

CENTRIFUGATION

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Definition

- Centrifugation is a process used to separate or concentrate materials suspended in a liquid medium.
- The theoretical basis of this technique is the effect of gravity on particles in suspension.
- Two particles of different masses will settle in a tube at different rates in response to gravity.

Principle and theory of centrifugation

- Centrifugal effect:

Centrifugal force in terms of the ratio to the gravitational force is known as centrifugal effect.

- Consider a body of mass m rotating in a circular path of radius r at a velocity v . The force acting on the body in a radial direction is given by:

- $F = \frac{mv^2}{r}$

Here, F = centrifugal force

m = mass of the body

v = velocity of body

r = radius of circle of rotation

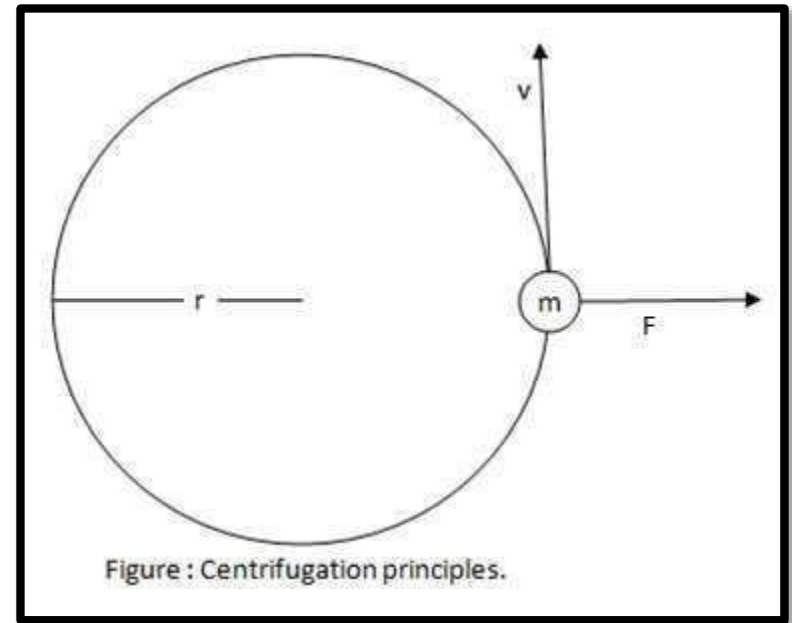


Figure : Centrifugation principles.

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- The same body will be acted upon by a gravitational force. It can be expressed as:

$$G = mg$$

where, G = gravitational force g = gravitational constant

- The centrifugal effect is the ratio of the two forces, so that:

$$\begin{aligned} C &= F / G \\ &= mv^2 / mgr \\ &= v^2 / gr \end{aligned}$$

But, $v = 2\pi rn$ Where, n = speed of rotation.

So,

$$\begin{aligned} F / G &= (2\pi rn)^2 / gr \\ &= 4\pi^2 r^2 n^2 / gr \\ &= 2 \pi^2 n^2 d / g \dots\dots\dots(1) \end{aligned}$$

Where, d = *diameter of rotation*.

- The gravitational constant has a value of 9.807 m/s^2 , so that equation (1) may be simplified to:
- Centrifugal effect = $2.013 n^2 d$
- Provided that , n is expressed in S^{-1} and d is in meter.
- From the equation, it can be drawn that the centrifugal effect is directly proportional to the diameter, but is proportional to the square of the speed of the rotation.
- Thus, if it is necessary to increase the centrifugal effect, it is of greater advantages to use a centrifuge of the same size at a higher speed, rather than use a ⁵ larger centrifuge at the same speed of rotation.



Factors affecting centrifugation process

- ❑ Liquid viscosity
- ❑ Liquid density
- ❑ Solids concentration
- ❑ Particle size distribution
- ❑ Surface charge of particles
- ❑ Type and shape of particles
- ❑ Feed rate
- ❑ Agitation speed
- ❑ Size of centrifuge
- ❑ Height of cake
- ❑ Mode of operation
- ❑ Time at full speed

Classification of centrifuge

Industrial centrifuges can be classified into 3 main types:

(1) Filtration centrifuge:

Those using perforated baskets, which perform a filtration type operation (work like a spin dryer).

- E.g. perforated basket centrifuge, semi-continuous centrifuge

(2) Sedimentation centrifuge:

Those with a solid walled vessel, where particles sediment towards the wall under the influence of the centrifugal force.

- E.g. Tubular bowl centrifuge, Non-perforated basket centrifuge, super centrifuge, conical disc centrifuge

(3) Continuous centrifuge:

Those where a continuous process or very high capacity is required.

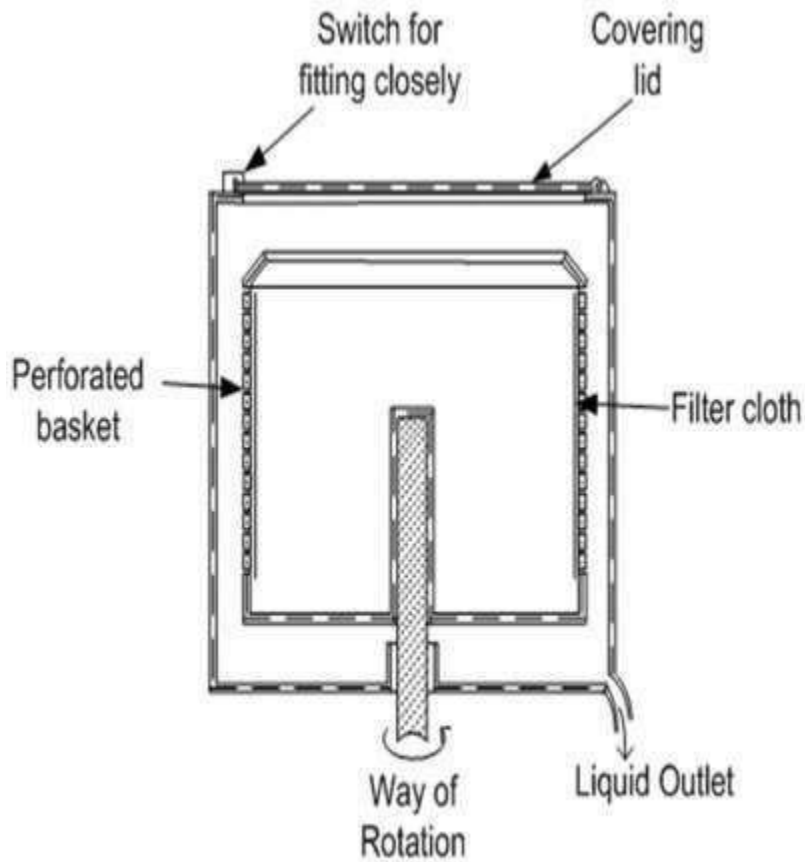
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- ▶ E.g. Continuous horizontal centrifugation

1. Perforated basket centrifuge

- Principle:
- ✓ Perforated basket centrifuge is a filtration centrifuge. The separation is through a perforated wall based on the difference in the densities of solid and liquid phases.
- ✓ The bowl contains a perforated side-wall. During centrifugation, the liquid phase passes through the perforated wall while solid phase is retained in the bowl.
- ✓ The solid is removed by a blade.
- ✓ In this centrifuge a basket is mounted above a driving shaft such arrangement is described as

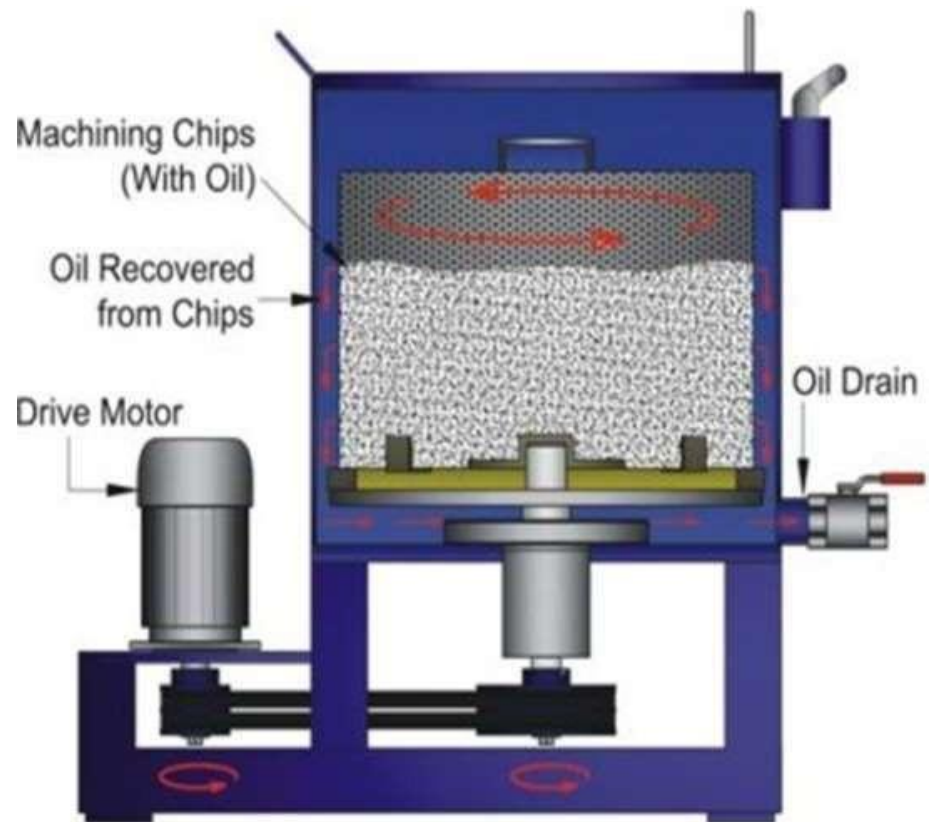
□ Construction:

- ✓ It consist of perforated basket which is made up of stainless steel and lined with filter cloth.
- ✓ The basket is suspended above the shaft and driven by a motor or turbine.
- ✓ Surrounding the basket casing is provided which collect the filtrate and discharge them to the outlets.



Model of perforated basket centrifuge

<http://jeepakistan.blogspot.com>



□ Working:

- ✓ Liquid feed is inserted to the bowl/basket when it is stationary in such a way that it distributes evenly in the basket.
- ✓ Power is supplied to start the rotation of basket. The basket should achieve its maximum speed quickly. It rotates at 1000 rpm.
- ✓ During the process liquid passes through perforated walls and solid remains inside the wall.
- ✓ The solid is collected after drying by spinning and liquid is collected from outlet.

Uses : (1) Perforated basket centrifuge is extensively used for separating crystalline drugs (such as aspirin) from the mother liquor. Free flowing product can be obtained because mother liquor is removed completely.

(2) It is also used for removing unwanted solids from a liquid. For example, precipitated proteins are removed from insulin.

(3) Sugar crystals are separated using perforated basket centrifuge.

Advantages : (1) The centrifuge is very compact and it occupies very little floor space.

(2) It can handle slurries with a high proportion of solids and even those having paste like consistency.

(3) The final product has very low moisture content.

(4) In this method, the dissolved solids are separated from the cake.

(5) The process is rapid.

Disadvantages : (1) The entire cycle is complicated resulting in considerable labour costs.

(2) It is a batch process.

(3) If the machine is adapted for prolonged operation, there is considerable wear and tear of the equipment. On prolonged operation, the solids may form hard cake, due to the centrifugal force, which is difficult to remove simultaneously.

2. Semi continuous centrifuge

- It is also known as short cycle automatic batch centrifuge.
- Principle:
 - ✓ This centrifuge is a filtration centrifuge. The separation is through a perforated wall based on the difference in the densities of solid and liquid phases.
 - ✓ The bowl contains a perforated side-wall. During centrifugation, the liquid phase passes through the perforated wall while solid phase is retained in the bowl.
 - ✓ The solid is removed by cutting with a blade.

□ Working:

- ✓ The perforated basket is allowed to rotate and Liquid feed is inserted to the bowl/basket from side pipe in such a way that it distributes evenly in the basket.
- ✓ During the process liquid passes through perforated walls and solid remains inside the wall.
- ✓ The cake is washed with water. The wash escapes from the basket through the filtrate outlet.
- ✓ The solid is collected after drying by spinning and liquid is collected from outlet.
- ✓ In this centrifuge after achieving the desired thickness about 50 to 70 mm the feeler cuts off the air supply to diaphragm valve that automatically cuts of the entry of the slurry.

Construction : The construction of a semi-continuous centrifuge is shown in Figure 10-4. It consists of a vertical perforated basket, which is supported from a horizontal shaft driven by a motor. From the open side of the basket, provisions are made at the centre to introduce feed and wash pipe through horizontal tubes. A feeler (not shown) rides over the feed, which is connected to diaphragm valve through air supply. The feeler controls the thickness of the feed. Hydraulic cylinder attachment is made in such a manner that the discharge chute enters from the sides of basket, when discharge of crystals is desirable.

Advantages : Short-cycle automatic batch centrifuge is used when solids can be drained fast from the bowl.

Disadvantage : During discharge, considerable breakage of crystals is possible. Many moving parts are involved making the construction and functioning complicated.

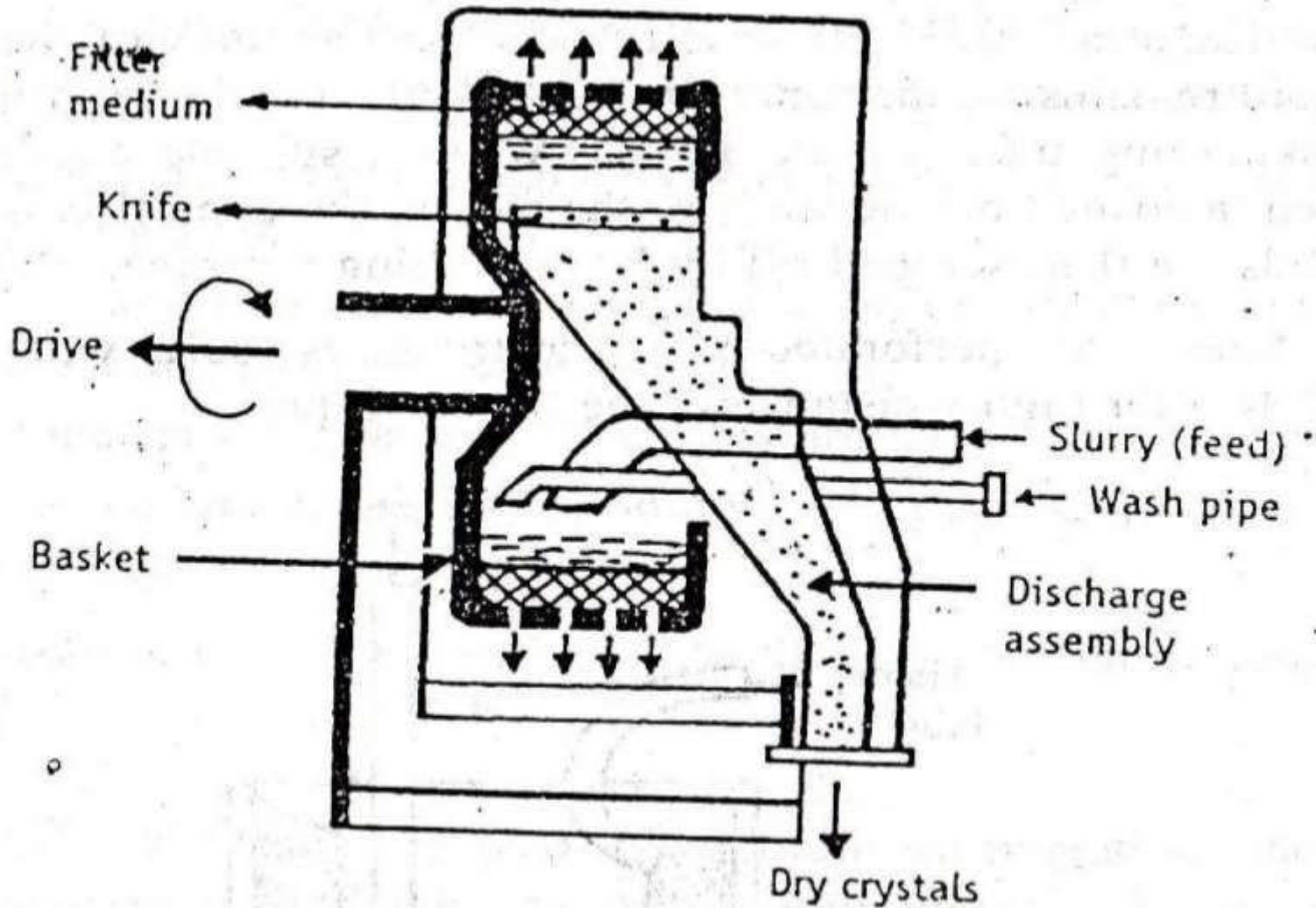


Figure 10-4. Construction of semi-continuous centrifuge.

3. Non-perforated basket centrifuge

□ Principle:

- ✓ This is sedimentation type centrifuge so separation takes place on the basis of difference in their densities without presence of perforated/porous medium.
- ✓ During centrifugation solid remains at side wall of the basket while liquid remains at the top which is collected by skimming tube.

Construction:

- ✓ It consist of basket made up of stainless steel. The basket is placed on the vertical shaft.
- ✓ Basket contains inlet tube and skimming tube.

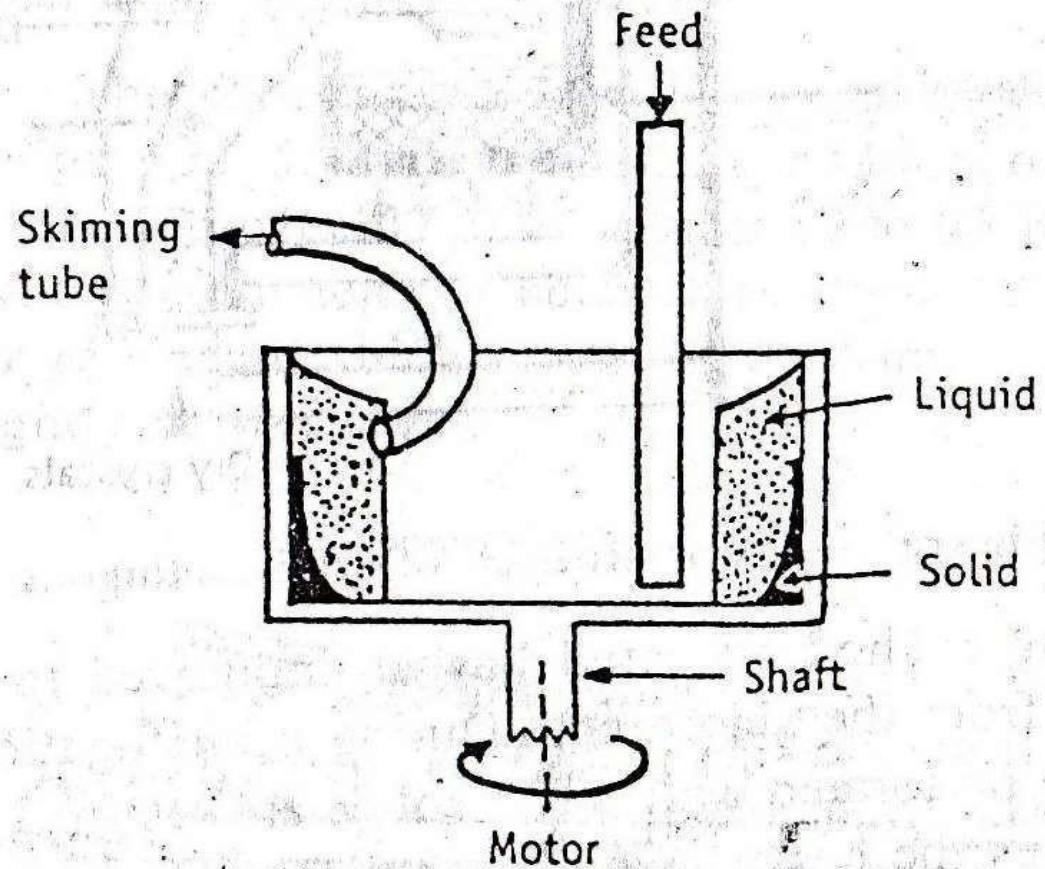


Figure 10-3. Construction of non-perforated basket centrifuge.

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- Working:
 - ✓ The suspension is fed continuously into the basket. During centrifugation solid phase is retained on the sides of the wall while liquid remains on the top.
 - ✓ The liquid is collected with skimming tube and solids are scraped off by using scrapper from the basket.
 - Uses:
 - ✓ It is useful when the deposited solids offer high resistance to the flow of liquid.
 - Advantages:
 - ✓ Cost is less than other centrifuges
 - Disadvantages:
 - ✓ Solid phase is retained on the sides of the basket.

4. Super centrifuge

- Principle:
- ✓ This is sedimentation type centrifuge so separation takes place on the basis of difference in their densities between to immiscible liquids.
- ✓ Centrifugation is done in the bowl of small centrifuge. During centrifugation the heavier liquid is thrown against the wall, while lighter liquid remains as inner layer.
- ✓ The two layers are simultaneously separated using modified wiers.

Construction : The construction of a supercentrifuge is shown in Figure 10-6. It consists of a long hollow cylindrical bowl of small diameter. It is suspended from a flexible spindle at the top and guided at the bottom by loose-fit bushing. It can be rotated on its longitudinal axis. Provision is made at the bottom for the feed inlet using pressure system. Two liquid outlets are provided at different heights at the top of the bowl, for simultaneous recovery of the separated liquids using modified weirs.

Working : The centrifuge is allowed to rotate on its longitudinal axis at a high frequency usually about 2000 revolutions per minute with the help of drive-assembly. The feed is introduced from the bottom of the centrifuge using a pressure system. During centrifugation, two liquid phases separate based on the difference in their densities. The heavier liquid is thrown against the wall, while the lighter liquid forms an inner layer. Both liquids rise to the top of the vertical bowl.

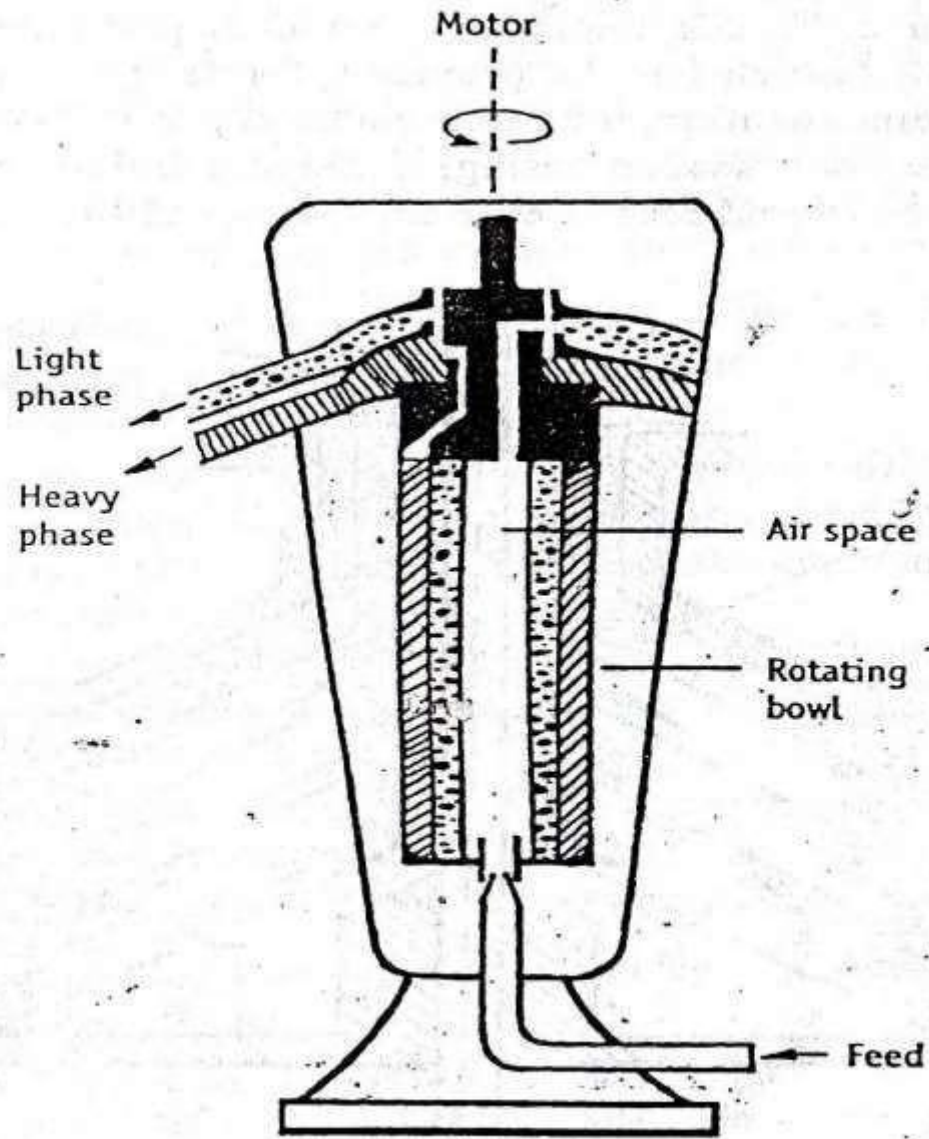


Figure 10-6. Construction of supercentrifuge.

The liquid-liquid interface (the so-called neutral zone) is maintained by an hydraulic balance. These two layers are simultaneously separately removed from different heights through modified weirs (as shown in Figure 10-6). Thus the supercentrifuge can work for continuous separation of immiscible liquid phases.

□ Uses:

✓ Used for separating liquid phase of emulsion in foods and pharmaceuticals.

□ Advantage:

✓ Continuous operation.

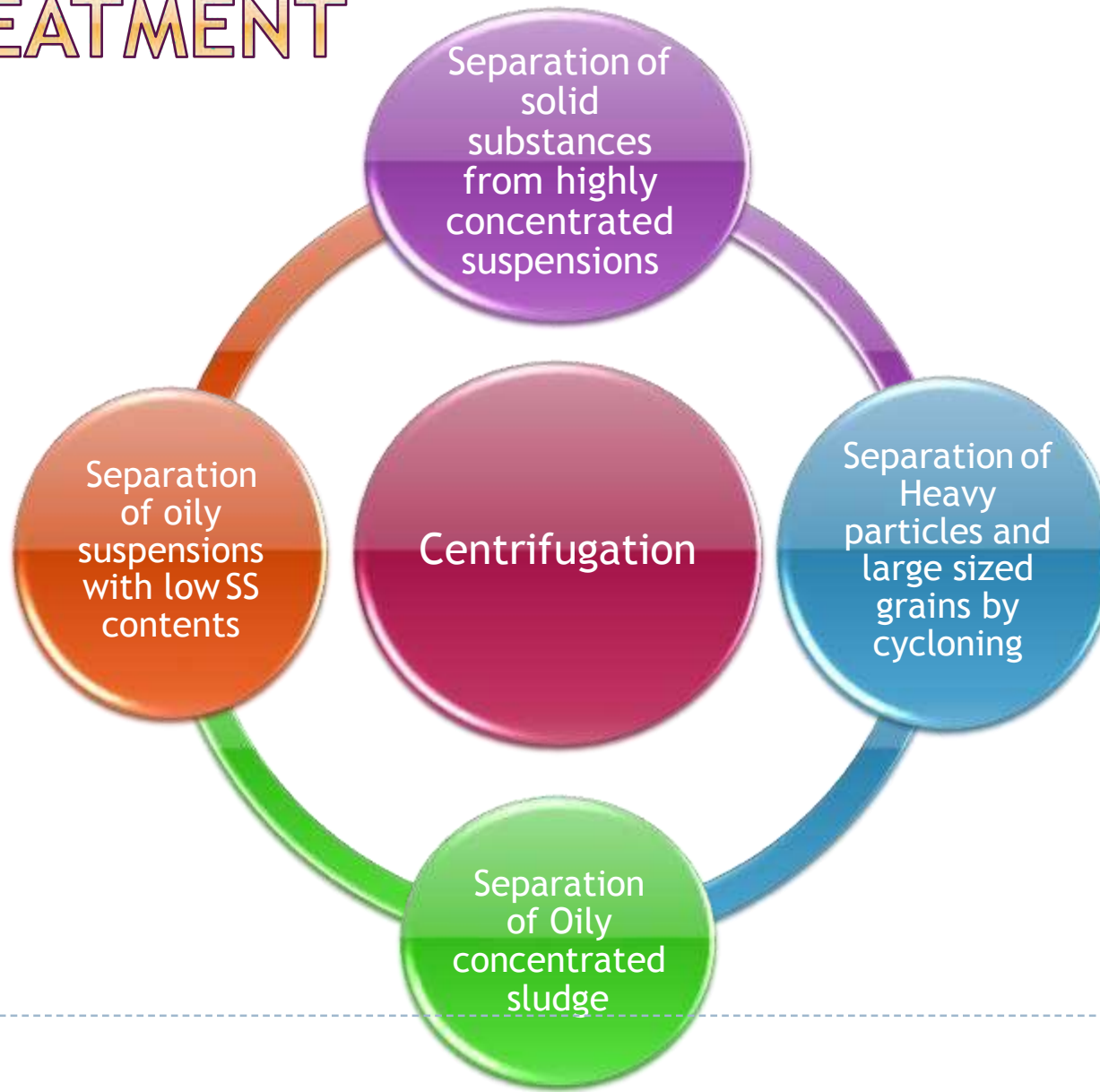
✓ Can handle much higher concentration.

✓ Produces dry solids.

□ Disadvantage:

✓ Sediment does not have uniform structure.

APPLICATION IN WATER TREATMENT



OTHER APPLICATIONS

- Separating chalk powder from water
 - Removing fat from milk to produce skimmed milk
 - Separating textiles
 - Removing water from lettuce after washing it in a salad spinner
 - Separating particles from an air-flow using cyclonic separation
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- The clarification and stabilization of wine
- Separation of water particles from clothes while spin-drying in washing machines
- Separation of urine components and blood components in forensic and research laboratory



- To separate two miscible substances
- To analyze the hydrodynamic properties of macromolecules
- Purification of mammalian cells
- Fractionation of sub-cellular organelles (including membranes / membrane fractions)
- Fractionation of membrane vesicles
- Separating chalk powder from water
- Removing fat from milk to produce skimmed milk
- Separating particles from an air-flow using cyclonic separation
- The clarification and stabilization of wine
- Separation of urine components and blood components in forensic and research

laboratories

- Aids in separation of proteins using purification techniques such as salting out,

e.g. ammonium sulfate precipitation.

THANK YOU