MIXING AND AGITATION

"Many processing operations depend for their success on the effective agitation & mixing of fluids" ……McCabe

Mixing and agitation is the heart of the chemical industry. Almost all process equipment's need some type of mixing or agitation. Uniformity of composition and desired flow pattern depends upon the type of agitator and the speed of agitation. It is also necessary to control the quality of the product, specifically where there is evaluation of heat and the temperature has to be maintained constant.

Agitation

- It is an induced motion of a material in a specified way.
- The pattern is normally circulatory.
- It is normally taken place inside a container.

Mixing

- Random distribution, into & through one another of two or more initially separate phases

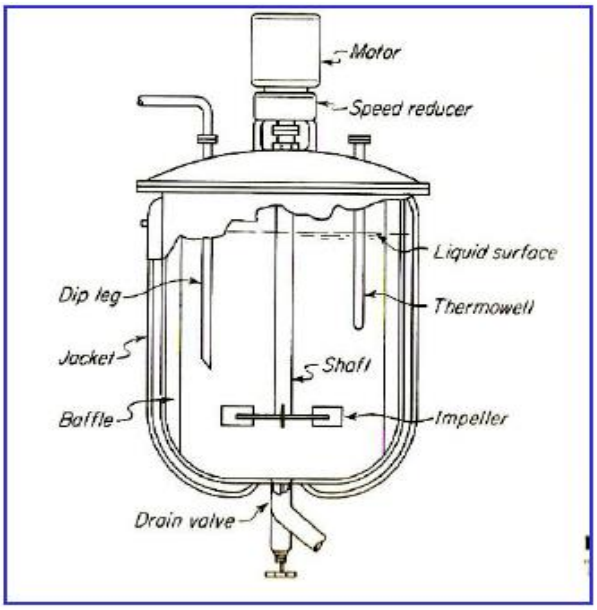


Fig. 1 Agitated Vessel

- Liquids are agitated in a tank
- Bottom of the tank is rounded
- Impeller creates a flow pattern.
- Small scale tank (less than 10 litres) is constructed using Pyrex glass.
- For larger reactors/tank, stainless steel is used.
- Speed reduction devices are used to control the agitation speed.

- Mixing Flow : 3 patterns (axial, radial, tangential flow)

Purpose of Agitation:

1. Blending of two miscible liquids, such as ethyl alcohol and water.
2. Dissolving solids in liquids, such as salt in water.
3. Dispersing a gas in a liquid as fine bubbles,
4. Suspending of fine solid particles in a liquid,

- in the catalytic hydrogenation of a liquid, solid catalyst particles and hydrogen bubbles are dispersed in the liquid.

5. Agitation of the fluid to increase heat transfer between the fluid and a coil or jacket in the vessel wall.

A good mixing should achieve the following:

1. Minimum power requirement.
2. Efficient mixing in optimum time.
3. Best possible economy.
4. Minimum maintenance, durable and trouble free operation.
5. Compactness.

Important consideration in the designing are:

- Determination of amount of energy required or power required for satisfactory performance of mixing operation.
- Process has to be well defined e.g. a mixing system is to be designed to make up and hold in uniform suspension a 15% slurry.
- Description of the components to be mixed. Their properties at initial stage, final stage, overall specific gravity, initial and final viscosity, concentration etc.
- Details of the tank geometry.
- Outline of the mixing cycle: It depends upon the nature of the operation. Decide whether the process is a batch, semi-continuous or continuous etc.

Factors affecting the designing of the agitator:

- Type of vessel
- Circulation pattern.
- Location of the agitator
- Shape and size of the vessel
- Diameter and width of the agitator
- Method of baffling

- Power required
- Shaft overhang

<u>Mixing Flow patterns (3 types)</u>:

(i) **Axial flow.**

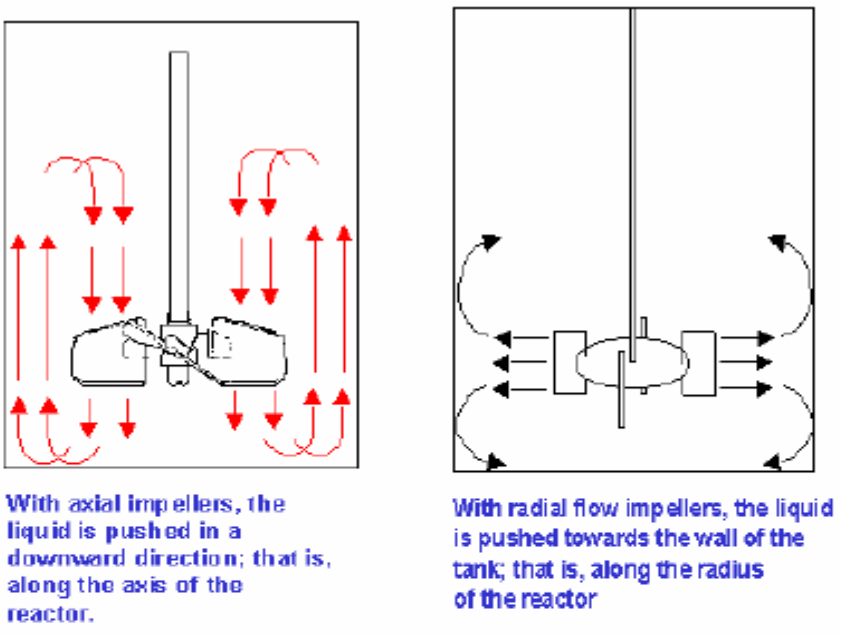
- Impeller makes an angle of less than 90^{o} with the plane of rotation thus resultant flow pattern towards the base of the tank (i.e. marine impellers).
- More energy efficient than radial flow mixing.
- More effective at lifting solids from the base of the tank.

(ii) **Radial flow.**

- Impellers are parallel to the axis of the drive shaft.
- The currents travel outward to the vessel wall & then either upward or downward.
- Higher energy is required compared to axial flow impellers.

(ii) **Tangential flow.**

- The current acts in the direction tangent to the circular path around the shaft.
- Usually, it produce vortex (disadvantageous) & swirling the liquid.



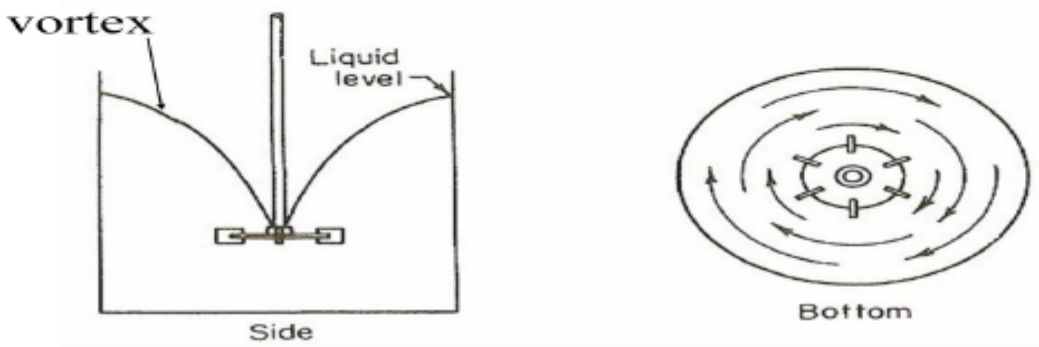


Fig. 2 (i) Axial Mixing (ii) Radial Mixing (iii) Tangential Mixing

Vortex

- If solid particles present within tank; it tends to throw the particles to the outside by centrifugal force.
- Power absorbed by liquid is limited.
- At high impeller speeds, the vortex may be so deep that it reaches the impeller

Preventing vortex

(i) Baffles on the tank walls

(ii) Impeller in an angular off-center position

(i) Baffles

Baffles are vertical plates that stick out radially from the tank wall

- If simple swirling motion is required no baffling is necessary.
- Generally 4 baffles are used located 90° apart.
- Baffle width is 10-12% tower diameter
- Baffle height 2 times impeller height

- With coils in the tank, baffles are placed inside the coil.

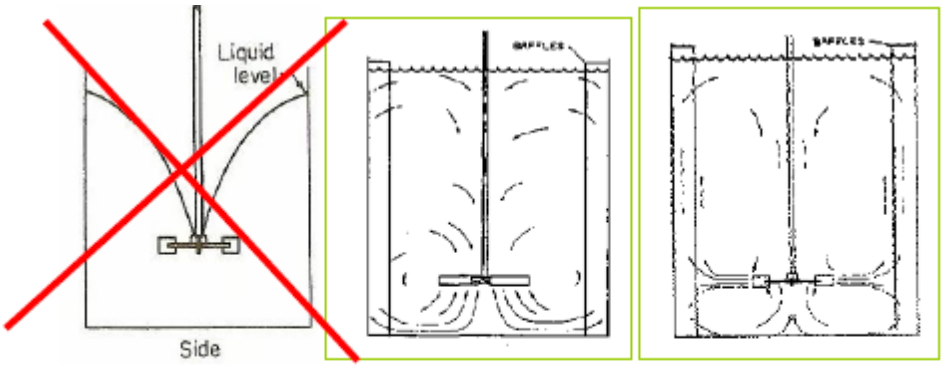


Fig. 3 Flow Pattern in presence of baffles (i) Vertex (ii) Axial Flow turbine (iii) Radial Flow Turbine

- Without baffles, the tangential flow (swirling) occurred in a mixing tank causes the entire fluid mass to spin (more like a centrifuge than a mixer).
- With baffles, most impellers show their true flow characteristics.
- Most common baffles are straight flat plates of metal (standard baffles).
- Most vessels will have at least 3 baffles. 4 is most common and is often referred to as the "fully baffled" condition.

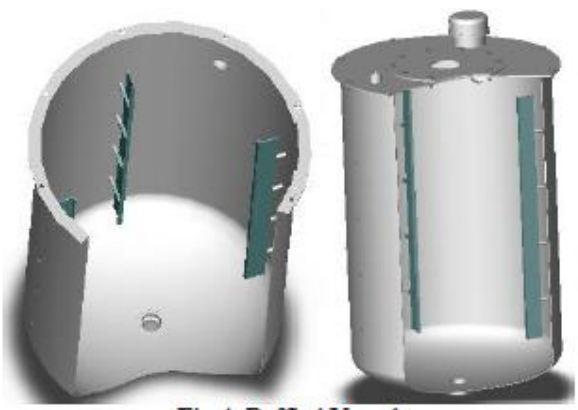


Fig 4. Baffled Vessel

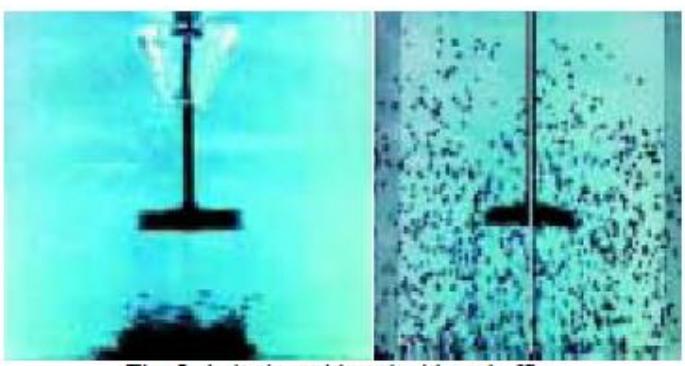


Fig. 5. Agitation with and without baffles

(ii) Impeller in an angular off-center position

Mount the impeller away from the center of the vessel & tilted in the direction perpendicular to the direction of flow.

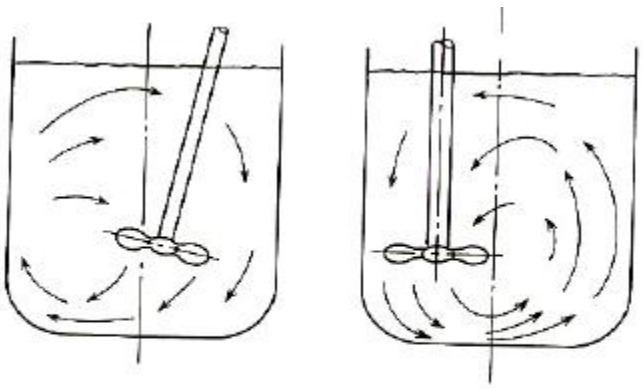


Fig. 6 Flow pattern for off mounted impeller

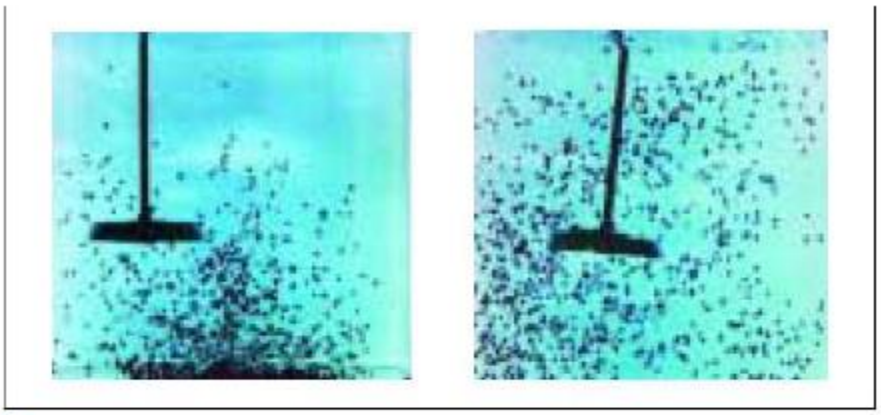


Figure 5. Off-center agitator mounting (left) reduces swirl in unbaffled vessels, while angled, off-center mounting (right) approximates the flow in fully-baffled vessels.

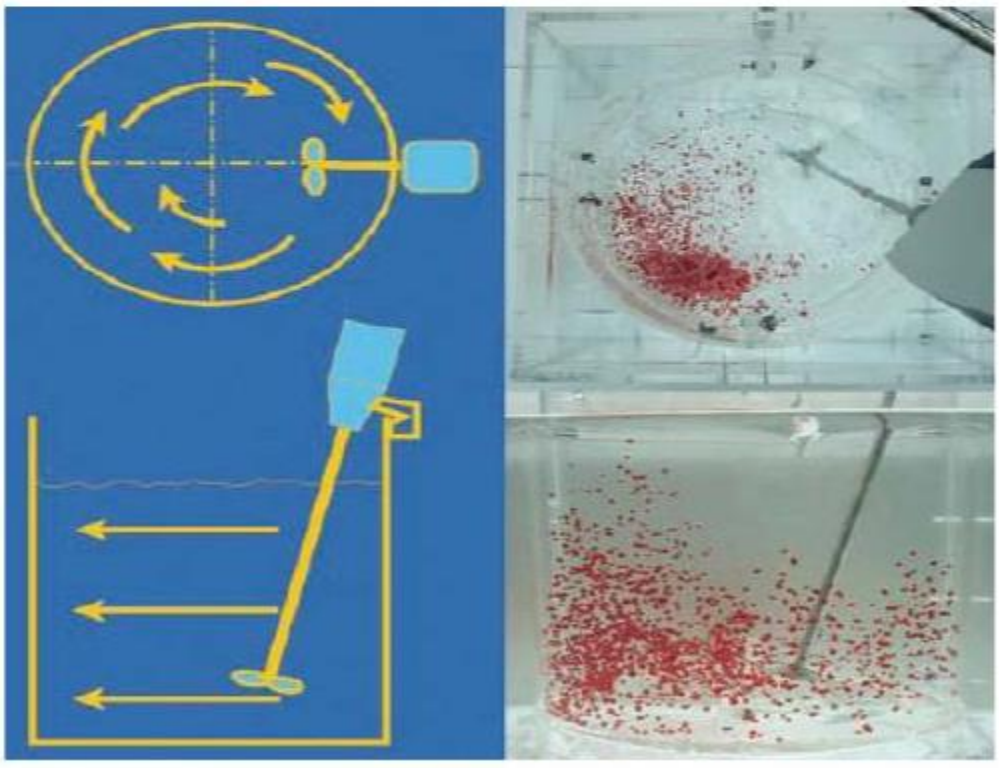


Fig. 7 (i) Side Mounted Impeller (ii) Angle Mounted Impeller

Types of impeller:

1. Paddle **2. Anchor** **3. Propeller** **4. Turbine**

5. Beater **6. Gate Type** **7. Helical** **8. Ribbon**

9. Toothed **10. Marine** **11. Plate Type**

Paddle type agitator

- Speed range 5-300rpm
- Used for large size vessels
- Agitator size almost touching vessel wall
- Normally used for reaction vessel having jacket by providing good heat transfer area
- Doesn't allow solid buildup at the wall

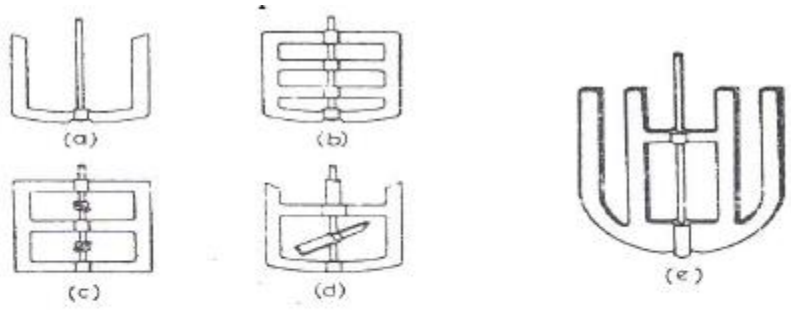


Fig. 14.1 Paddle Agitators: (a) Anchor, (b) Gate, (c) Gate with pitched cross arms, (d) Anchor with pitched cross arms, (e) Combined anchor and gate

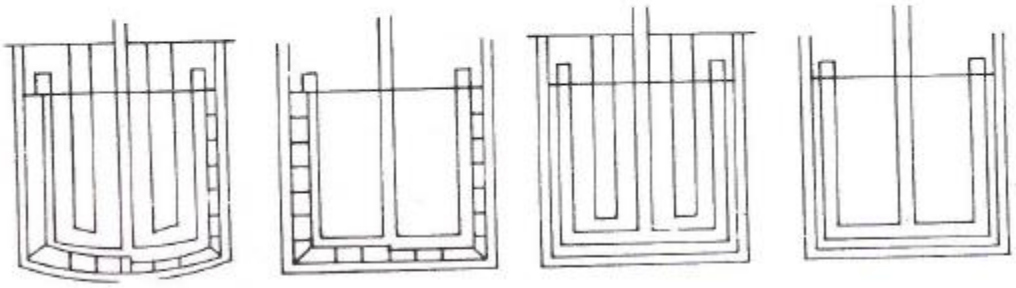


Fig. 4.1 Types of Anchor Agitator

Fig. 8 Paddle and Anchor Type Agitators

Propeller type agitator

- Axial flow impellers
- Maximum flow is achieved at axis of agitator
- Maximum vessel size is $1m^3$
- Maximum speed is 415 rpm
- Diameter of propeller is 15-30% of vessel diameter

Fig. 9 Propeller Type Agitator

Turbine type agitator

- Motion is achieved due to rotary action of impeller
- Two types are available
  - Axial flow turbine
  - Radial flow turbine

flat bladed
pitched bladed
curved bladed

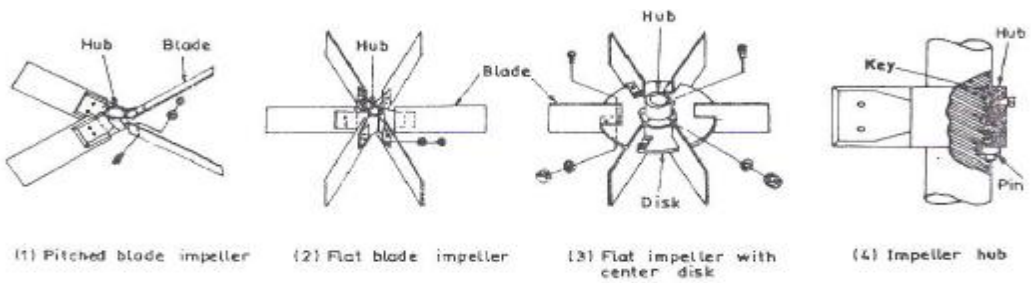


Fig. 4.8 Types of turbine impeller

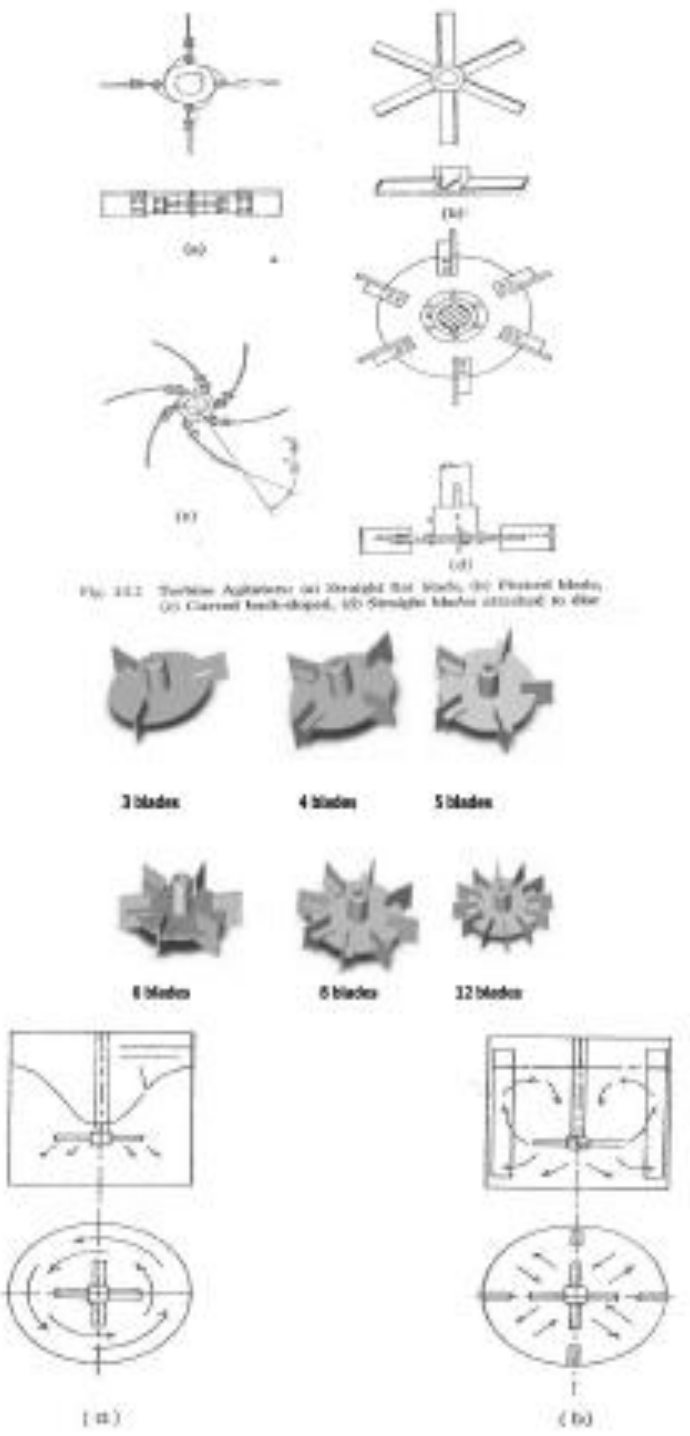


Fig. 14.9 Shows the Flow Pattern Generated by a Turbine:
(a) Agitator without baffles, (b) With baffles

Fig. 10 Different arrangement in Turbine Type agitator and flow pattern in turbine type agitator

Helical or ribbon type agitator

4 types are available in market
– Single helical
– Double helical
– Helical screw
– Ribbon type
• Good for top to bottom liquid circulation
• Used for blending for pseudo plastic materials
• High power requirement

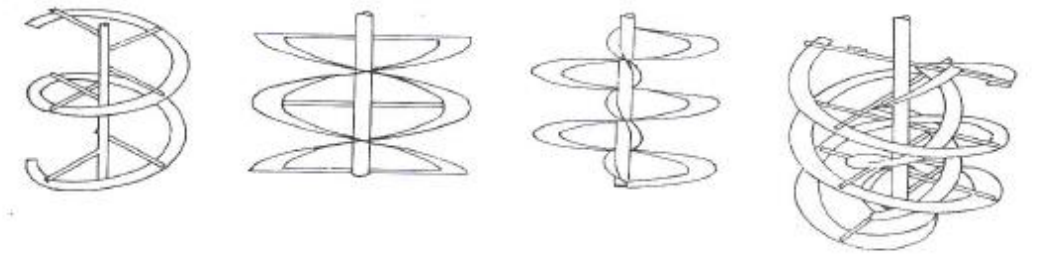


Fig. 4.2 Types of helical ribbon agitator

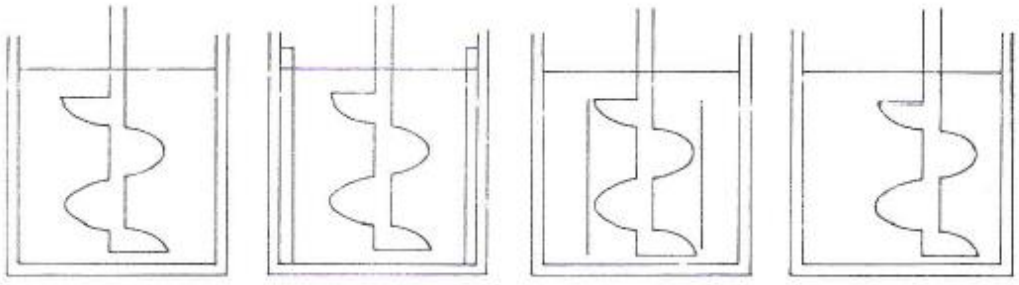


Fig. 11. Helical Ribbon Type Agitators

Specially designed Agitators

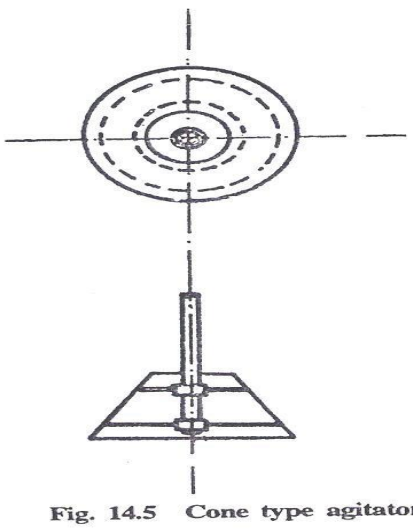


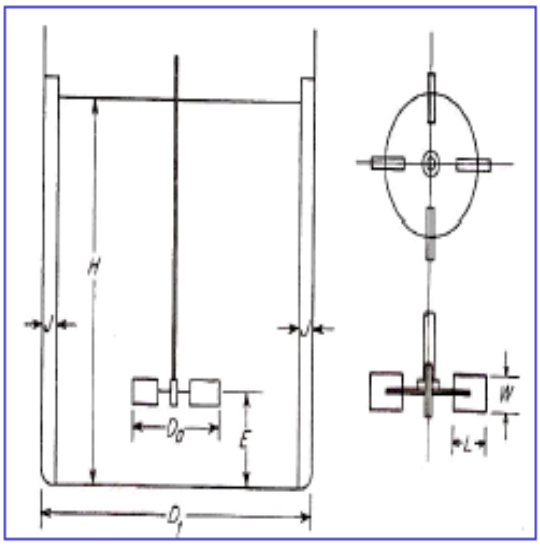
Fig. 14.5 Cone type agitator

- Cone type agitator is used for handling fibrous and dense slurries.
- Speeds are similar to turbine type
- Speed provides sufficient centrifugal force through surface friction to generate flow.

- Selection of the agitator depends upon the viscosity of the fluid to be agitated.
- When the blade area is small it can rotate at very high speed. For such cases the propeller and turbine type agitators are preferred. (μ = 1000 to 50000cps)
- When the blade area is larger it will rotate at the slow speed. For such cases the anchor bolts and helical screw type agitators are used. (μ >> 50000cps)

Mounting of the agitators are done in mainly two ways:

- Top entering agitators → Used in large units
- Side entering agitators → Used in small units and economical



$$\frac{D_a}{D_t}=\frac{1}{3} \qquad \frac{H}{D_t}=1 \qquad \frac{J}{D_t}=\frac{1}{12}$$

$$\frac{E}{D_t}=\frac{1}{3} \qquad \frac{W}{D_a}=\frac{1}{5} \qquad \frac{L}{D_a}=\frac{1}{4}$$

Fig. 13. Standard Turbine Design

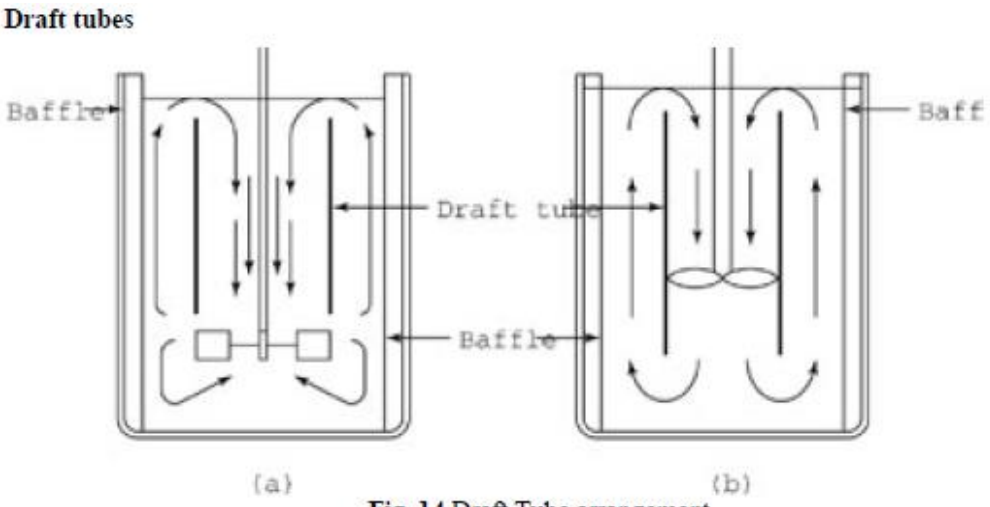


Fig. 14 Draft Tube arrangement

Circulation and Velocity in Agitated Vessels

• Volume of fluid circulated by impeller must be sufficient to sweep out entire vessel in reasonable time
• Velocity of stream leaving impeller must be sufficient to carry current to remotest parts of tank
• In mixing, also need turbulence
– Results from properly directed currents and large velocity gradients in liquid
• Circulation and generation of turbulence both consume energy
• Large impeller + medium speed = flow
• Small impeller + high speed = turbulence

Mixing Types

• Laminar
• Turbulent

POWER REQUIREMENT

➢ For an effective mixing, the volume of fluid circulated in a vessel via an impeller must be sufficient to sweep out the entire vessel in a reasonable time.
➢ Stream velocity leaving the impeller must be sufficient to carry currents to the remotest part of the vessel.

FACTORS AFFECTING THE POWER REQUIREMENT:

- Properties of fluid to be agitated
- Height of the liquid
- Tank size and dimensions
- Agitator type and size
- Speed of agitator