W_s = weight of test sample in suspension (g)

V = volume of sedimentation vessel to the mark (ml)

V_f = volume of pipette (ml)

In the Andreasen pipette h changes with sample withdrawal. As settling is still taking place during sample withdrawal (should take 20s) the height is usually taken as the mean of the height before and after sample withdrawal.

Calculation of time of settling: Stokes law is used to calculate the initial time from a knowledge of the limiting value of dst (e.g. 53 um if from sieving test). A 2: 1 time progression is then normally used after this. The advantages of the Andreasen pipette are that it is simple and of low cost. However, the main disadvantages, sample withdrawal can disturb the suspension. Some of the sample is also left behind in the pipette stem for the next sample. With care, however, reproducible results can be obtained.

An alternate method is the Measurement of density of the suspension. Some of the sample is also left behind in the pipette stem for the next sample. With care, however, reproducible results can be obtained.

Disadvantages.

a) Sample withdrawn can disturb the suspension
b) Sample left behind add to the next sample drawn

An alternate method is the measurement of density of the suspension. Two alternatives are:
a) measurement at known levels using hydrometers
b) measurements of density gradient using "divers".

Particles settle onto hydrometers and it is also difficult to know exactly where the density is being measured. Divers give more accurate results especially if they can be electronically sensed. Those are small glass vessels calibrated or adjusted to a known density (see fig. 15).

(a) Centrifugal Sedimentation.

With gravitational forces only particles greater than about 5 um can be analysed. For particles less than 5 um, prolonged settling times occur due to convection currents, Brownian motion and particle surface charge. Centrifugation extends the size range down to 0.02 um. However, because the centrifugal force varies radially, the analysis of particle size and behaviour is far more difficult than the above methods.

(b) Elutriation Methods.

The apparatus consists of a series of cylindrical vessels having conical bottoms and arranged in order of increasing diameter. The same flow Q of fluid passes through each column. Stoke's law is normally assumed to apply. The sizes separated d_1, d_2, d_3 etc are therefore calculated from

$$d_{st} = k(V)^{1/2}$$

and $V = \dfrac{\text{Rate of flow Q } (cm^3/s)}{\text{Cross sectional area of column } (cm^2)}$

The main advantages of elutriation are

i) Fractions of particles are produced
ii) Apparatus is simple
iii) Fluid can be liquid or gas

The disadvantages are:

i) To achieve laminar flow, tall columns are required and sharp bends must be avoided.
ii) Fluid flow across the tube is parabolic because of wall drag. In reality particles are normally dragged into the fastest flow region so that they tend to be cut by the maximum fluid velocity. The effect is also less significant with larger elutriation.
iii) Process is lengthy and it is not easy to maintain a constant flow over the necessary period of elutriation.

The Cyclosizer.

The elutriation columns are replaced by specially designed hydrocyclones which are mounted "upside-down" and a closed box is fitted to each apex nozzle. Not all the solids which would normally leave via the apex do so. They are continuously carried back into the conical body. This repeated sorting produces a sharp separation as well as affording additional opportunity for the small particles to leave through the vortex finder.

The cyclosizer shown below ,comprises a set of five, 3" diameter hydrocyclones in series with decreasing diameter feed inlets and vortex finders, giving an increasing centrifugal force.

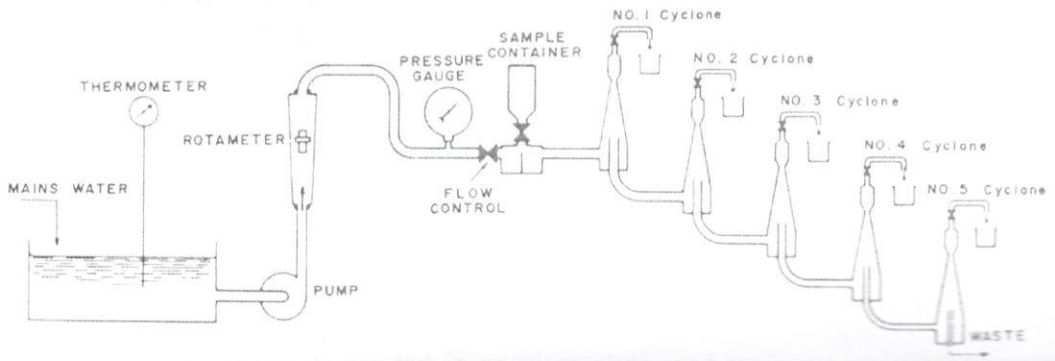

FIG. 4.11. Warman cyclosizer.

The sample is therefore divided into five fractions. The cyclosizer can be used for particles in the range 8-50mm and has the advantage that a run takes only 10-30 minutes.

4.1.3 Streaming Methods.

These measures particle size by measurement of individual particles in a flowing stream of fluid passing a suitable detector. It is essential that the stream concentration be so low that only one particle is detected at a time.

One of the most successful applications is the coulter counter shown below.

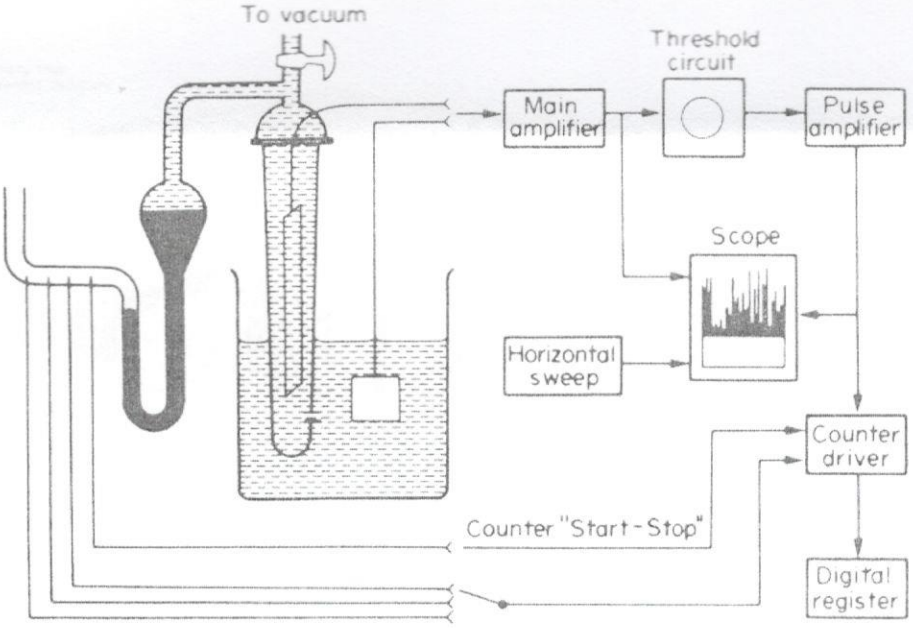

FIG. 4.13. Coulter counter.

The device has particles suspended in an electrolyte, and their presence produces a change in resistance as they pass between two electrodes. This signal is amplified and counted. By setting suitable detection limits, only particles greater than a certain size can be detected. Further, by successive adjustment of the limits, a cumulative size distribution can be built-up. Since the signal depends on the particle volume, this method measures d_v.

4.1.4 On-Stream Particle size analysis.

On-stream analysers have considerable advantages in mineral processing, e.g. in the control of grinding circuits.

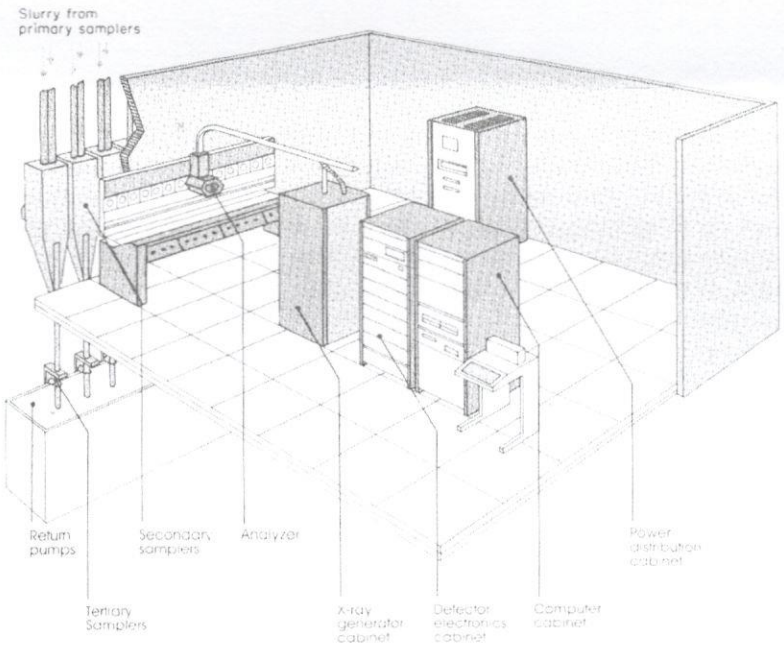

Figure 4.13. Courier 300 on-stream X-ray analysis system.

The size distribution of the product from a grinding operation often plots as an approximately straight line (e.g. on log-log paper). When the product from a mill changes, it will often do so in such a way that a family of parallel straight lines is produced. Hence the deviation can be defined by determining only one point on the curve. This obviously simplifies the problem.

Sampling, however, presents problems in on-stream analysis because an analyser usually requires a uniform rate a flow much lower than that in the process stream which may vary in flow rate, solids concentration, etc.

Several analysers have been designed. In one of the more common ones, the sample is pumped into a rectangular section tube which is bent through one turn of a helix. Centrifugal forces cause the particles, initially uniformly dispersed, to form a concentration gradient across the tube. The concentration profile is measured using a transmission beta radiation gauge. Calibration of the gauge enables the difference in signals to be interpreted in terms of e.g. weight % greater than a particular size.

References and Recommended Readings.

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