UNIT III – TOPIC 1

Heat Exchange

Heat exchange is a fundamental process where thermal energy transfers between two or more fluids at different temperatures without mixing them physically. This process is crucial across industries from power generation to food processing.

When we think about heat exchange, imagine two streams of water—one hot and one cold—flowing through a device with a thin metal wall separating them. The heat naturally moves from the hot water to the cold water through the metal, following the second law of thermodynamics.

Heat exchangers are designed in several configurations:

The shell-and-tube design features tubes running through a larger cylindrical shell. One fluid flows through the tubes while another flows around them within the shell. This creates a large surface area for heat transfer without the fluids mixing.

Plate heat exchangers use thin metal plates stacked together. The fluids flow through alternating spaces between the plates, allowing for efficient heat transfer across the plate surfaces while keeping the fluids separate.

The effectiveness of heat exchange depends on several factors:

- Temperature difference between the fluids
- Surface area available for heat transfer
- Heat transfer coefficient of the materials involved
- Flow rates of the fluids
- Physical properties like viscosity and thermal conductivity

Engineers often use the concept of "overall heat transfer coefficient" to calculate the rate of heat exchange, taking into account the resistances to heat transfer through different materials and fluid boundary layers.

Evaporation

Evaporation is the process where a liquid changes into a vapor or gas state. Unlike boiling, which occurs throughout the liquid at its boiling point, evaporation happens only at the surface and can occur at any temperature (though it speeds up at higher temperatures).

In industrial settings, evaporation is commonly used to:

- Concentrate solutions by removing solvent (typically water)
- Separate mixtures based on differences in volatility
- Recover valuable materials from solutions
- Create dry products from liquid feedstocks

Consider how salt is produced from seawater—large ponds allow water to evaporate, leaving behind concentrated salt that can be harvested. Similarly, in the food industry, evaporation concentrates fruit juices, milk, and other liquid foods.

Evaporators in industry come in several types:

- Multiple-effect evaporators use the vapor from one effect (stage) to heat the next, improving energy efficiency
- Falling film evaporators pass liquid down the inside of heated tubes, creating a thin film that efficiently evaporates
- Flash evaporators rapidly decrease pressure, causing instantaneous evaporation

The energy required for evaporation (latent heat of vaporization) is significant, making energy efficiency a major consideration in evaporation system design. Modern systems often include vapor recompression or multiple effects to minimize energy consumption.

Size Reduction

Size reduction involves breaking larger particles into smaller ones through the application of forces. This process is essential in industries ranging from mining to pharmaceuticals and food processing.

Size reduction serves several purposes:

- Increasing surface area for faster dissolution or chemical reactions
- Creating specific particle sizes needed for product performance
- Liberating valuable materials from unwanted components
- Improving mixing and blending properties
- Facilitating easier handling and processing

The physics behind size reduction involves applying enough stress to overcome the cohesive forces holding materials together. This can happen through several mechanisms:

- Compression: Squeezing material between two surfaces
- Impact: High-velocity collisions between particles and hard surfaces
- Attrition: Particles rubbing against each other or surfaces, creating frictional forces
- Cutting: Using sharp edges to slice through material
- Shearing: Applying forces in opposite directions

Equipment for size reduction varies widely depending on the initial material properties and desired result:

- Crushers for initial reduction of large, hard materials
- Mills (ball mills, hammer mills, etc.) for finer grinding
- Colloid mills for very fine particles approaching colloidal size
- Cutting machines for fibrous or tough materials

Energy efficiency is a major concern in size reduction operations, as typically less than 5% of the input energy actually goes into creating new surfaces—most is lost as heat, noise, and equipment wear.

Understanding the relationship between energy input and the resulting particle size distribution is key to optimizing these processes, often analyzed using relationships like Kick's Law, Rittinger's Law, or Bond's Law depending on the material and size range.