# A Simple sub-sieve sizer employing elutriation with water

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## INTRODUCTION :

Particle size determination of fine minerals and clay powders below 40 micron is required in the industry. Various types of apparatus are in vogue today for their sub-sieve sizing. Stokes' law forms the basis of this determination by subjecting the sample to sedimentation or elutriation. The medium used may be any fluid including air or water. Some of the commonly used units for the purpose may be named such as Andreasen Pipette[1], Sedigraph[2] both working on sedimentation principle; Haultain air separator[3] and Blythe water elutriator[4] both working on the principle of elutriation. Beaker decantation and Andreasen Pipette are the simplest units. However, they are time consuming and require repetition of the tests for accuracy and reliability. The other commerical units are rapid but expensive.

An apparatus in glass has been fabricated indigenously at National Metallurgical Laboratory, Jamshedpur, which is simple, cheap and combines the advantages of Haultain and Blythe elutriators. In the present study, a sample of fine pure quartz was separated in the new apparatus and the separated fractions were observed under microscope to study the performance of the unit. The preliminary tests carried out revealed the separation to be effective. The unit holds promise to be a substitute of the commercial and imported units.

### Principle :

In the process of elutriation, particles falling in a rising fluid can be classified into two sizes. When the fluid in a sorting column is rising with a certain velocity, the particles having terminal velocities higher than this velocity settle at the bottom of the sorting column and the particles with lower terminal velocities are lifted to the top of the sorting column and be carried away to the next tube. Terminal velocities of the particles falling in a fluid can be calculated using the Stokes' law equation for Reynolds number $\left( Re = \frac{2 r Vm \triangle'}{\mu} \right)$

$$Vm = \frac{2}{9} \frac{( \triangle - \triangle' ) r^2 g}{\mu}$$

Where $\triangle$ = specific gravity of the particle,

$\triangle'$ = specific gravity of the fluid medium,

r = radius of the particle,

$\mu$ = viscosity of the medium,

Vm = terminal velocity of the particle.

g = gravitational acceleration

In the elutriation, when the volumetric flow rate of rising fluid is constant, the velocity of the rising fluid in the columns depends on their diameters. The narrow diameter column gives high velocity and the one with wide diameter giving low fluid velocity. Higher velocities of the rising medium allow coarser particles to settle while lower velocities allow finer parlicles to settle. Various size classes of particles can be obtained when the sample is separated in columns of increasing diameters connected in series. Upper size limit of the particles to follow Stokes'

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law may be calculated using the condition Re $< 0.2$. The details of the principles and design of the unit are described elsewhere[5].

**Construction of the Apparatus :**

The apparatus consists of four vertical glass sorting columns with increasing diameters to give five sized fractions. All the four columns are connected in series as shown in Fig. (1) through polythene tubes and firmly fitted on a wooden board. Diameter of the columns is increasing approximately by $\sqrt{2}$ times in every stage, as exact $\sqrt{2}$ series of the glass tubes were not available. The internal diameters of the four sorting columns chosen are 1.35, 2.05 2.8 and 3.8 cm. respectively. Water passes through them at a constant flow rate through a rotameter from a constant head reservoir. Stopcocks are provided at the top for feeding and at the bottom of all sorting columns to discharge the products.

**Procedure :**

About 20 g of the test sample is fed in the form of slurry into the first column through a glass funnel inserted at the top through the stopcock. Water is then allowed to enter the first column at constant flow rate. Water entrains some fine particles of the sample leaving the coarser ones at the bottom. The suspended particles are carried away to the second column where again some are settled and some are suspended and the process continues. Settled particles are gently agitated by inserting a narrow plastic tube into the column in order to dislodge and remove entrapped fines. Glass permits the entire process to be observed as against some commercial units. Water flow is stopped after ensuing that all columns are free from turbidity and no classification is going on. Sized and settled fractions are collected into beakers by opening stopcocks. Overflow of the fourth column gives fifth fraction. Water from all five beakers is decanted; the samples are dried and weighed to give particle size distribution. The temperature of water is recorded.

**Experimental Results :**

Quartz sample (100%−270mesh—Tyler) is used in the test to determine its size analysis. (The internal diameters of the four sorting columns used are 1.35 cm, 2.05 cm, 2.80 cm, and 3.8 cm.) It is aimed in this test to get +44 microns size fraction in the first column as a result of which it is possible to get +29 microns in the second column, +21 microns in the 3rd coulmn, +16 microns in the fourth column and −16 microns in the overflow of the fourth column.

**Calculation :**

To lift a particle of 44 microns diameter. the rising fluid in the first column should have a velocity as calculated below by substituting the data values in the Stokes' equation.

$\triangle$ = Specific gravity of the particle (quartz) = 2.655

$\triangle'$ = Specific gravity of the medium (water) = 1.0

r = Radius of the particle (wanted) 22 $\mu$ = $22 \times 10^{-4}$ cm

g = Gravitational acceleration = 980 cm / sec$^2$

$\mu$ = Viscosity of the medium water at 31° C temperature = $0.784 \times 10^{-2}$ poise

$$\therefore Vm = \frac{2}{9} \times \frac{(2.655-1.0)\ 484 \times 10^{-8} \times 198}{0.784 \times 10^{-2}}$$

= 0.2224 cm / sec.

= 13.344 cm / min

Thus 44 microns size particle falls with a velocity of 0.2224 cm/sec. The corresponding flow rate of water required to pass through 1.35 cm. tube at 31°C would be 19 cc/min from the following relation, flow rate = cross sectional area of tube $\times$ $V_m$. The various particle sizes obtainable from the tubes of different sizes in the series are as shown in Table 1 :

**Table—1**

| | Diameter (cm) | Velocity of the rising water (cm/min) | Size of the particle to be lifted (in microns) |
|---|---|---|---|
| First column | 1.35 | 13.34 | 44 |
| Second column | 2.05 | 5.78 | 29 |
| Third column | 2.80 | 3.10 | 21 |
| Fourth column | 3.80 | 1.68 | 16 |

Theoretical values of the size ranges are as given above. In this test, the weight percentages of the sized fractions obtained are as given in Table 2.

**Table—2**

| | First column | Second column | Third column | Fourth column | Overflow of the Fourth column |
|---|---|---|---|---|---|
| Calculated size in microns | +44 | —44+29 | —29+21 | —21+16 | —16 |
| Wt. percentage | 19.635 | 33.256 | 22.443 | 14.598 | 10.071 |

**Microscopic examination of the fractions :**

The sized fractions obtained in elutriation test were examined under microscope[6]. Various sizes in different fractions are given in Table No. 3. In the present study width across or short diameter of the particle is considered as the size of the particle. Stokes' equation is used in the study only to arrive at requisite flow rate.

**Table—3 : Percentage distribution obtained of different size particles in five fractions**

| Number of microscopic divisions | 10 & +10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 & —1 |
|---|---|---|---|---|---|---|---|---|---|---|
| In microns | 45 & +45 | 40.5 | 36.0 | 31.5 | 27.0 | 22.5 | 18.0 | 13.5 | 9.0 | 4.5 & —4.5 |
| % of grains in First fraction (+44μ) | 85 | 5 | 4 | 6 | | | | | | |
| Second fraction (—44+29μ) | 3 | 10 | 15 | 40 | 4 | 15 | 13 | | | |
| Third fraction (—29+21μ) | | | | | 15 | 45 | 15 | 12 | 13 | |
| Fourth fraction (—21+16μ) | | | | | | | 45 | 15 | 25 | 15 |
| Fifth fraction (—16μ) | | | | | | | | | 20 | 80 |

Note : The desired particle size spread is indicated with a line in each fraction.

It is found that all the fractions contain some fine particles also. This is due to the fact that in the process of elutriation, flow rate is not constant across the sorting column, being maximum at the centre and minimum at the walls responsible for some overlap in the observed size ranges.

Photomicrographs of the five sized fractions obtained (Fig. 2) show that inspite of the presence of some fine particles in all the fractions, the separation is reasonably good. Numerically from the above Table No. 3, the fines appear considerable but in fact they are low on weight basis.

It is proposed to study samples of different specific gravity and their sizes would be studied under microscope to establish the performance of the new unit developed.

**Summary and Conclusion :**

Particle size determination of mineral fines and clays is an important characteristic and needed in industry. There are several imported units for its quick determination. A simple indigenous unit has been fabricated at the National Metallurgical Laboratory. This is based on water elutriation principle. A sample of pure quartz fines (—270 mesh) was tested in the unit which gave excellent separation as observed under microscope.

It is proposed to study samples of different densities to establish its performance.

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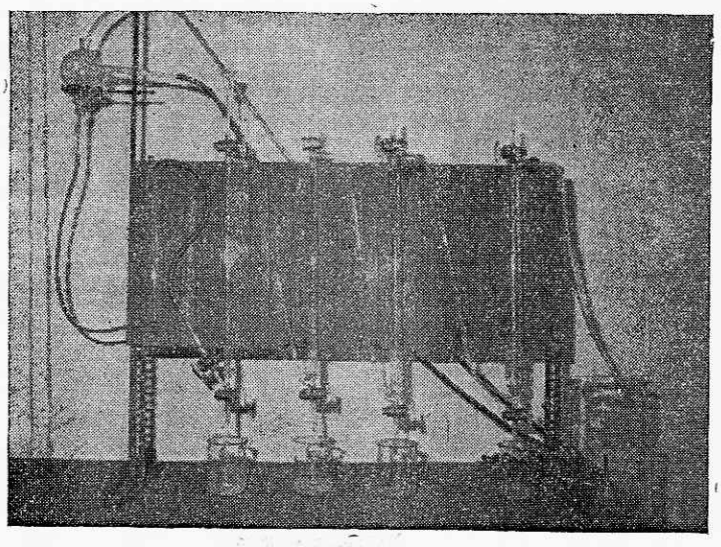

Fig, 1 : Photograph of the fabricated apparatus

Fig. 2a ; Photomicrograph of the sized fraction from first column. X 270.

Fig. 2b : Photomicrograph of the sized fraction from second column. X 270.

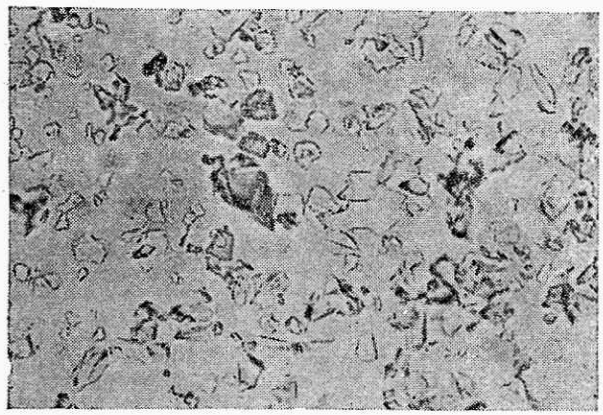

Fig. 2c : Photomicrograph of the sized fraction from third column. X 270.

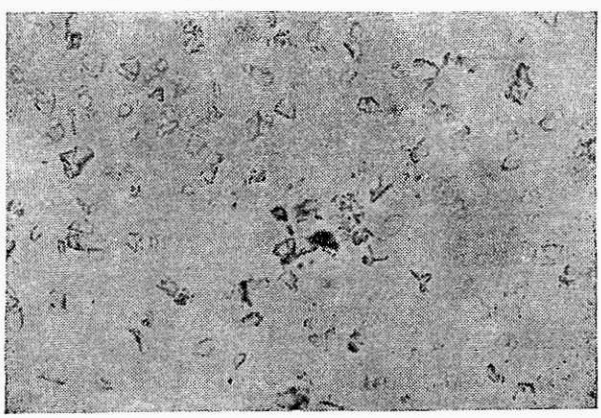

Fig. 2d : Photomicrograph of the sized fraction from fourth column. X 270.

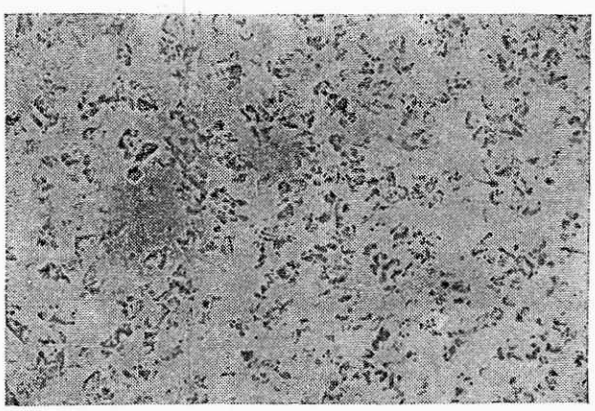

Fig. 2e : Photomicrograph of the sized fraction from the overflow of fourth column. X 270.

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## DISCUSSION :

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*Question 1* : What are the advantages of this particular elutriator over the other elutriators ?

*Author* : 1. It can be made at low cost indigenously.

2. No power is required for running the unit.

3. Since whole unit is made up of glass entire classification operation is distinctly visible.

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*Question 1* : Surface charge of particles will have any effect on elutriation by formation. Is it necessary to add some dispersing agent ?

*Author* : Yes. It is possible. But in our tests with quartz powder this problem was not faced.

*Question 2* : We are using Resin Beads of 0.3 mm size for Uranium Recovery. They get disintegrated in course of use. Will it be possible to separate out the coarser particles from the fine broken beads by elutriation. Sp. gravity of Beads is 1.2. Will you please elucidate the effect of diameter on elutriation.

*Author* : It is possible to separate the disintegrated fines from the coarse counterpart particles provided Reynolds number is below 0.2 in the test to be carried out with your sample. Since your sample is a lighter one ( Sp. gr. 1.2 ) the maximum size limit of the particles to be elutriated may exceed 80 microns. It is also advisable to screen the coarser particles (say+80 microns) before feeding the minus fraction to the elutriator.