UNIT OPERATION (I)

Department of Chemical and Petroleum Industries Engineering
Fourth Year
AL-Mustaqbal University Collage

Lecture **(1)**
Drying (1)

UNIT OPERATION DEFINITION

Definition of *chemical engineering*

It is a group of industrial processes in which row materials are changed or separated into useful products.

Definition of *unit operation:*

A physical change (physical treatment) to which material is subjected especially in coordination with a unit process (as filtration, distillation, or extraction)

Classification of Unit Operation

1.Material handling, transportation / Fluid flow process

Pumping
Compression
fluidization

2. Mechanical unit operations

Size reduction
Size enlargement
Mixing, agitation, blending, etc.

3. Mass transfer Operations

Evaporation
Distillation
Absorption
Extraction
leaching.

4. Heat transfer operations

conduction
convection
radiation

Definition of *unit Process :*

A chemical change(chemical treatment) to which material is subjected (as nitration , oxidation , sulpfonation, esterification)

First Course

1- Drying
2- Humidification , Dehumidification and Cooling towers
3- Evaporation
4- Crystallization

References

Smith and McCabe, Unit Operations of Chemical Engineering, 7th ed., 2004,

Coulson and Richardson, 2002 - Chemical Engineering Vol. 2.

DRYING

1- Drying

Introduction
Terminology and definitions
Use of psychrometric charts
Rate of drying and drying time
Mechanism of moisture movement during drying
Material and heat balance calculations
Drying equipment .

INTRODUCTION

- **Drying** is one of the oldest methods of preserving food. Dried foods can be stored for long periods without deterioration occurring. The reasons for this are (**1**) that the microorganisms which cause food spoilage are unable to grow and multiply in the absence of sufficient water and (**2**) many of the enzymes which promote undesired changes in the chemical composition of the food cannot function without water.

In most cases, drying is accomplished by vaporizing the water that is contained in the food, and to do this the latent heat of vaporization must be supplied. There are, two important process-controlling factors that enter into the unit operation of drying:

(a) transfer of heat to provide the necessary latent heat of vaporization,

(b) movement of water or water vapour through the food material and then away from it to effect separation of water from food.

DEFINITION

Drying is a complex operation involves two operations:

1. Heat transfer **2. Mass transfer**

It is a process of removal of small amount of water , or another solute by application of heat to obtain dry solid. latent heat must be transferred to cause the water to evaporate.

Physical changes may occur include shrinkage, puffing, and crystallization. In some cases, desirable or undesirable chemical or biochemical reactions may occur, leading to changes in color, texture, odor, or other properties of the solid product.

Drying operation often follows evaporation, filtration, or crystallization. It is often the final operation in a manufacturing process, carried out immediately prior to packaging or dispatch.

OBJECTIVES OF DRYING

- Drying is one of the oldest methods of preserving food.
- To preserve perishable raw food against deterioration or spoilage by reducing moisture content and reducing water activity.
- To reduce the cost and difficulty of packaging, handling, transportation and storage by converting the material into a dry solid, thus reducing its weight and in most cases volume.

THE DIFFERENCES BETWEEN DRYING AND EVAPORATION

	Drying	Evaporation
1	The main operation usually carried out on solid materials, e.g. powders, or products.	The main operation usually carried out on liquid materials, e.g. solution, or products.
2	Drying in most of the cases means the removal of small amounts of water from solids.	Evaporation include the removal of large amounts of water from solutions.
3	Drying involves the removal of water at temperatures below its boiling point.	Evaporation involves the removal of water by boiling a solution.
4	In drying, water is usually removed by circulating air over the material in order to carry away the water vapour.	In evaporation, water is removed from material as pure water vapour mixed with other gases.

PSYCHROMETRY

The capacity of air for moisture removal depends on its humidity and its temperature. The study of relationships between air and its associated water is called psychrometry.

Humidity (**Y**) is the measure of the water content of the air. The absolute humidity is the mass of water vapour per unit mass of dry air and the units are therefore kg kg^{-1} . Absolute humidity is often called just '**humidity**'. It is named absolute humidity or humidity ratio in charts.

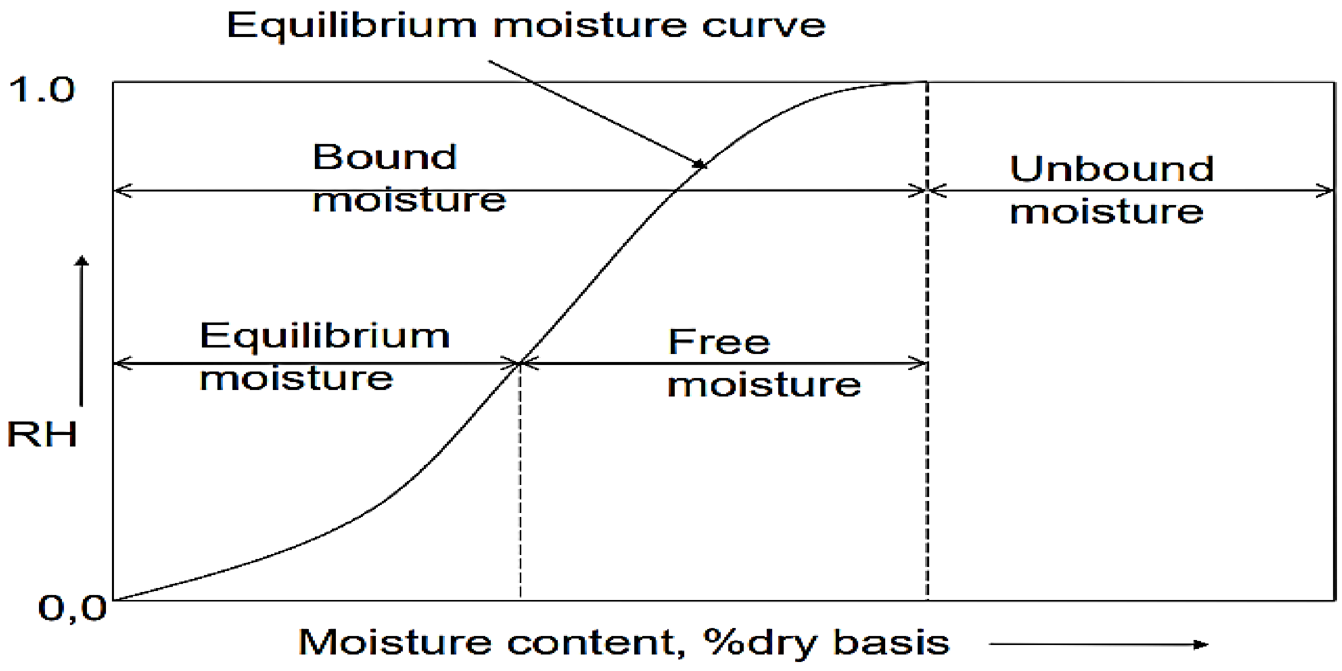
Air is said to be saturated with water vapour at a given temperature and pressure if its humidity is a maximum under these conditions. If further water is added to saturated air, it must appear as liquid water in the form of a mist or droplets. Under conditions of saturation, the partial pressure of the water vapour in the air is equal to the saturation vapour pressure of water at that temperature.

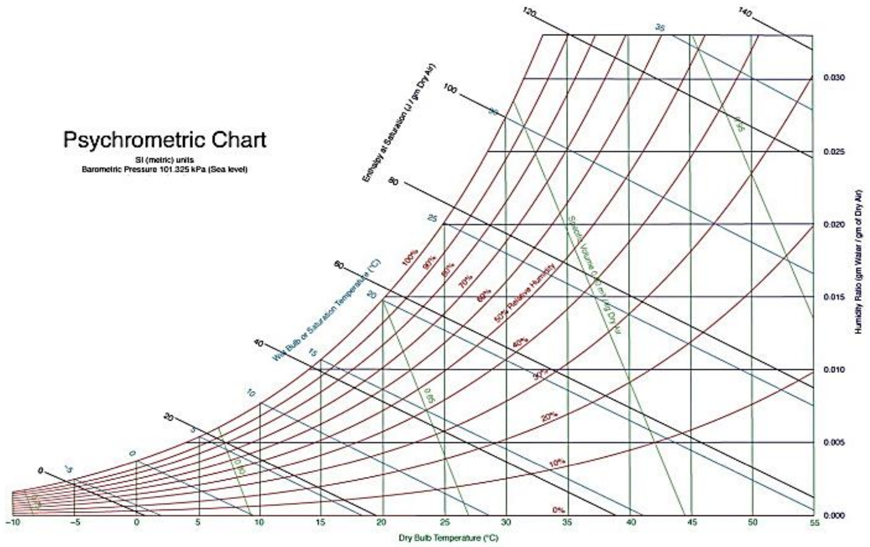
The total pressure of a gaseous mixture, such as air and water vapour, is made up from the sum of the pressures of its constituents, which are called the partial pressures. The partial pressures are added to obtain the total pressure.

Wet-bulb Temperatures

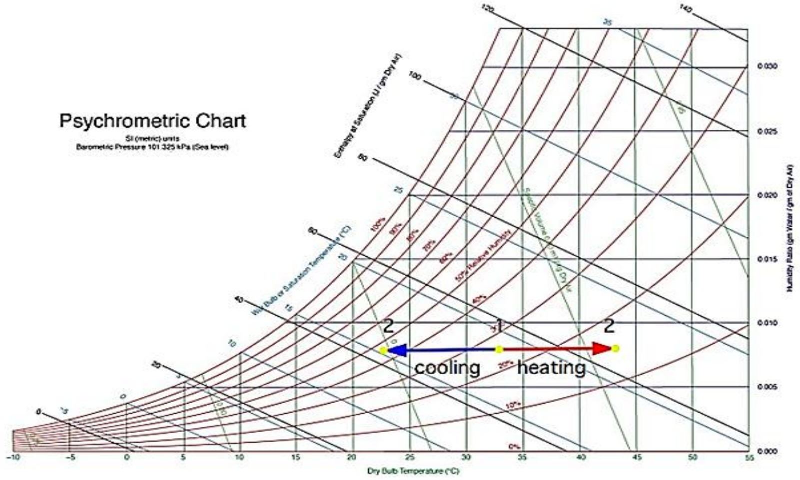
A **wet-bulb temperature**, as compared with the ordinary temperature, which is called the **dry-bulb temperature**, is the temperature reached by a water surface, such as that registered by a thermometer bulb surrounded by a wet wick, when exposed to air passing over it. The wick and therefore the thermometer bulb decreases in temperature below the dry-bulb temperature, until the rate of heat transfer from the warmer air to the wick is just equal to the rate of heat transfer needed to provide for the evaporation of water from the wick into the air stream.

Equilibrium moisture / Free moisture
Bound moisture/ Unbound moisture

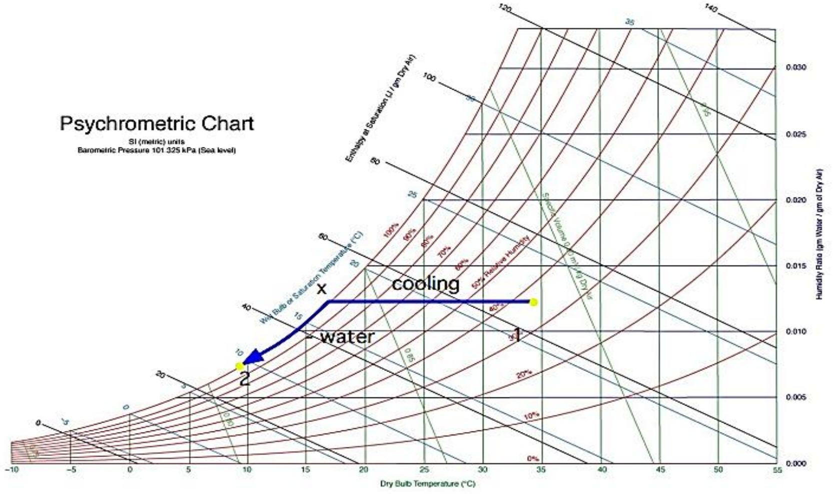




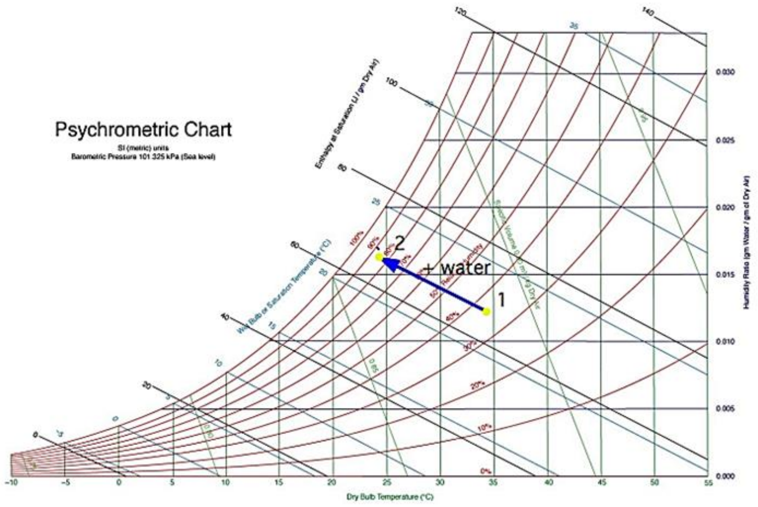
Sensible heating / cooling



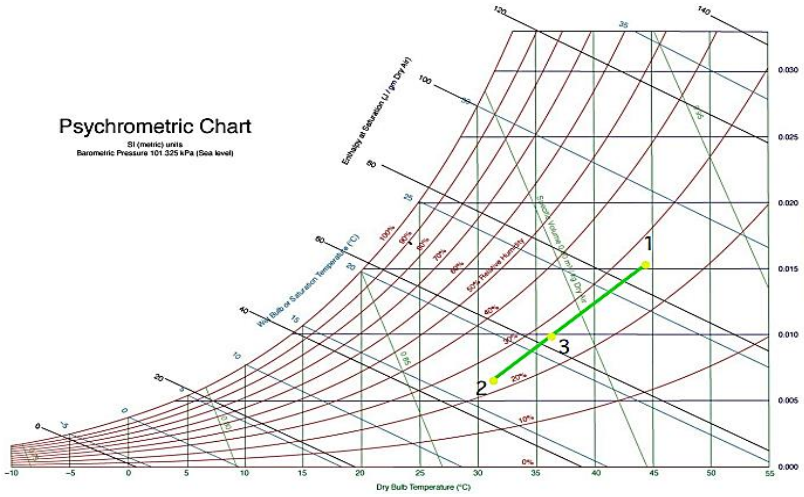
cooling with dehumidification



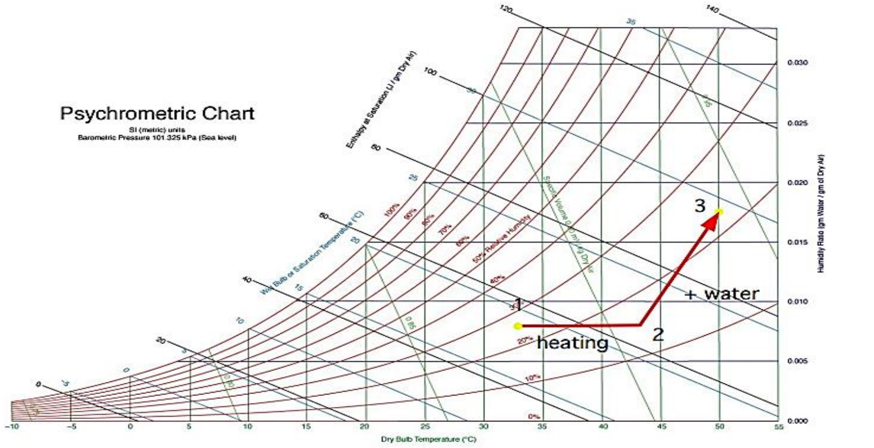
Adiabatic (evaporative) cooling



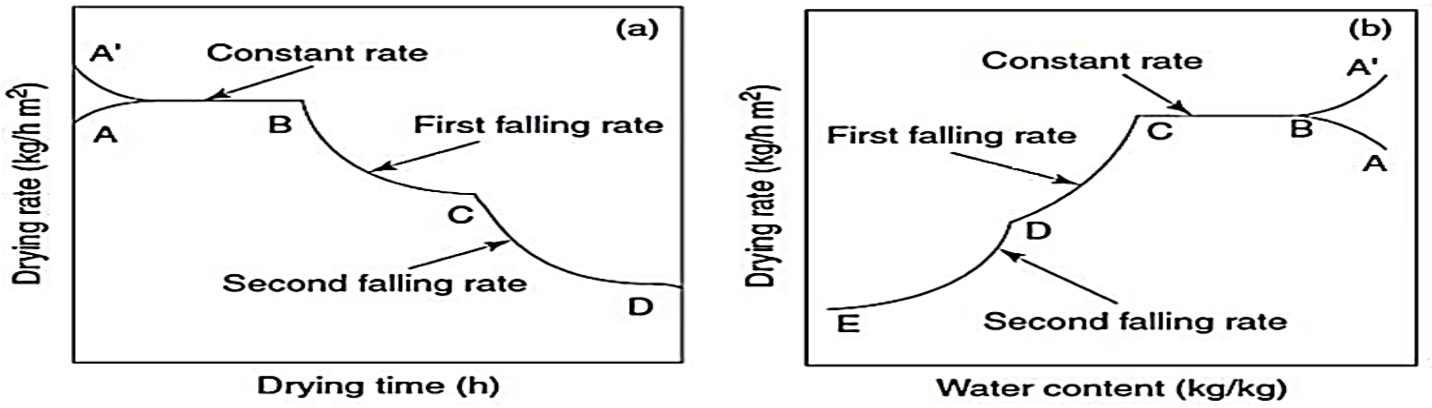
Adiabatic mixing



Heating with humidification



Typical drying rate curves



(a) drying rate versus drying time **(b)drying rate versus water content**

Constant rate:

Section B to C of the curve, known as the constant rate periods, represents removal of unbound water from the product. The surface of the product is very wet. In the constant-rate period, the water is being evaporated as a free water surface.

Falling rate:

The falling rate period (from point C) is reached when the drying rate starts to decrease. The rate of drying is governed by the internal flow of liquid or vapor. The falling rate period can be divided into two steps.

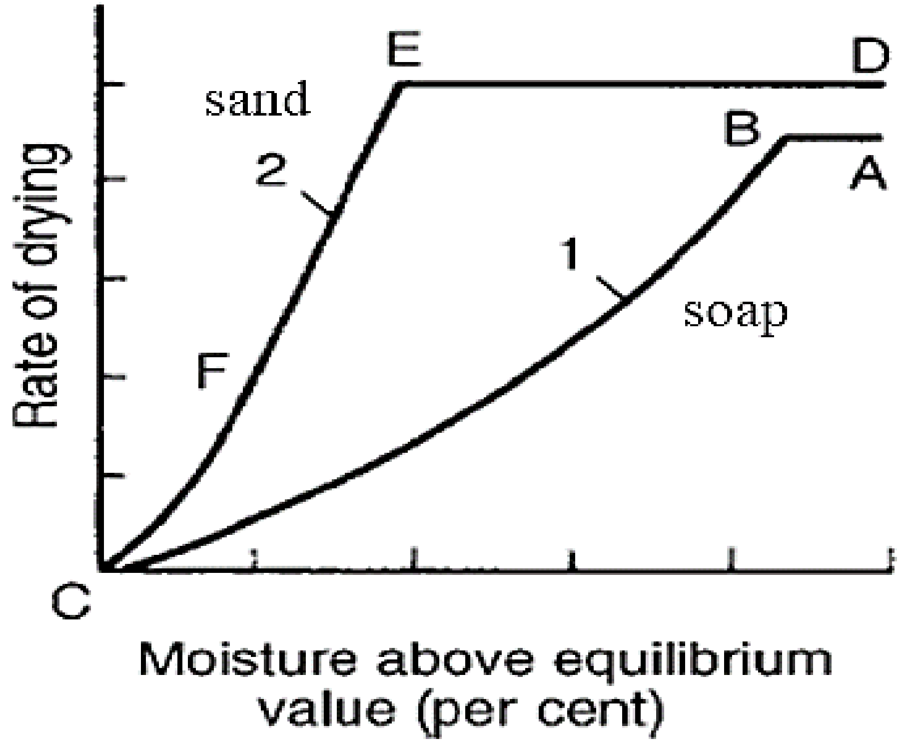
- ✓ First falling drying rate (C to D)

  occurs when wetted spots in the surface continually diminish until the surface is dried (Point D).

- ✓ Second falling drying rate (D to E)

  begins at point D when the surface is completely dry and until the EMC is reached.

RATE OF DRYING: The form of the drying rate curve varies with the structure and type of material, and two typical curves (**for two different materials**) are shown in Figure



Curve 1: AB zone is constant rate of drying.

BC zone is a steady fall in the rate of drying as the moisture content is reduced.

B point is called ***critical moisture content.***

Curve 2: DE represents a constant rate period.

EF and FC are falling rate periods.

EF is a straight line, is known as the first falling rate period,

FC is the final stage.

The mass rate of evaporation is

$$r = h_C A \Delta T / \lambda_i \qquad \text{(kg/s)}$$

Where:

h_C = the heat transfer coefficient from air to wet surface depends on air velocity and direction of flow, W/m^2 ^{o}C

A = Area of solid surface,

λ_i = Latent heat of vaporization,

ΔT = Temp difference

$h_C = 8.8 G^{0.8} / D_e^{0.2}$ (when parallel air flow)

$h_C = 24.2\ G^{0.37}$ (when perpendicular air flow)

where: G = mass air velocity (kg/m^{2}s),

D_e = equivalent diameter.

During ***constant rate period*** the rate of drying depends upon h_C, ΔT and A.

The rate of drying during the ***1st falling rate*** period depends upon the mechanism by which moisture from inside the material is transferred to the surface.

During the ***2nd falling rate*** period from within the solid, vapor reaching the surface by molecular diffusion.