# B. Mixing of Fluids

## Mechanism:

- **Bulk transport:** Movement of large portion o a material from one location to another location in a give system. Rotating blades and paddles are used.

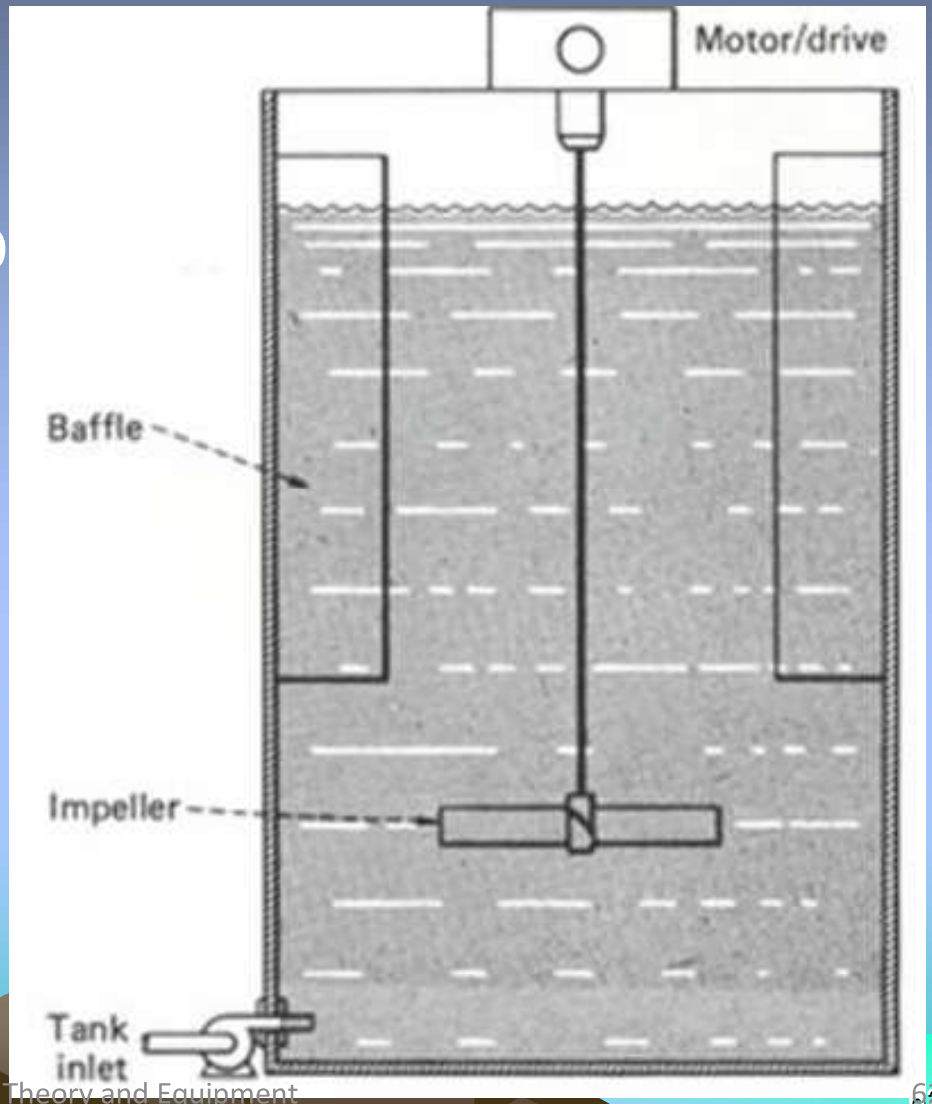
- **Turbulent mixing:** Highly effective, mixing is due to turbulent flow which results in random fluctuation of the fluid velocity at any given point within the system. Fluid velocity at a given point changes in 3 directions (X, Y and Z).

- **Laminar mixing:** Mixing of two dissimilar liquids through laminar flow, i.e., applied shear stretches the interface between them. Suitable for liquids which require moderate mixing.

- **Molecular diffusion:** Mixing at molecular level in which molecules diffuse due to thermal motion.

# Mixing Apparatus for fluids

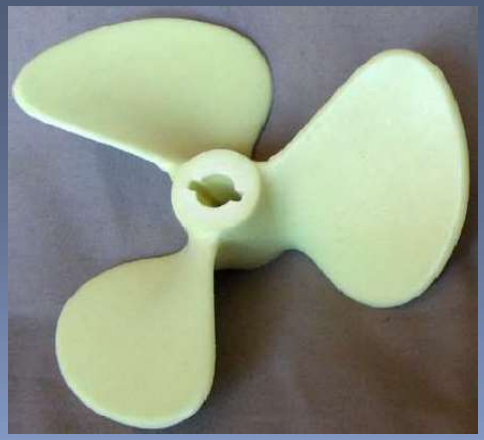
- A Container and
- A Mixing Device o
  Impeller



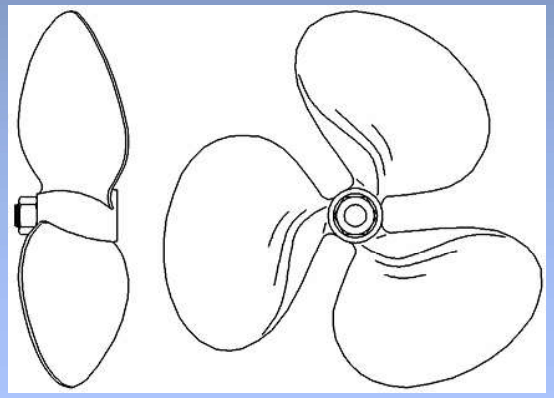
# Mixing Device

- Based on shape and pitch , the are classified into 3 types,
  - Propellers
  - Turbines
  - Paddles

# Propellers



- It consists of number of blades, generally 3 bladed design is most common for liquids. Blades may be right or left handed depending upon the slant of their blades.
- Two are more propellers are used for deep tank.
- Size of propeller is small and may increased up to 0.5metres depending upon the size of the tank.
- Small size propellers can rotate up to 8000rpm and produce longitudinal movement.



## Advantages of propellers:

Used when high mixing capacity is required.

Effective for liquids which have maximum viscosity of 2.0pascals.sec or slurry up to 10% solids of fine mesh size.

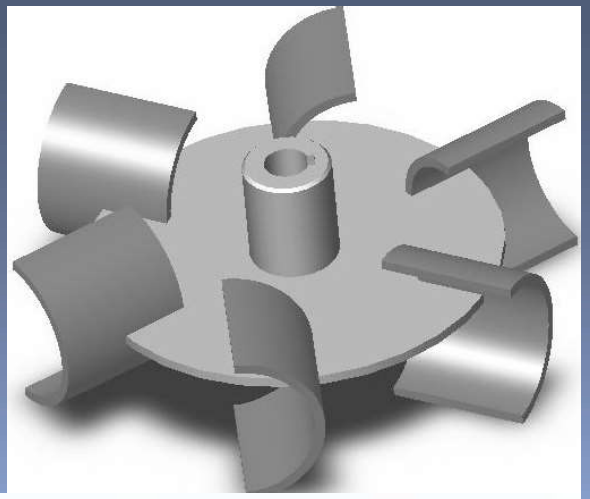
Effective gas-liquid dispersion is possible at laboratory scale.

## Disadvantages of propellers:

Propellers are not normally effective with liquids of viscosity greater than 5pascal.second, such as glycerin castor oil, etc.,

# Turbines

- A turbine consists of a circular disc to which a number of short blades are attached. Blades may be straight or curved.
- The diameter of the turbine ranges from 30-50% of the diameter of the vessel.
- Turbines rotates at a lower speed than the propellers (50-200rpm).
- Flat blade turbines produce radial and tangential flow but as the speed increases radial flow dominates. Pitched blade turbine produces axial flow.



Near the impeller zone of rapid currents, high turbulence and intense shear is observed. Shear produced by turbines can be further enhanced using a diffuser ring (stationary perforated ring which surrounds the turbine).

Diffuser ring increase the shear forces and liquid passes through the perforations reducing rotational swirling and vortexing.

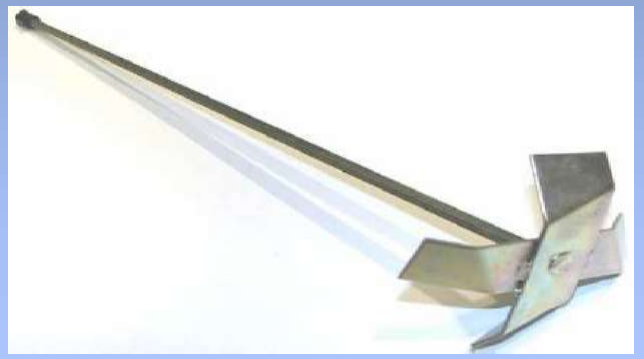
# Advantages of Turbines:

•Turbines give greater shearing forces than propellers through the pumping rate is less. Therefore suitable for emulsification.

•Effective for high viscous solutions with a wide range of viscosities up to 7.0 Pascal. Second.

- In low viscous materials of large volumes turbine create a strong currents which spread throughout the tank destroying stagnant pockets.
- They can handle slurries with 60% solids.
- Turbines are suitable for liquids of large volume and high viscosity, if the tank is baffled.

# Paddles



- A paddle consists of a central hub with long flat blades attached to it vertically.
- Two blades or four blades are common. sometimes the blades are pitched and may be dished or hemispherical in shape and have a large surface area in relation to the tank in which they are used.
- Paddles rotates at a low speed of 100rpm.
- They push the liquid radially and tangentially with almost no axial action unless blades are pitched.
- In deep tanks several paddles are attached one above the other on the same shaft.
- At very low speeds it gives mild agitation in unbaffled tank but as for high speeds baffles are necessary.

## Uses of paddles:

Paddles are used in the manufacture of antacid suspensions, agar and pectin related purgatives, antidiarrheal mixtures such as bismuth-kaolin.

## Advantages of paddles:

Vortex formation is not possible with paddle impellers because of low speed mixing.

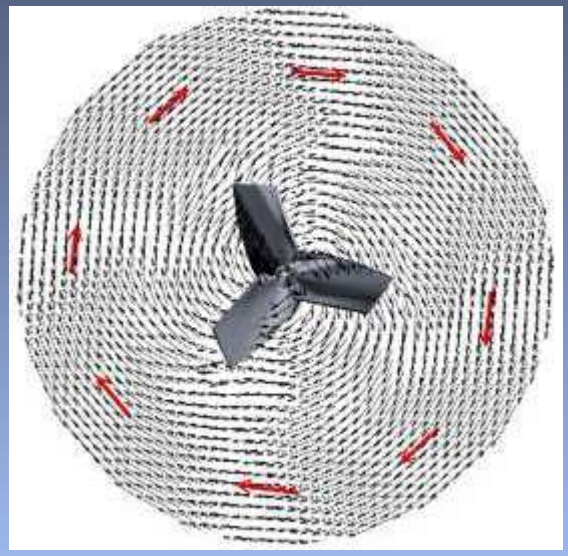
## Disadvantages of paddles:

Mixing of the suspension is poor therefore baffled tanks are required.

# Flow pattern during mixing

## 1. Tangential component or circular:

Acts in the direction tangent to the circle of rotation around the impeller shaft. If shaft is placed vertically and centrally, tangential flow follows a circular path around the shaft and creates a vortex in the l

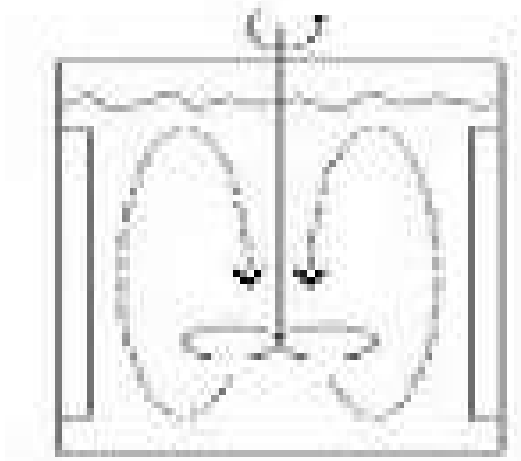


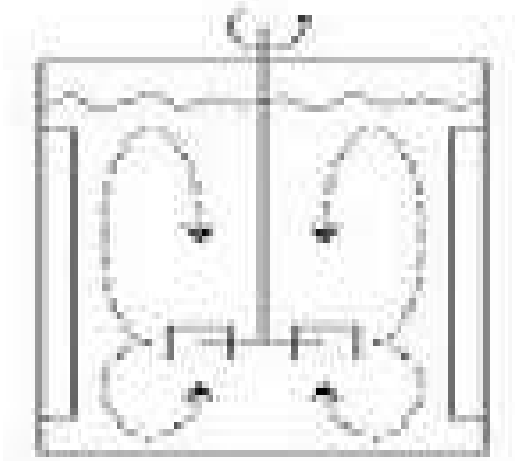
## 2.Radial component:

Acts in the direction vertical to the impeller shaft. Excessive radial flow takes the material to the container wall then material falls to the bottom and rotate as the mass beneath the impeller

## 3. Axial component or longitudinal or vertical:

Acts in the direction parallel to the impeller shaft. Inadequate longitudinal component causes the liquid and solid to rotate in layers without mixing. Adequate longitudinal pattern is best used to generate strong vertical currents particularly when suspending solids are present i





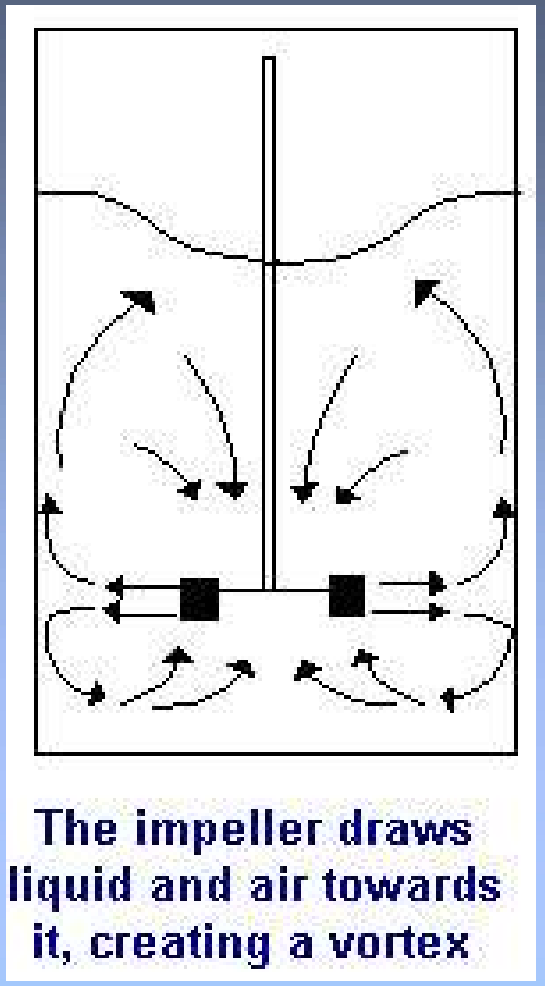
| Impeller type | Flow component |
|---|---|
| Propellers | Axial |
| Turbines | Axial or tangential or both |
| Paddles | Radial and tangential |
| Paddles with pitch | Radial, tangential and axial |

# Vortex formation

- A strong **circulatory flow pattern** sometimes manifests into formation of a vortex near the impeller shaft.

Vortex can be formed when

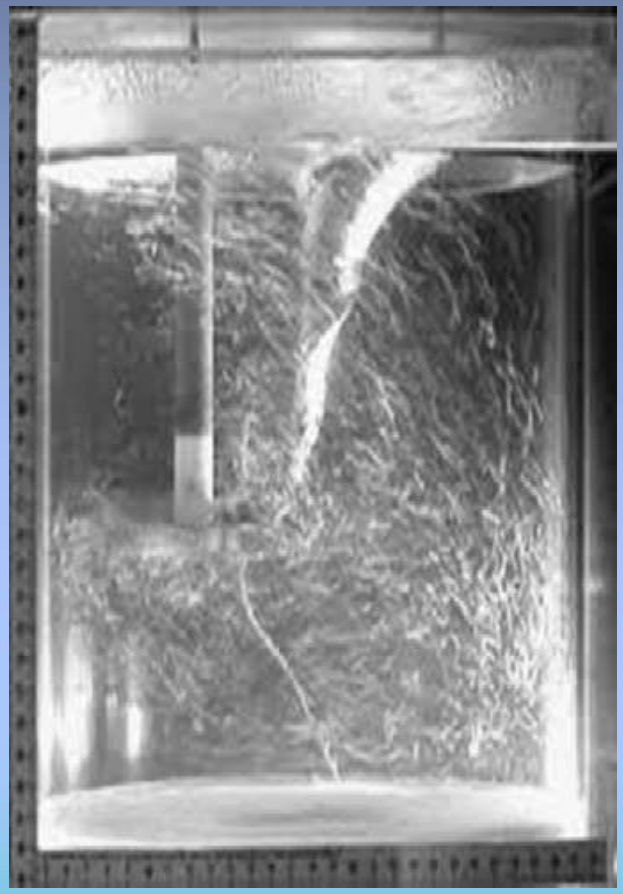
- Shaft is placed symmetrically in the tank.
- Blades in the turbines are arranged perpendicular to the central shaft.
- At high impeller speeds
- In unbaffled tanks



**The impeller draws liquid and air towards it, creating a vortex**

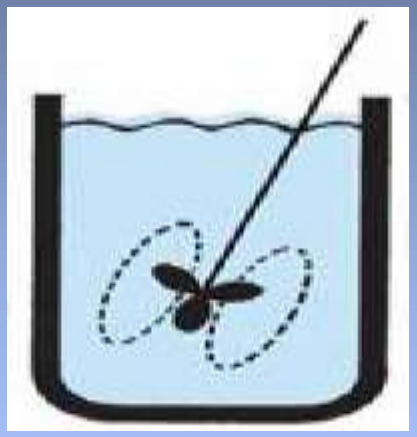
# Disadvantages of vortex formation

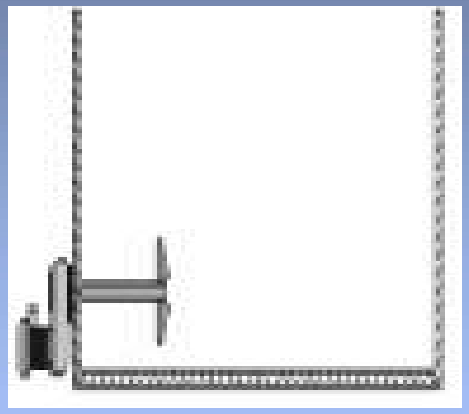
- Vortex formation **reduces mixing intensity** by reducing velocity of the impeller relative to the surrounding fluid.
- When vortex reaches the impeller, air from the surface of the liquid are drawn and **air bubbles are produced**.
- Air bubbles in the fluid can create **uneven loading** of the impeller blades.
- Entrapped air **causes oxidation** of the substances in certain cases.



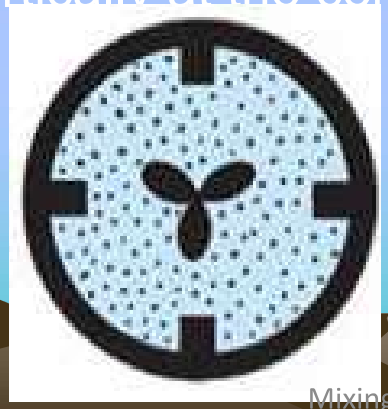
# Prevention of vortex formation

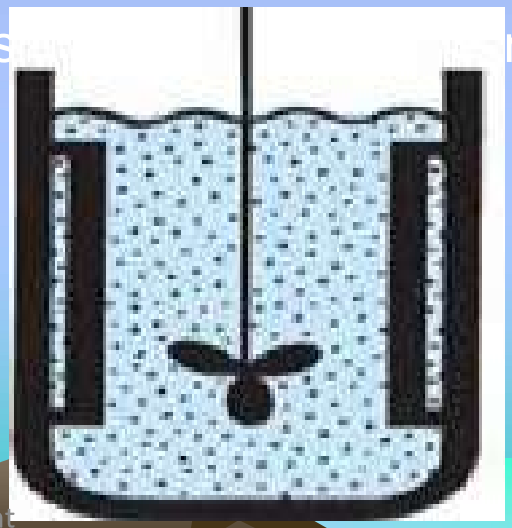
1. Impeller should in in any one of the position that can **avoid symmetry** such as off central, inclined, side entering, etc., and should be deep in the liquid.



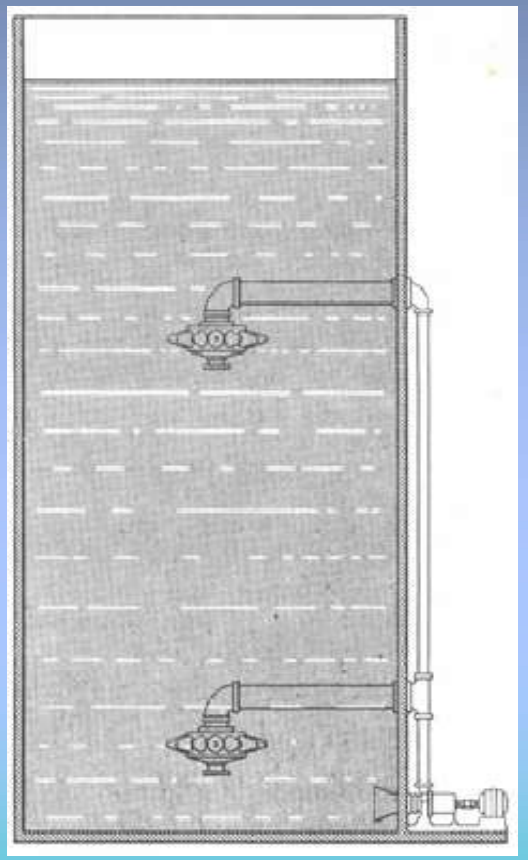


2. **Baffled containers should be used.** In s n be mounted vertically at the center.

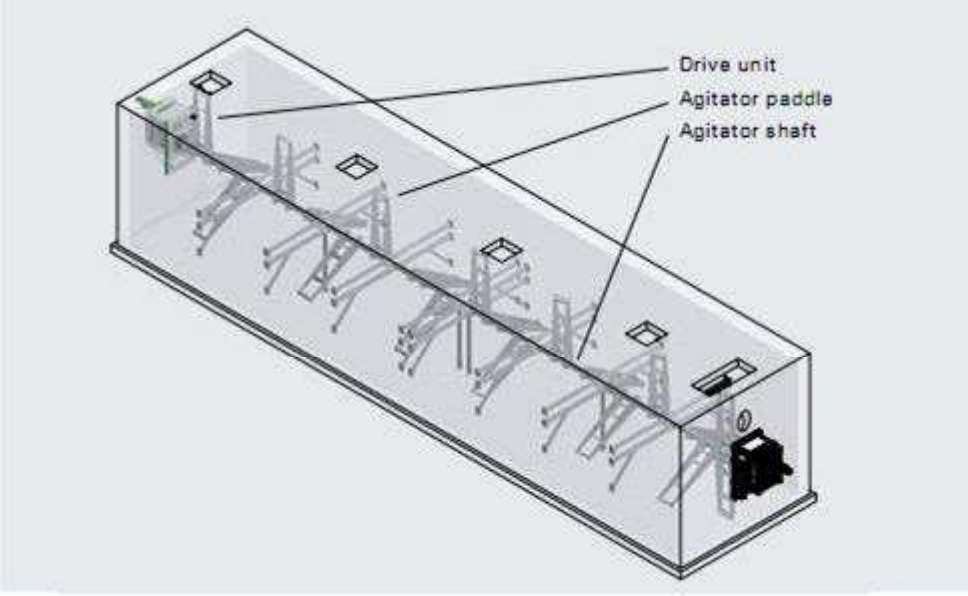




3. Two or more impellers are mounted on the same shaft where greater depth is required. This system is known as push and pull mechanism. The bottom impeller is placed about one impeller diameter above the bottom of the tank. It creates zone of high turbulence.

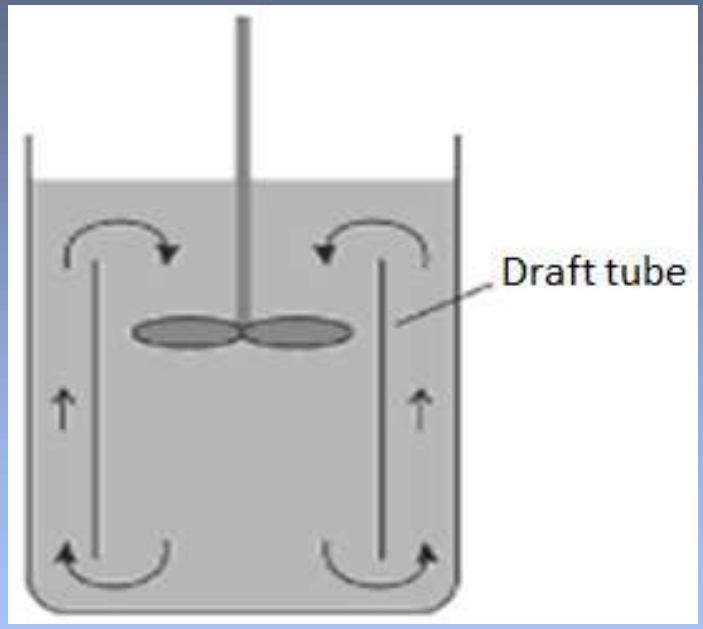


4. **Tank other than cylindrical in shape** are used to prevent vortex formation. However, such shapes may facilitate the formation of dead spots



# Return flow with Draft tubes

- Draft tubes are placed to control the direction and velocity of the flow to the impeller.
- These are mounted around the propeller. In case of turbines, draft tubes are mounted immediately above the impeller.




## Uses:

- Draft tubes are fitted to equipment used in the manufacture of certain emulsions.
- When solid particles tend to float on the surface of the liquid, they are dispersed using draft tubes.
- Air jet mixers of continuous mixing of liquids employ draft tubes.

## Disadvantage:

- Draft tubes add to the fluid friction in the system. These reduce rate of flow.

# Factors influencing mixing of liquids in tanks

- Material related factors-
  - Properties of liquids: physical properties of materials to be mixed.
    e.g.: Density, Viscosity and miscibility.

- Equipment related factors-
  - Shape of impeller: Propeller type, straight, vertical, curved, or pitched.
  - Position of impeller: Central, off-center, side entry, vertical or inclined etc.,
  - Shape and size of the container: cylindrical or other geometric forms. Presence or absence of baffles.
  - Cost of equipment and its maintenance.

- Process related factors-
  - Speed of rotation of the impeller.
  - Time required for mixing.
  - Amount of power that can be expended.
  - Ease of operation.
  - Batch size.

# Equipment for Liquid mixing

1. Air jet mixer
2. Jet mixer
3. Flow mixer or line mixer or pipe mixer

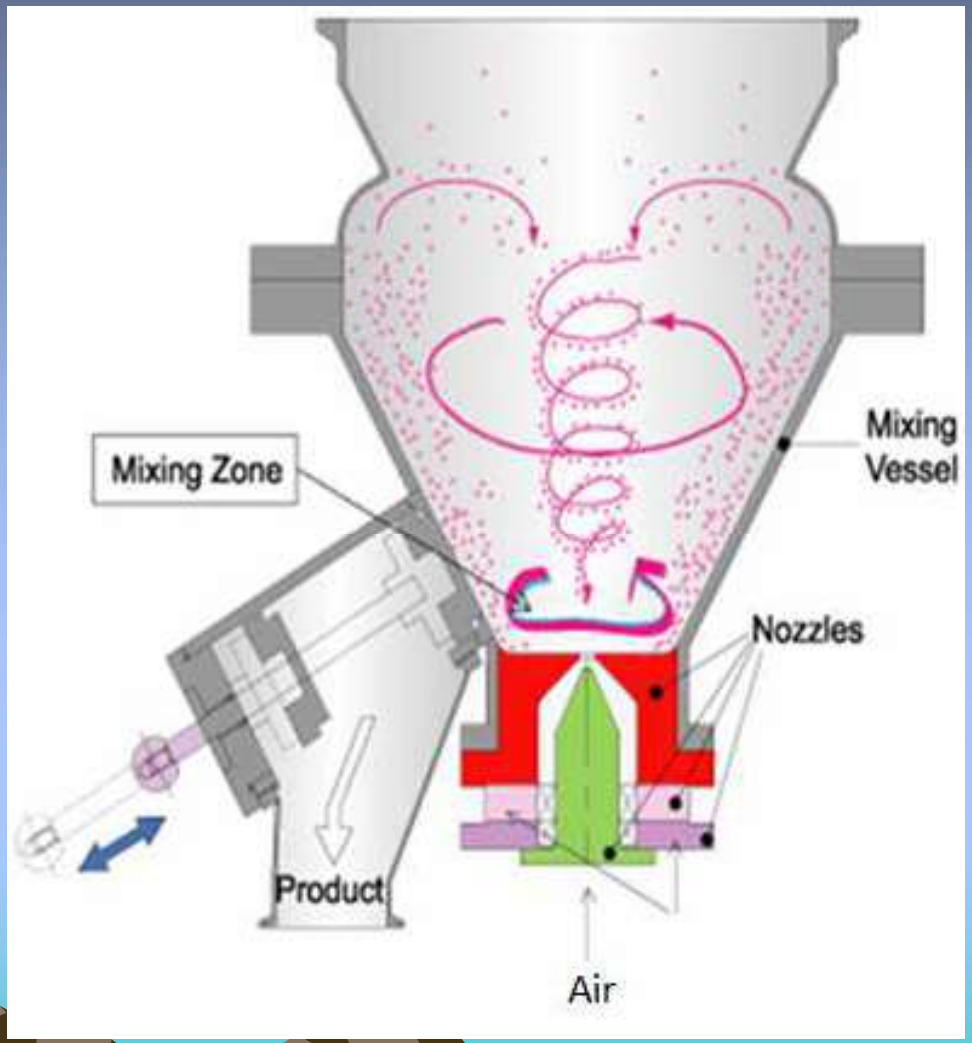
# 1. Air jet mixer

**Principle:**

When compressed air jets are passes rom the bottom of a vessel, air bubbles are formed in the liquid phase. The buoyancy of the bubbles lifts the liquids, which are confines to the central portion due to the presence of drat tubes. The liquids flow down from the periphery of the vessel and enter from the bottom due to suction effect.

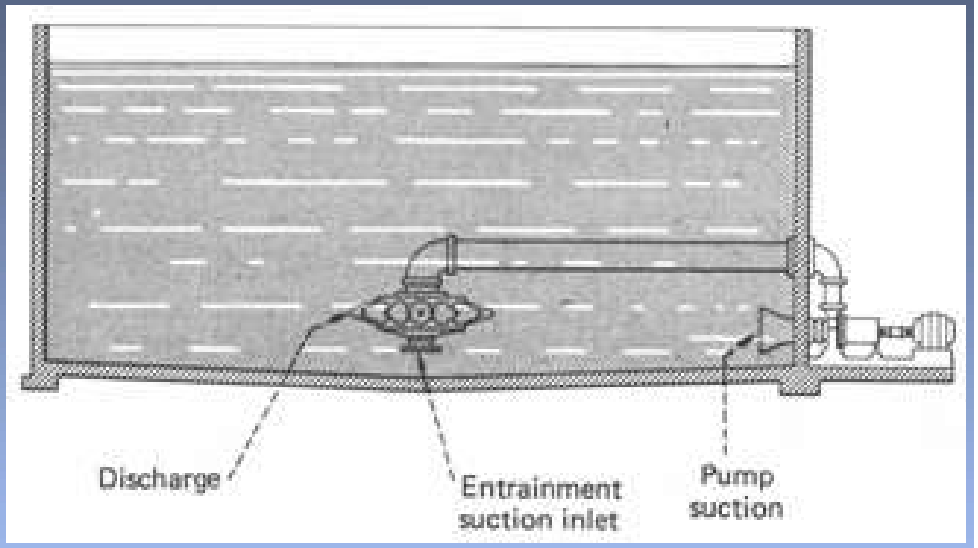
**Construction:**

Compresses air or suitable gas is allowed to pass at high pressure from the inlet provided at the bottom of the tank. This causes buoyancy of the bubbles which lifts the liquid rom bottom to the top of the vessel.

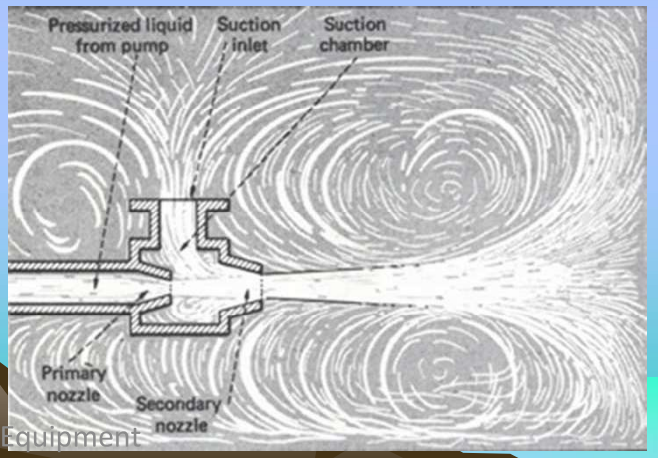


# 2. Jet mixer

- It consists of a vessel and a mixing device known as Jet.
- A typical jet-mixing system has 12 jets arranged radially in a cluster in the centre of the mixing tank. The cluster of jets is called an eddy jet mixer.
- An individual jet has two concentric nozzles with a suction chamber between them.

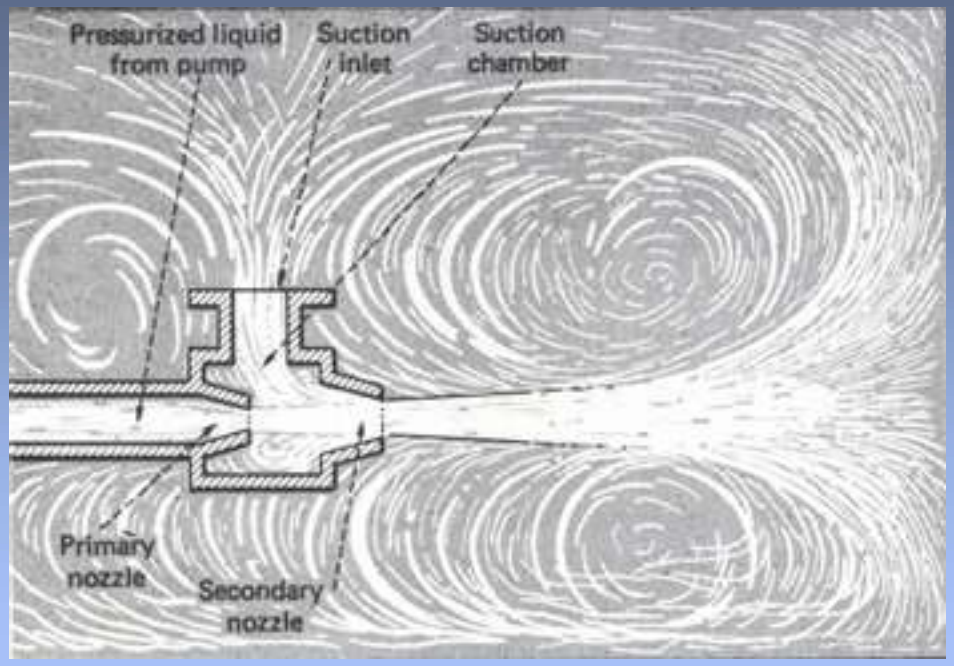



- A single eddy jet mixer may have 4 - 24 jets, but 8 - 12 is the usual configuration.
- Likewise, a single tank may have 1 or more eddy jet mixers, though 1 is most usual.



# 2. Jet mixer

- The tank contents are pumped through the top of the mixer to the primary nozzles. Then, after passing through the common suction chamber, the 12 streams of fluid are discharged into the tank through the secondary nozzles.
- As the pressurized fluid flows through the primary nozzle and into the chamber, it creates a suction because of its high velocity-typically 6-10 m/s for low-shear mixing and 10-20 m/s for high shear.




- This suction draws fluid from the tank into the chamber, where the large velocity difference causes intense mixing.
- The mixed fluid is then expelled from the jet through the secondary nozzle. This forms a cone that entrains the surrounding liquid, and a plume that spreads horizontally before rising to the surface. The plume imparts most of its energy to the fluid in its path, causing circulation and mixing throughout the tank. Mixing in the tank is less intense than in the suction chamber.

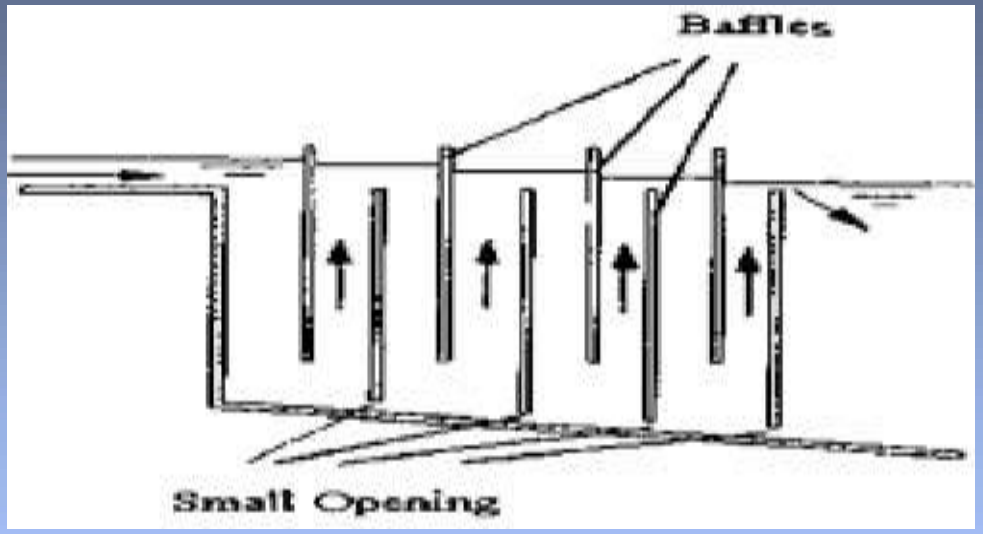
# Applications of Jet mixer

- Jet mixers tend to be used in situations that require turbulence, rapid approach to homogeneity, and high local shear rates.
- Jet mixing is normally used for liquids and slurries having viscosities below 1,000 cP; a mechanical agitator is generally more efficient for higher-viscosity fluids.
- Mainly useful for processes of liquid blending.

  e.g., neutralization or extraction.

# 3. Flow mixer or line mixer or pipe mixer

- It may consist a baffled pipe or an empty chamber.
- Liquids to be mixed are passed through the pipe/ chamber.
- Mixing takes place through bulk transport in the direction of flow.
- The power supplied to pump the liquid itself accomplishes mixing.
- For effective mixing controlling the feed rate is essential.




**Baffled pipe**

- If the input rate is difficult to control and fluctuations in the added proportions of the liquids are unavoidable, continuous mixing equipment of tank type is preferable, because hold-up of the liquids and back flow or recirculation is possible.

# Applications of pipe line mixer

- Used when large volume of liquids are to be mixed.
- Used for continuous mixing.

# Advantages of liquid mixing

- Liquid mixing promotes heat transfer between liquid and a heating source. This step is essential in the crystallization of drug substances. Uniform heat transfer in the solution yields crystals of same size.
- Liquid mixing is essential in the manufacture of number of dosageforms.

E.g.:

  - Suspensions
  - Emulsions
  - Solutions
  - Aerosols