | 0.1028 | 31.92 | 68.08 | 0.1212 | 28.81 | 71.19 | 0.1185 |
| 40 | 4.41 | 90.19 | 0.1053 | 17.00 | 51.08 | 0.1399 | 15.52 | 55.67 | 0.1340 |
| 60 | 4.52 | 85.67 | 0.1080 | 11.83 | 39.25 | 0.1596 | 17.92 | 37.75 | 0.1628 |
| 90 | 6.99 | 78.68 | 0.1127 | 9.77 | 29.48 | 0.1841 | 7.74 | 30.01 | 0.1792 |
| 150 | 12.57 | 66.11 | 0.1230 | 9.56 | 19.92 | 0.2241 | 11.56 | 18.45 | 0.2329 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 18.09 | 81.91 | 0.1105 | 27.76 | 72.24 | 0.1177 | 28.37 | 71.63 | 0.1182 |
| 40 | 13.98 | 67.93 | 0.1228 | 16.75 | 55.49 | 0.1342 | 13.16 | 58.47 | 0.1308 |
| 60 | 11.48 | 56.45 | 0.1331 | 11.19 | 44.30 | 0.1502 | 19.81 | 38.66 | 0.1608 |
| 90 | 11.95 | 44.50 | 0.1499 | 11.14 | 33.16 | 0.1737 | 6.28 | 32.38 | 0.1757 |
| 150 | 12.82 | 31.68 | 0.1777 | 11.46 | 21.70 | 0.2147 | 7.65 | 24.73 | 0.2011 |

## Table 47

CALCULATED DATA FOR TEST 3-5

| Time (Sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 28.13 | 71.87 | 0.1180 | 31.88 | 68.12 | 0.1212 | 23.40 | 76.60 | 0.1143 |
| 40 | 16.61 | 55.26 | 0.1345 | 18.39 | 49.73 | 0.1418 | 21.17 | 55.43 | 0.1343 |
| 60 | 8.94 | 46.32 | 0.1469 | 9.99 | 39.74 | 0.1586 | 11.74 | 43.69 | 0.1513 |
| 90 | 8.14 | 38.18 | 0.1618 | 8.34 | 31.40 | 0.1784 | 10.56 | 33.13 | 0.1737 |
| 150 | 9.22 | 28.96 | 0.1858 | 8.75 | 22.65 | 0.2101 | 11.55 | 21.58 | 0.2153 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 1.14 | 98.86 | 0.1006 | 56.26 | 43.74 | 0.1512 | 25.59 | 74.41 | 0.1159 |
| 40 | 1.10 | 97.76 | 0.1011 | 11.12 | 32.62 | 0.1751 | 20.56 | 53.85 | 0.1363 |
| 60 | 0.97 | 96.79 | 0.1016 | 5.02 | 27.60 | 0.1903 | 11.45 | 42.40 | 0.1536 |
| 90 | 1.58 | 95.21 | 0.1025 | 4.88 | 22.72 | 0.2098 | 10.74 | 31.66 | 0.1777 |
| 150 | 3.63 | 91.58 | 0.1045 | 4.84 | 17.88 | 0.2365 | 12.12 | 19.54 | 0.2262 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 6.46 | 93.54 | 0.1034 | 28.01 | 71.99 | 0.1179 | 14.06 | 85.94 | 0.1079 |
| 40 | 5.85 | 87.69 | 0.1068 | 24.60 | 47.39 | 0.1453 | 33.69 | 52.25 | 0.1384 |
| 60 | 4.92 | 82.77 | 0.1099 | 10.34 | 37.05 | 0.1643 | 12.50 | 39.75 | 0.1586 |
| 90 | 6.47 | 76.30 | 0.1145 | 7.83 | 29.22 | 0.1850 | 15.89 | 23.86 | 0.2047 |
| 150 | 11.16 | 65.14 | 0.1239 | 8.52 | 20.70 | 0.2198 | 7.58 | 16.28 | 0.2478 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 21.46 | 78.54 | 0.1128 | 23.40 | 76.60 | 0.1143 | 2.98 | 97.02 | 0.1015 |
| 40 | 16.32 | 62.22 | 0.1268 | 21.28 | 55.32 | 0.1344 | 34.62 | 62.40 | 0.1266 |
| 60 | 10.79 | 51.43 | 0.1395 | 11.41 | 43.91 | 0.1509 | 17.11 | 45.29 | 0.1486 |
| 90 | 10.31 | 41.12 | 0.1560 | 9.84 | 34.07 | 0.1714 | 11.37 | 33.92 | 0.1717 |
| 150 | 11.22 | 29.90 | 0.1829 | 10.76 | 23.31 | 0.2071 | 16.09 | 17.83 | 0.2368 |

## Table 48

### Calculated Data for Test 4-1

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 10.95 | 89.05 | 0.1060 | 11.95 | 88.05 | 0.1066 | 12.52 | 87.48 | 0.1069 |
| 40 | 12.91 | 76.14 | 0.1146 | 14.53 | 73.52 | 0.1166 | 14.23 | 73.25 | 0.1168 |
| 60 | 8.54 | 67.60 | 0.1216 | 9.56 | 63.96 | 0.1250 | 9.97 | 63.28 | 0.1257 |
| 90 | 8.88 | 58.72 | 0.1305 | 9.94 | 44.02 | 0.1507 | 10.67 | 52.61 | 0.1379 |
| 150 | 11.52 | 47.20 | 0.1456 | 12.39 | 41.63 | 0.1550 | 13.49 | 39.12 | 0.1599 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 0.60 | 99.40 | 0.1003 | 12.13 | 87.87 | 0.1067 | 12.41 | 87.59 | 0.1068 |
| 40 | 0.75 | 98.65 | 0.1007 | 13.50 | 74.37 | 0.1160 | 14.20 | 73.39 | 0.1167 |
| 60 | 0.71 | 97.94 | 0.1011 | 8.66 | 65.71 | 0.1225 | 9.83 | 63.56 | 0.1254 |
| 90 | 1.05 | 96.89 | 0.1016 | 7.32 | 58.39 | 0.1309 | 10.29 | 53.27 | 0.1370 |
| 150 | 2.84 | 94.06 | 0.1031 | 9.53 | 48.86 | 0.1431 | 13.82 | 39.45 | 0.1592 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 2.53 | 97.47 | 0.1013 | 14.98 | 85.02 | 0.1084 | 13.09 | 86.91 | 0.1073 |
| 40 | 3.55 | 93.92 | 0.1032 | 17.50 | 67.52 | 0.1217 | 6.94 | 79.97 | 0.1118 |
| 60 | 2.99 | 90.93 | 0.1049 | 9.69 | 57.83 | 0.1332 | 7.54 | 72.43 | 0.1175 |
| 90 | 4.13 | 86.80 | 0.1073 | 9.97 | 47.86 | 0.1446 | 9.58 | 62.85 | 0.1261 |
| 120 | 8.50 | 78.30 | 0.1130 | 11.50 | 36.36 | 0.1658 | 18.47 | 44.38 | 0.1513 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 8.23 | 91.77 | 0.1044 | 12.81 | 87.19 | 0.1071 | 11.25 | 88.75 | 0.1061 |
| 40 | 11.30 | 80.47 | 0.1115 | 15.19 | 72.00 | 0.1179 | 19.23 | 69.52 | 0.1199 |
| 60 | 8.86 | 71.61 | 0.1182 | 9.93 | 62.07 | 0.1269 | 12.72 | 56.80 | 0.1327 |
| 90 | 9.94 | 61.67 | 0.1273 | 10.34 | 51.73 | 0.1390 | 13.31 | 43.49 | 0.1516 |
| 150 | 13.94 | 47.73 | 0.1447 | 12.60 | 39.13 | 0.1599 | 13.60 | 29.89 | 0.1829 |

# Table 49

## CALCULATED DATA FOR TEST 4-2

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 12.85 | 87.15 | 0.1071 | 13.58 | 86.42 | 0.1076 | 14.36 | 85.64 | 0.1081 |
| 40 | 11.27 | 75.88 | 0.1148 | 12.34 | 74.08 | 0.1162 | 12.87 | 72.77 | 0.1172 |
| 60 | 7.47 | 68.41 | 0.1209 | 8.31 | 65.77 | 0.1233 | 8.75 | 64.02 | 0.1250 |
| 90 | 9.91 | 58.50 | 0.1307 | 11.30 | 54.47 | 0.1355 | 11.65 | 52.37 | 0.1382 |
| 150 | 11.42 | 47.08 | 0.1458 | 12.03 | 42.44 | 0.1535 | 13.47 | 38.90 | 0.1603 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 0.77 | 99.23 | 0.1004 | 16.14 | 83.86 | 0.1092 | 14.09 | 85.91 | 0.1079 |
| 40 | 0.69 | 98.54 | 0.1007 | 12.50 | 71.36 | 0.1184 | 12.80 | 73.11 | 0.1170 |
| 60 | 0.66 | 97.88 | 0.1011 | 7.53 | 63.83 | 0.1252 | 8.90 | 64.21 | 0.1248 |
| 90 | 1.24 | 96.64 | 0.1017 | 8.62 | 55.21 | 0.1346 | 11.82 | 52.39 | 0.1382 |
| 150 | 2.84 | 93.80 | 0.1033 | 9.78 | 45.43 | 0.1484 | 14.11 | 38.28 | 0.1616 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 2.86 | 97.14 | 0.1015 | 17.32 | 82.68 | 0.1100 | 8.43 | 91.57 | 0.1045 |
| 40 | 2.95 | 94.19 | 0.1030 | 14.30 | 68.38 | 0.1209 | 14.35 | 77.22 | 0.1138 |
| 60 | 2.47 | 91.72 | 0.1044 | 8.31 | 60.07 | 0.1290 | 10.86 | 66.36 | 0.1228 |
| 90 | 4.43 | 87.29 | 0.1070 | 11.42 | 48.65 | 0.1434 | 9.44 | 56.92 | 0.1325 |
| 150 | 8.06 | 79.23 | 0.1123 | 11.10 | 37.55 | 0.1632 | 17.70 | 39.22 | 0.1597 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 9.77 | 90.23 | 0.1053 | 14.88 | 85.12 | 0.1084 | 20.15 | 79.85 | 0.1119 |
| 40 | 9.96 | 80.27 | 0.1116 | 13.00 | 72.12 | 0.1178 | 10.32 | 69.53 | 0.1199 |
| 60 | 7.63 | 72.64 | 0.1173 | 8.73 | 63.39 | 0.1256 | 7.65 | 61.88 | 0.1271 |
| 90 | 11.05 | 61.59 | 0.1274 | 11.23 | 52.16 | 0.1385 | 12.20 | 49.68 | 0.1419 |
| 160 | 13.48 | 48.11 | 0.1442 | 12.53 | 39.63 | 0.1589 | 13.20 | 36.48 | 0.1656 |

## Table 50

### Calculated Data for Test 4-3

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 10.94 | 89.06 | 0.1060 | 11.50 | 88.50 | 0.1063 | 12.82 | 87.18 | 0.1071 |
| 40 | 13.42 | 75.64 | 0.1150 | 15.10 | 73.40 | 0.1167 | 14.76 | 72.42 | 0.1175 |
| 60 | 8.60 | 67.04 | 0.1221 | 9.48 | 63.92 | 0.1251 | 10.17 | 62.25 | 0.1267 |
| 90 | 8.03 | 59.01 | 0.1302 | 8.98 | 54.94 | 0.1349 | 9.45 | 52.80 | 0.1376 |
| 150 | 12.78 | 46.23 | 0.1471 | 13.52 | 41.42 | 0.1554 | 14.83 | 37.97 | 0.1623 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 0.74 | 99.26 | 0.1004 | 14.02 | 85.98 | 0.1078 | 12.96 | 87.04 | 0.1072 |
| 40 | 0.84 | 98.42 | 0.1008 | 16.76 | 69.22 | 0.1202 | 14.34 | 72.70 | 0.1173 |
| 60 | 0.74 | 97.68 | 0.1012 | 8.40 | 60.82 | 0.1282 | 10.39 | 62.31 | 0.1267 |
| 90 | 1.10 | 96.58 | 0.1018 | 7.42 | 53.40 | 0.1368 | 9.90 | 52.41 | 0.1381 |
| 150 | 3.06 | 93.52 | 0.1034 | 10.23 | 43.17 | 0.1522 | 15.30 | 37.11 | 0.1641 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 2.15 | 97.85 | 0.1011 | 13.38 | 86.62 | 0.1074 | 15.46 | 84.54 | 0.1088 |
| 40 | 3.25 | 94.60 | 0.1028 | 16.81 | 69.81 | 0.1197 | 15.56 | 69.98 | 0.1219 |
| 60 | 2.77 | 91.83 | 0.1044 | 10.42 | 59.39 | 0.1298 | 12.10 | 56.88 | 0.1326 |
| 90 | 3.72 | 88.11 | 0.1065 | 8.47 | 50.92 | 0.1401 | 8.67 | 48.21 | 0.1440 |
| 150 | 8.89 | 79.22 | 0.1123 | 13.79 | 37.13 | 0.1641 | 17.82 | 30.39 | 0.1814 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 7.19 | 92.81 | 0.1038 | 13.46 | 86.54 | 0.1075 | 11.07 | 88.93 | 0.1049 |
| 40 | 11.05 | 81.76 | 0.1106 | 15.14 | 71.40 | 0.1183 | 13.29 | 75.64 | 0.1150 |
| 60 | 8.24 | 73.52 | 0.1166 | 10.09 | 61.31 | 0.1277 | 9.70 | 65.94 | 0.1232 |
| 90 | 9.07 | 64.45 | 0.1246 | 9.07 | 52.24 | 0.1384 | 10.40 | 55.54 | 0.1342 |
| 150 | 15.38 | 49.07 | 0.1428 | 13.71 | 38.53 | 0.1611 | 14.30 | 41.24 | 0.1557 |

## Table 51

### Calculated Data for Test 4-4

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 Microns | | | 19.5 Microns | | |
| 20 | 13.06 | 86.94 | 0.1073 | 13.77 | 86.23 | 0.1077 | 14.96 | 85.04 | 0.1084 |
| 40 | 12.14 | 74.80 | 0.1156 | 13.34 | 72.89 | 0.1171 | 13.87 | 71.17 | 0.1185 |
| 60 | 8.23 | 66.57 | 0.1226 | 9.11 | 63.78 | 0.1252 | 9.57 | 61.60 | 0.1274 |
| 90 | 8.18 | 58.39 | 0.1309 | 9.38 | 54.40 | 0.1356 | 9.59 | 52.01 | 0.1387 |
| 150 | 12.29 | 46.10 | 0.1472 | 13.41 | 40.99 | 0.1562 | 13.88 | 38.13 | 0.1619 |
| | 252 Microns | | | 60 Microns | | | 13.8 Microns | | |
| 20 | 0.53 | 99.47 | 0.1003 | 14.86 | 85.14 | 0.1084 | 14.47 | 85.53 | 0.1081 |
| 40 | 0.66 | 98.81 | 0.1006 | 14.75 | 70.39 | 0.1192 | 13.84 | 71.69 | 0.1181 |
| 60 | 0.72 | 98.09 | 0.1010 | 7.37 | 63.02 | 0.1260 | 9.90 | 61.79 | 0.1272 |
| 90 | 1.15 | 96.94 | 0.1016 | 8.34 | 54.68 | 0.1352 | 9.71 | 52.08 | 0.1386 |
| 150 | 3.07 | 93.87 | 0.1032 | 12.47 | 42.21 | 0.1539 | 14.47 | 37.61 | 0.1631 |
| | 178 Microns | | | 39 Microns | | | 9.8 Microns | | |
| 20 | 2.16 | 97.84 | 0.1011 | 19.80 | 80.20 | 0.1117 | 18.57 | 81.43 | 0.1108 |
| 40 | 2.62 | 95.22 | 0.1025 | 15.27 | 64.93 | 0.1241 | 15.71 | 65.72 | 0.1234 |
| 60 | 2.62 | 92.60 | 0.1039 | 10.09 | 54.84 | 0.1350 | 10.33 | 55.39 | 0.1344 |
| 90 | 3.64 | 88.96 | 0.1060 | 8.22 | 46.62 | 0.1465 | 9.97 | 45.42 | 0.1484 |
| 150 | 8.76 | 80.20 | 0.1116 | 10.41 | 36.21 | 0.1662 | 11.80 | 33.62 | 0.1725 |
| | 125 Microns | | | 27.5 Microns | | | -8 Microns | | |
| 20 | 8.13 | 91.87 | 0.1043 | 15.64 | 84.36 | 0.1089 | 11.73 | 88.27 | 0.1064 |
| 40 | 9.56 | 82.31 | 0.1102 | 14.18 | 70.18 | 0.1194 | 12.60 | 75.67 | 0.1150 |
| 60 | 8.13 | 74.18 | 0.1161 | 9.67 | 60.51 | 0.1286 | 9.81 | 65.86 | 0.1232 |
| 90 | 9.19 | 64.99 | 0.1240 | 9.19 | 51.32 | 0.1396 | 8.81 | 57.05 | 0.1324 |
| 150 | 15.18 | 49.81 | 0.1417 | 13.11 | 38.21 | 0.1616 | 15.48 | 41.57 | 0.1551 |

## Table 52

### Calculated Data for Test 4-5

| Time (sec.) | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ | % Rec. | A-X | $1/(A-X)^{\frac{1}{2}}$ |
|---|---|---|---|---|---|---|---|---|---|
| | Overall | | | 89 microns | | | 19.5 microns | | |
| 20 | 23.21 | 76.79 | 0.1141 | 12.22 | 87.78 | 0.1067 | 27.74 | 72.26 | 0.1176 |
| 40 | 14.82 | 61.97 | 0.1270 | 19.66 | 68.12 | 0.1212 | 17.60 | 54.66 | 0.1353 |
| 60 | 10.08 | 51.89 | 0.1388 | 15.56 | 52.56 | 0.1379 | 10.71 | 43.95 | 0.1509 |
| 90 | 9.00 | 42.89 | 0.1527 | 12.57 | 39.99 | 0.1581 | 9.46 | 34.49 | 0.1703 |
| 150 | 9.74 | 33.15 | 0.1737 | 10.06 | 29.93 | 0.1828 | 10.62 | 23.87 | 0.2047 |
| | 252 microns | | | 60 microns | | | 13.8 microns | | |
| 20 | 0.68 | 99.32 | 0.1003 | 35.14 | 64.86 | 0.1242 | 25.75 | 74.25 | 0.1160 |
| 40 | 0.81 | 98.51 | 0.1008 | 15.67 | 49.19 | 0.1426 | 18.26 | 55.99 | 0.1336 |
| 60 | 1.03 | 97.48 | 0.1013 | 8.78 | 40.41 | 0.1573 | 11.19 | 44.80 | 0.1494 |
| 90 | 1.89 | 95.59 | 0.1023 | 6.81 | 33.60 | 0.1725 | 9.93 | 34.87 | 0.1693 |
| 150 | 7.14 | 88.45 | 0.1063 | 6.02 | 27.58 | 0.1904 | 11.49 | 23.38 | 0.2068 |
| | 178 microns | | | 39 microns | | | 9.8 microns | | |
| 20 | 1.61 | 98.39 | 0.1008 | 38.51 | 61.49 | 0.1275 | 9.99 | 90.01 | 0.1054 |
| 40 | 3.89 | 94.50 | 0.1029 | 15.35 | 46.14 | 0.1472 | 23.24 | 66.77 | 0.1224 |
| 60 | 4.93 | 89.37 | 0.1057 | 9.35 | 36.79 | 0.1649 | 14.26 | 52.51 | 0.1380 |
| 90 | 7.23 | 72.34 | 0.1176 | 7.47 | 29.32 | 0.1847 | 9.76 | 42.75 | 0.1530 |
| 150 | 13.65 | 68.69 | 0.1207 | 7.29 | 22.03 | 0.2130 | 15.85 | 26.92 | 0.1928 |
| | 126 microns | | | 27.5 microns | | | -8 microns | | |
| 20 | 5.58 | 94.42 | 0.1029 | 32.14 | 67.86 | 0.1214 | 28.82 | 71.18 | 0.1185 |
| 40 | 14.48 | 79.94 | 0.1118 | 17.07 | 50.79 | 0.1403 | 12.85 | 58.33 | 0.1309 |
| 60 | 14.58 | 65.36 | 0.1237 | 9.90 | 40.89 | 0.1564 | 12.37 | 45.96 | 0.1475 |
| 90 | 14.34 | 51.02 | 0.1400 | 8.69 | 32.20 | 0.1762 | 10.69 | 35.27 | 0.1684 |
| 150 | 13.29 | 37.73 | 0.1628 | 9.22 | 22.98 | 0.2096 | 11.98 | 23.29 | 0.2072 |

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