Unit – I Unit Operations
Introduction to process & Instrumentation for Chemical

• Chemical Process Control and Instrumentation

• Automatic and Instrument control chemical processes are common and essential. Instruments should not be chosen simply to record a variables, of the process. But their function is to assure consistent quality by sensing controls, recording and maintaining desired operating conditions. Instruments are the essential tool for modern processes. They are classified as
  • Indicating Instruments
  • Recording Instruments
  • Controlling Instruments
Continuous-flow stirred-tank reactor (CSTR)

• In a continuous-flow stirred-tank reactor (CSTR), reactants and products are continuously added and withdrawn.

• In practice, mechanical or hydraulic agitation is required to achieve uniform composition and temperature, a choice strongly influenced by process considerations.

• The CSTR is the idealized opposite of the well-stirred batch and tubular plug-flow reactors.

• Analysis of selected combinations of these reactor types can be useful in quantitatively evaluating more complex gas-, liquid-, and solid-flow behaviors.
Continuous-flow stirred-tank reactor (CSTR)
Continuous-flow stirred-tank reactor (CSTR)

• Roll of Instrumentation Engineering
  • Measurement and control of tank and jacket Temperature
  • Measurement and control of tank level
  • Measurement and control of inlet and outlet flow
  • Measurement and control of speed of motor
Definitions, application & comparison: Batch Process, Continuous Process
Continuous processes

- A chemical that is needed in a large amount is usually made by a continuous process.
- Production goes on all the time.
- Ammonia is made by a continuous process called the Haber process.
Batch processes

• A chemical that is needed in a small amount or only as needed (a specialty chemical) is usually made by a batch process.
• Production does not go on all the time.

• Pharmaceutical drugs (medicines) are made by batch processes.
## Comparison: Batch Process, Continuous Process

<table>
<thead>
<tr>
<th>Factor</th>
<th>Continuous</th>
<th>Batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of factory equipment</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Rate of production</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Shutdown times</td>
<td>Rare</td>
<td>Often</td>
</tr>
<tr>
<td>Workforce</td>
<td>Few people needed</td>
<td>many people needed</td>
</tr>
<tr>
<td>Ease of automation</td>
<td>relatively easy</td>
<td>relatively difficult</td>
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</table>
Importance & applications of Unit Operations
Unit Operation

• The basic physical operations of chemical engineering in a chemical process plant, that is distillation, fluid transportation, heat and mass transfer, evaporation, extraction, drying, crystallization, filtration, mixing, size separation, crushing and grinding, and conveying.

• In simple terms, the operation which involves physical changes are known as Unit Operation.

• Those operations, which involves chemical changes are known as Unit Process.
Unit Operation Examples

• Distillation is a unit operation is used to purify or separate alcohol in the brewery industry.
• The same distillation separates the hydrocarbon in a petroleum industries.
• Dry grapes and other food products or similar drying of filter precipitate like rayon industry where yarn is produced.
• Absorption of oxygen from air in a fermentation process of a sewage treatment plant and half hydrogen gas in a process for liquid hydrogenation of oil.
• Evaporation of salts solutions similar to evaporation of sugar solution in the industry.
• Settling and sedimentation of suspend solids similar to minimizing and sewage treatment plant.
• Flow of liquid hydrocarbon in a petroleum refinery and flow of milk in a daily plant for the solidification in spray dryer.
Brief Description & Uses
Agitation

• Processes Agitation is a means whereby mixing of phases can be accomplished and by which mass and heat transfer can be enhanced between phases or with external surfaces.

• Applications:
  • FOOD
  • DAIRY
  • WATER AND WASTE WATER
  • CHEMICAL
  • WINE
  • MINERAL PROCESSING
  • Numerous other industries which require gas dispersion, re-pulping, solids suspension and a host of other specialties.
Drying

• Drying is a mass transfer process consisting of the removal of water or another solvent by evaporation from a solid, semi-solid or liquid.

• This process is often used as a final production step before selling or packaging products.

• To be considered "dried", the final product must be solid, in the form of a continuous sheet (e.g., paper), long pieces (e.g., wood), particles (e.g., cereal grains or corn flakes) or powder (e.g., sand, salt, washing powder, milk powder).

• A source of heat and an agent to remove the vapor produced by the process are often involved. In bio products like food, grains, and pharmaceuticals like vaccines, the solvent to be removed is almost invariably water.

• Desiccation may be synonymous with drying or considered an extreme form of drying.
Drying

• Application:
  • Drying of food
    • Drying of fish in Lofoten in the production of stockfish
    • Baking of bread
  • Non-food products
    • Timber processing
    • Paper
    • Flax
    • Washing powder
    • Drying of sewage sludge from sewage treatment plants
Evaporation

- **Evaporation** is the process by which water changes from a liquid to a gas or vapor.

- Water boils at 100 degrees C, but it actually begins to evaporate at 0 degrees C; it just occurs extremely slowly. As the temperature increases, the rate of evaporation also increases.

- The amount of evaporation depends on the temperature, and it also depends on the amount of water there is to evaporate.

- For example, there is not much evaporation occurring in the Sahara Desert, but why? Although it can get extremely hot in the Sahara, it's just sand - there's just not much water to be evaporated.
Evaporation

• **Applications**
  • Industrial applications
    • printing and coating processes
    • Recovering salts from solutions
    • Drying a variety of materials such as lumber, paper, cloth and chemicals
  • Laboratory
    • The use of evaporation to dry or concentrate samples is a common preparatory step for many laboratory analyses such as spectroscopy and chromatography.
  • Domestic
    • When clothes are hung on a laundry line, even though the ambient temperature is below the boiling point of water, water evaporates.
    • In a clothes dryer, hot air is blown through the clothes, allowing water to evaporate very rapidly.
Blending

- Blending is a process of combining materials.
- Blending is the process of solid-solid mixing or mixing of bulk solids with small quantity of liquid.
Blending Vs Mixing

• The terms "mixing" and "blending" are often used interchangeably, but technically they are slightly different.
• Blending is a process of combining materials, but blending is a relatively gentle process compared to mixing.
• Blending is the process of solid-solid mixing or mixing of bulk solids with small quantity of liquid.
• Mixing is the process of thoroughly combining different materials to produce a homogenous product.
• The terminology mixing is more closely associated with liquid-liquid, gas-liquid, and viscous materials.
Blending

• Applications:

• Chemical Process Industry:
  • Mixing and blending of specialty chemicals, explosives, fertilizers, dry powdered detergents, glass or ceramics, and rubber compounds.

• Pharmaceutical Industry:
  • Blending of active ingredients of a drug with excipients like starch, cellulose, or lactose.

• Food industry:
  • Preparation of cake mix, spices, and flavors
Crushing and Grinding are a must in the Mining Industry, and indeed they are essential stages.

The main target/purpose for both is to reduce the size of the ore (rock) particle before subjecting it to reagents (chemical reactions).

Crushing involves reducing the ore size from various sizes ranging from particles as big as a human body, or just the size of your head or toe to an average 90 to 140mm for primary crushing or 40 to 55mm for secondary.

Note the size depends on the plant design but generally it’s a reduction in ore size from about 1000mm to 150mm for clarity’s sake.

Mostly followed by secondary crushing that will reduce the size further to about 40mm or 70mm.
Crushing and Grinding

• Grinding on the other hand involves reducing the size such that 80% of the material will pass through a 150micron mess (150µm).

• Grinding is usually done by mills such as Ball Mills or rod mills again the exact specifications depends on the design of the processing plant.

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Crushing and Grinding

Applications
- Dryer Feed & Discharge Material
- Filter Cake
- Frozen Vegetables
- Rendered Products
- Candy
- Salt
- Bakery Waste
Conveying

• Conveying is a operation to convey material from one place to other.
• Conveyors are used for movement of materials, products and loads throughout a manufacturing or distribution facility, conveyors are horizontal, inclined or vertical devices.
• Conveyors are used to move materials over a fixed path.
• Conveyors are used:
  • When material is to be moved frequently between specific points
  • To move materials over a fixed path
  • When there is a sufficient flow volume to justify the fixed conveyor investment
Conveying

• There are two primary types of Conveyors. These include:

• Gravity conveyor: - The simplest kind, gravity conveyors feature an incline and use the force of gravity, or of a person, to push the load along the conveyor surface.

• Powered conveyor: Driven by either an electric or pneumatic power system, a powered conveyors’ movement is driven by motors and drives.

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Conveying

Application

• Dough Processing
• Confectionery Meat
• Poultry and Seafood Processing Dairy
• Industry Agriculture Packaging
Filtration

• It may be define as a process of separation of solids from a fluid by passing the same through a porous medium that retains the solids but allows the fluid to pass through

• Applications:
  • In water treatment plants
  • In wastewater treatment plants
  • Production of sterile products
  • Membrane filters
  • Production of bulk drugs
  • Production of liquid dosage

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Filtration

- Slurry: Suspension to be filtered
- Filter medium: Porous medium used to retain solid
- Filter cake: Accumulated solids on the filter
- Filtrate: Filtered liquid
Crystallization

• Crystallization is the process by which a chemical is separated from solution as a high-purity, definitively shaped solid.
• Crystallization from solution is a common unit operation for separating chemical species and producing solids with specific properties.
• Crystallization is an example of a separation process in which mass is transferred from a liquid solution, whose composition is generally mixed, to a pure solid crystal.
Crystallization

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Application

• production of Glauber's salt
• Crystalline form of sodium sulfate
Centrifugation

• In centrifugation, a centrifugal force, generated by high speed rotations, is used to separate solids from liquids.
• Centrifugation can be used to recover solids from slurries, to clarify liquids, or to clarify solids.

Applications
• Blood sample separation
• Milk cream separation
• Milk FAT separation
Centrifugation

Alfa Laval, Richmond, VA
Thanks