Bioreactor Design Criteria

1. Microbiological and biochemical characteristics of the cell systems (Microbial, mammalian, plant cell)
2. Hydrodynamic characteristics of the bioreactor
3. Mass and heat characteristics of the bioreactor
4. Kinetics of cell growth and product formation
5. Genetic stability characteristics of the cell system
6. Aseptic equipment design
7. Control of bioreactor environment
8. Implication of bioreactor design on downstream product separation
9. Capital and operating costs of the bioreactor
10. Potential for bioreactor scale-up

Bioreactor Configuration

- It affects the liquid flow pattern

- The performance of a fermentation in terms of yield and production rate.

Principle Types of Bioreactor (Fermenter)

- Batch fermenter(BF) or BR
- Continuous stirred-tank fermenter(CSFR) or CSTR
- Tubular fermenter(TF) or TR
- Fluidized bed fermenter(FBF) or FBR

Aeration and Agitation

- **Impeller(Agitator)**
  - **To diminish the size of air bubbles to give a bigger interfacial area for oxygen transfer and to decrease the diffusion path.**
  - **To maintain a uniform environment throughout the vessel contents.**
- **Disk turbine, Vaned disc, Open turbine of variable pitch, Marine propeller**
- **Baffles**
  - **To prevent liquid swirl(vortex) and thereby enables the impeller to impose power on the liquid in the form of turbulence and flow.**
  - **To improve aeration efficiency (metal strips : roughly 1/10 of the vessel diameter)**

Aeration System (Sparger)

- **Porous sparger**
  - **Sintered glass, ceramics or metal**
  - **Usually for non-agitated vessels**
  - **Blocking problem by growth of the microbial culture**
- **Orifice sparger(perforated sparger)**
  - **Small stirred fermenters**
- **Nozzle sparger(Open or partially close pipe)**

Bioreactors

1. **Batch reactor : Free enzyme**
   - High viscosity or insoluble substrate can be used
   - New enzyme required for each batch
   - Substrate inhibition can be a problem

2. **Continuous stirred tank reactor(CSTR) : Free or Immobilized enzyme**
   - pH control simple
   - Enzyme addition/replacement simple
   - Colloidal or insoluble substrates can be used
   - Less problem with substrate inhibition

3. **Continuous-flow stirred tank with ultrafiltration : Free or Immobilized enzyme**
   - Colloidal or insoluble substrates can be used
   - Poor enzyme stability over long term operation
   - Enzyme denatured or adsorbed at membrane surface
4. **Plug-flow : Immobilized enzyme**
   - High conversion efficiency
   - Less problem with product inhibition
   - Cannot be used with insoluble or high viscosity substrates
5. **Fluidized-bed : Immobilized enzyme**
   - Better heat and mass transfer
   - Insoluble and high viscosity substrates can be used
   - Low pressure drop
   - Energy input to maintain a fluidized-bed is large

Advantage of Immobilized Biocatalysts

1. Biocatalyst may be reused or used continuously

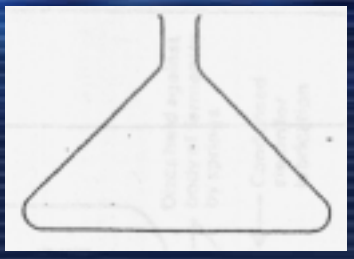
   (conversion per unit of enzyme increased)

2. Environmental stability may be enhanced over a broader range (pH, temp.)

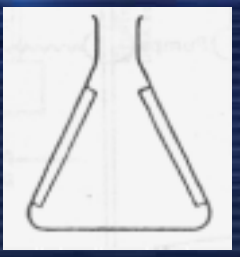
3. Yield and conversion may be improved

Shake Flasks for Fermentation

Standard shake flask
Or the Erlenmeyer flask



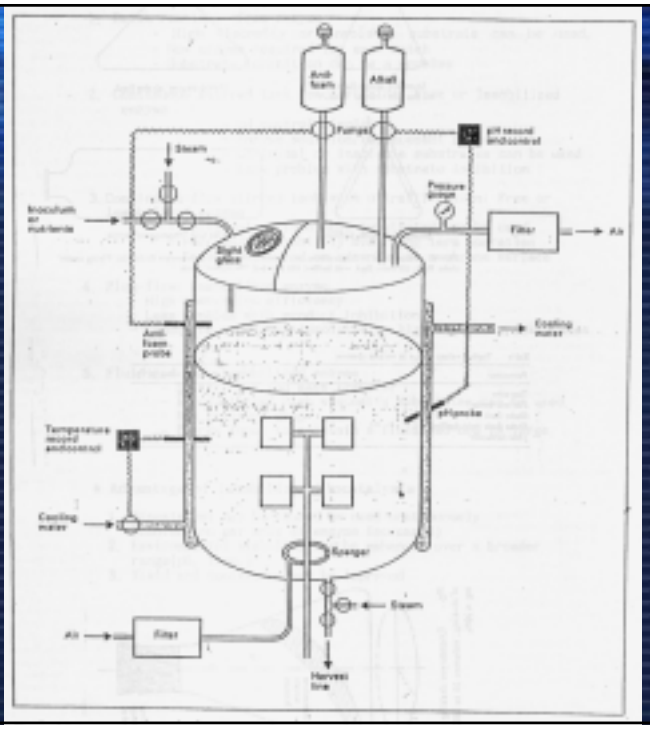
'Flying saucer' shake flask

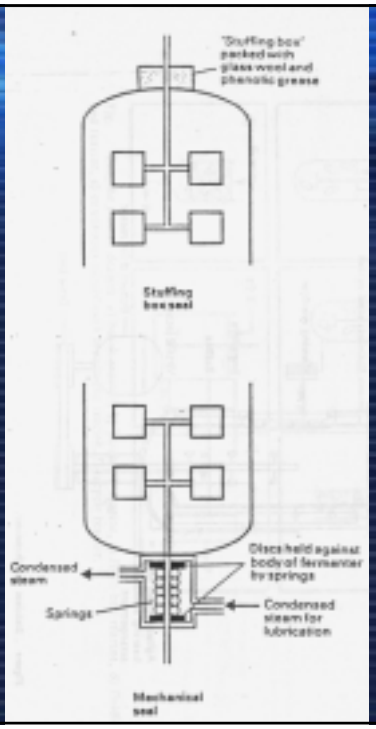


Shake flask with baffle

Flat bed 'Thompson' bottle

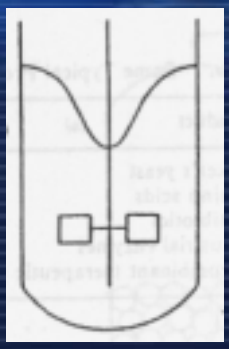
Stirred Tank Reactor



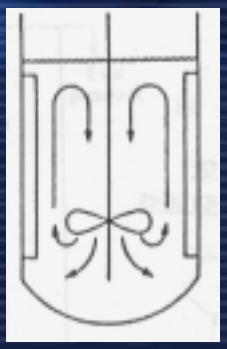


- The original ‘stuffing box’ seal and a modern mechanical seal used to prevent ingress of microorganisms where the agitator shaft passes through the body of the fermenter.
- Mechanical seals can be used with either top- or bottom-driven agitators. Stuffing boxes cannot be used with a bottom-drive system for the vessel contents would leak out.

Impeller Type



Turbine impeller
- Large vortex
- no baffles



Marine impeller
- Axial flow with baffle

Turbine impeller
- Radial flow with baffle

Impeller Type

Straight Blade Turbine

Pitched Blade Turbine

Curved Blade Turbine

DispersiMax Blade Turbine

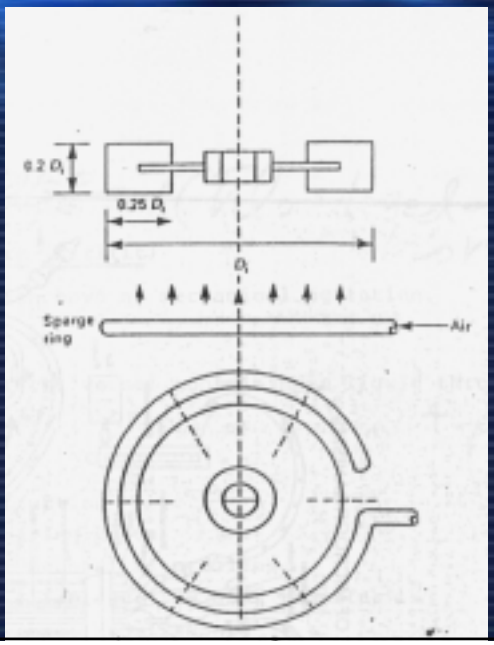
Bar Turbine

Anchor Impeller

Helical Impeller

Marine Propeller

Flat-Blade Turbine and Sparge Ring



Tower Fermenters (Airlift)

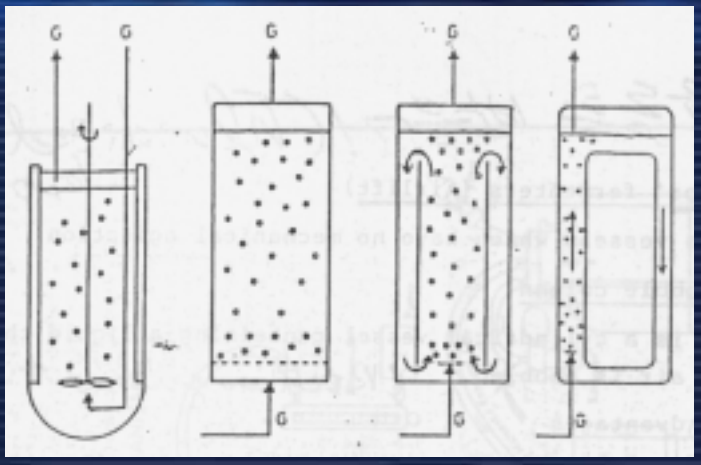
- are vessels which have no mechanical agitation.

1. Bubble column
   - Is a cylindrical vessel containing a liquid through which air is bubbled.
   - Advantages
     - Simple construction
     - Absence of moving parts
     - Avoidance of mechanical problems
     - High energy efficiency for mass transfer
     - Lower power input requirements

2. Airlift loop fermenters

- are fermenters in which the liquid is recirculated by the density difference between the gased and the ungassed section of the equipment.
- Internal loops (or draft tubes)
  - are essentially modifications of the bubble column, in which the rising gassed liquid is separated from the downflow liquidby a concentric cylinder or draft tube.
- External loops
  - are fermenters where the upflow and downflow streams flow in two separate cylinders or tubes, the riser and the downcomer section, connected at the top and bottom by side arms.
- Various modifications
  - Split-cylinder loop airlift
  - Airlift with motionless mixers
  - Multistage airlift

Types of Reactors Employed for Aerobic Fermentations.



Stirred vessel, Bubble column, Loop reactors (Internal loop and External loop)

Bubble Column

External Loop Reactor