Drying- General Introduction and Drying Curve

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Definition

Drying is the process of removal of small amount of liquid(water/volatile liq./moisture) by application of heat to obtain dry solid or solid product.

In general drying process involves to operations; 1) Heat transfer 2) Mass transfer Drying and Evaporation are relatively same term but are distinguish in terms of removal of water. Here are some differences between drying and evaporation;

Difference between Drying and Evaporation

DRYING

1. In drying processes, the main operation usually carried out on solid materials, e.g. powders, or products
2. Drying in most of the cases means the removal of relatively small amounts of water from solids.
3. Drying involves the removal of water at temperatures below its boiling point.
4. In drying , water is usually removed by circulating air over the material in order to carry away the water vapour

EVAPORATION

1. In evaporation processes, the mainoperation usually carried out on liquid materials, e.g. solution, orProducts
2. Evaporation include the removal of large amounts of water from solutions.
3. Evaporation involves the removal of water by boiling a solution.
4. While in evaporation , water is removed from the material as pure water vapour mixed with other gases

Application/ need of drying

- Preservation of drug products
- Preparation of bulk drugs
- Improved handling
- Improved characteristics
- Reduction in transport cost
- Purification of crystalline products
- Prevention of corrosion

For Preservation of drugs

Drying is necessary in order to avoid deterioration. A few examples are...

- blood products, tissues undergo microbial growth
- effervescent tablets, synthetic & semi synthetic drugs undergo chemical decomposition.

For preparation and improvement of characteristics of bulk drugs

Drying is the final stage of processing .

- Eg: dried aluminium hydroxide
- spray dried lactose
- powdered extracts

Improved characteristics:

 Drying produces materials of spherical shape, uniform size, free flowing & enhanced solubility.

1.Granules are dried to improve the fluidity & compression characteristics. These are essential for production of tablets and capsules.

2.Viscous & sticky materials are not free flowing, Drying modifies these characteristics.

Improved handling of material

Removal of moisture makes the material light in weight and reduces bulk.

Thus cost of transportation will be less & storage will be efficient.

If moisture is present, size reduction of drugs is difficult.

Drying reduces the moisture content.

Factors affecting rate of drying

Particle size
Nature of material
Nature of moisture (bound/unbound)
Surface area
Initial and final moisture content
Thickness of material bed
Temperature
Amount of moisture
Nature of product

Theory of Drying

In a wet solid mass water may be present in two forms;

1) Bound water:

Bound water is the minimum water held by the material that exerts an equilibrium vapour pressure less than the pure water at the same temperature.

2) Unbound water:

It is the amount of water held by the material that exerts an equilibrium vapour pressure equal to that of pure water at the same temperature.

- Unbound water exists largely in the voids of solid thus in non- hygroscopic material all the liquid is unbound water.

Theory of drying can be discussed under two headings

A) Equilibrium relationships

B) Rate relationships

A) Equilibrium relationships: Air of constant humidity and temperature is passed over wet material after long exposure equilibrium is reached.

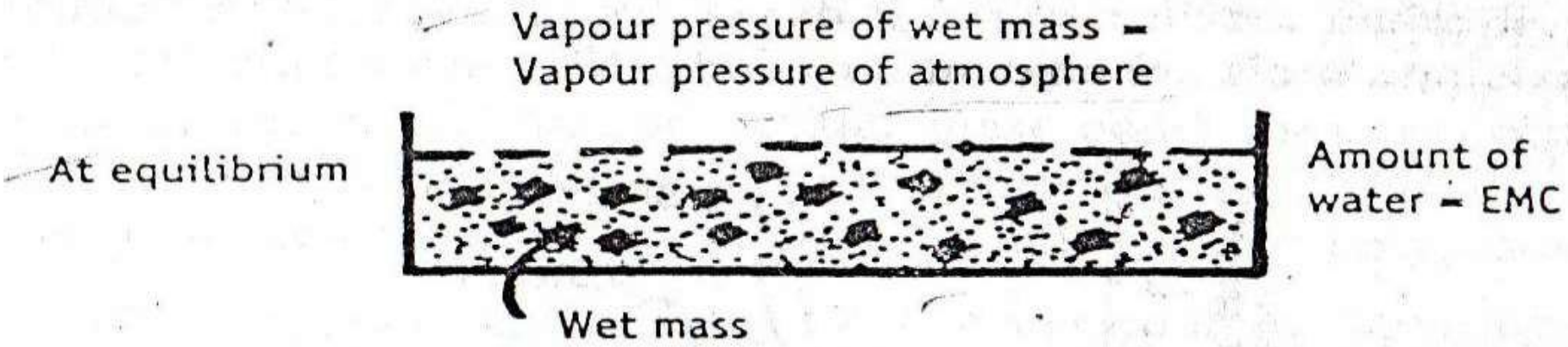
B) Equilibrium moisture content (EMC): It is amount of water which exerts vapour pressure equal to the vapour pressure of atmosphere surrounding it.

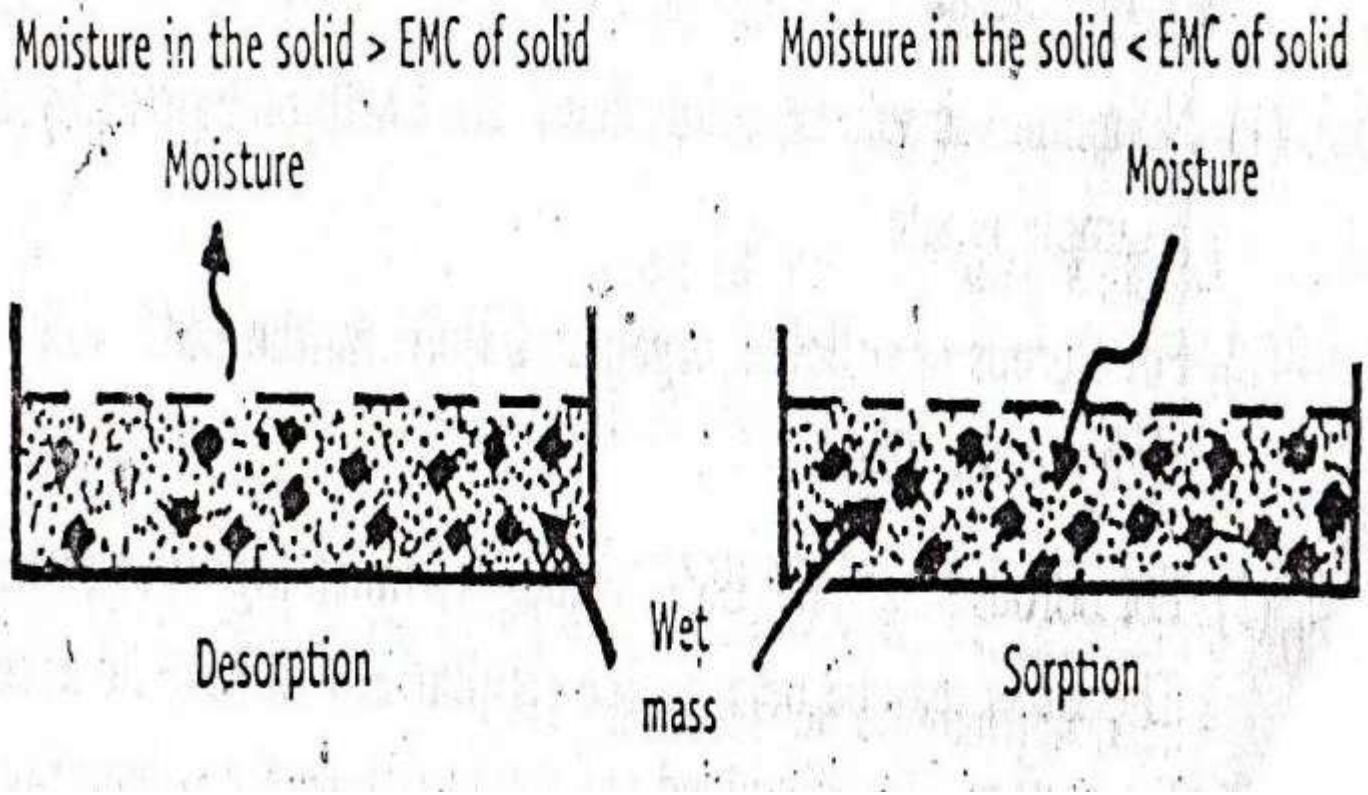
Based on the conditions of temperature and humidity solid will either lose or absorb the moisture;

1) When air is continuously passed over the solid containing moisture more than EMC then solid lose water till the EMC is reached. This phenomenon is known as Desorption.

2) When air is continuously passed over the solid containing moisture less than EMC then solid absorb water till EMC is reached. This phenomenon is known as Sorption.

Moisture in solid>EMC=desorption (lose water)
Moisture in solid<EMC=sorption (gain water


Vapour pressure of wet mass =
Vapour pressure of atmosphere
At equilibrium
Amount of
water = EMC
Wet mass


Moisture in the solid > EMC of solid
Moisture in the solid < EMC of solid
Moisture
Moisture
Desorption
Wet
mass
Sorption

Free moisture content

Free moisture content (FMC): It is the amount of water that is free to evaporate from solid.
FMC =Total water content – EMC

B) Rate relationships:
Rate relationship is observed by considering a simple model which mimic the conditions of a dryer. In this model wet slab of solid is considered and hot humid air is passed over it. The change in weight is determined by weighing the slab at different time interval and following calculations are made

$$\% \text{ Loss on drying } (LOD) = \frac{\text{mass of water in sample (kg)}}{\text{total mass of wet sample (kg)}} \times 100$$

$$\% \text{ Moisture content } (MC) = \frac{\text{mass of water in sample (kg)}}{\text{mass of the dry sample (kg)}} \times 100$$

$$\text{Drying rate} = \frac{\text{weight of water in sample (kg)}}{\text{time (h)} \times \text{weight of the dry solid (kg)}}$$

Drying Curve

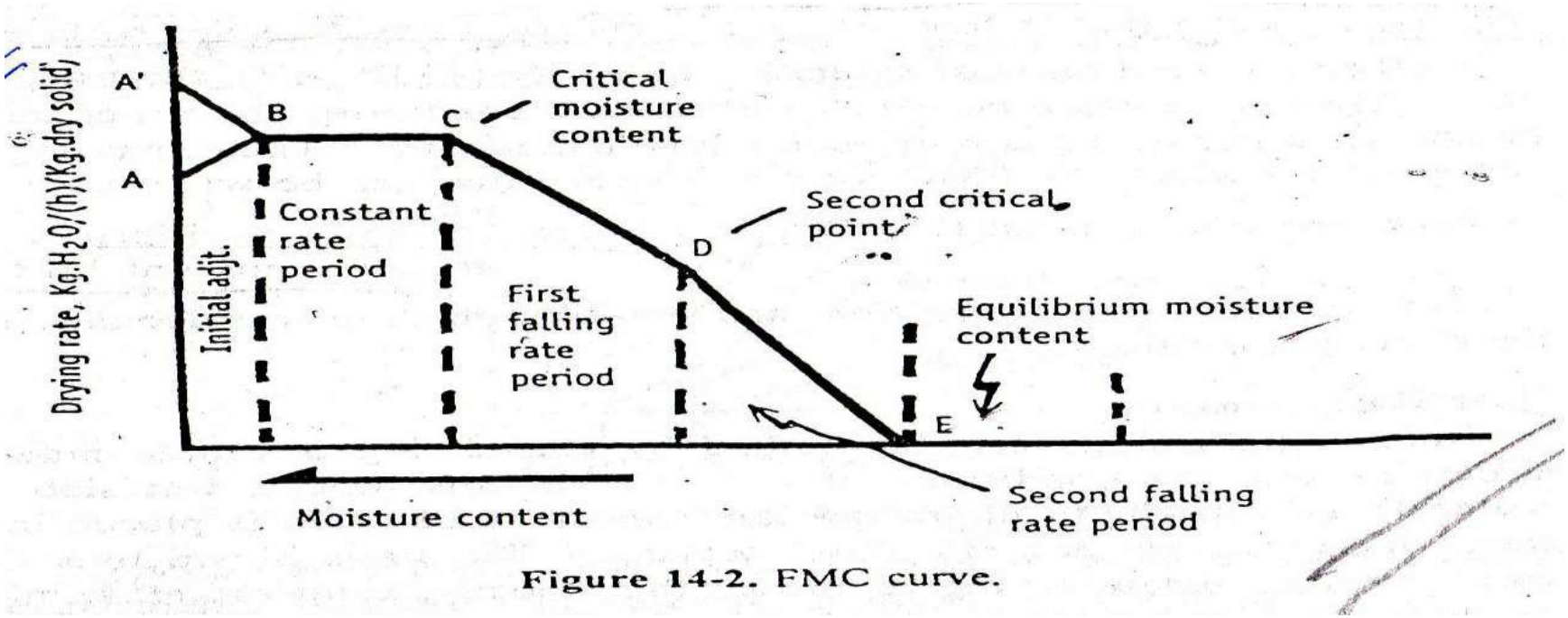
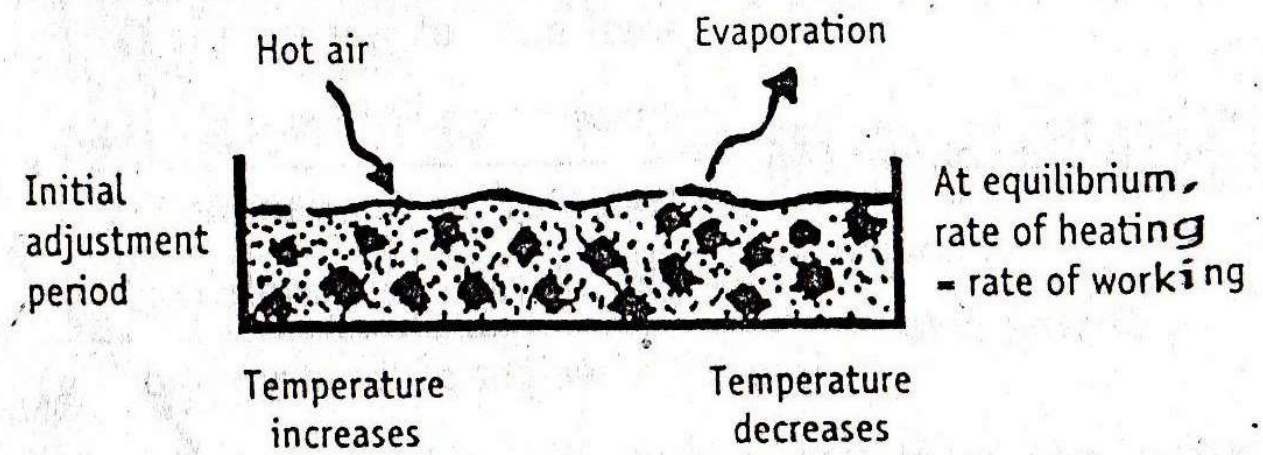


Figure 14-2. FMC curve.

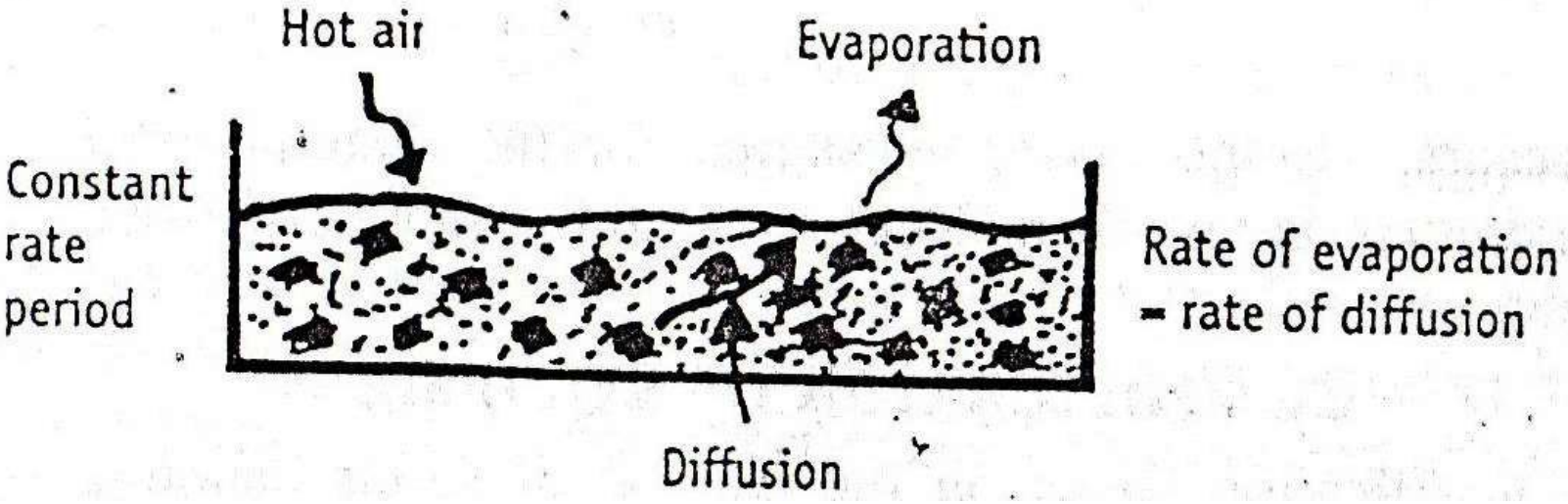
Drying Curve

(1) The time corresponding to AB represents the *initial adjustment period*.. During this period, the solids absorb heat and the temperature increases. At the same time, the moisture begins to evaporate and thus tends to cool the drying solid. After some time, the temperature stabilises (heating and cooling rates become equal). This temperature is equal to the wet bulb temperature of the drying air and is referred by the point B.



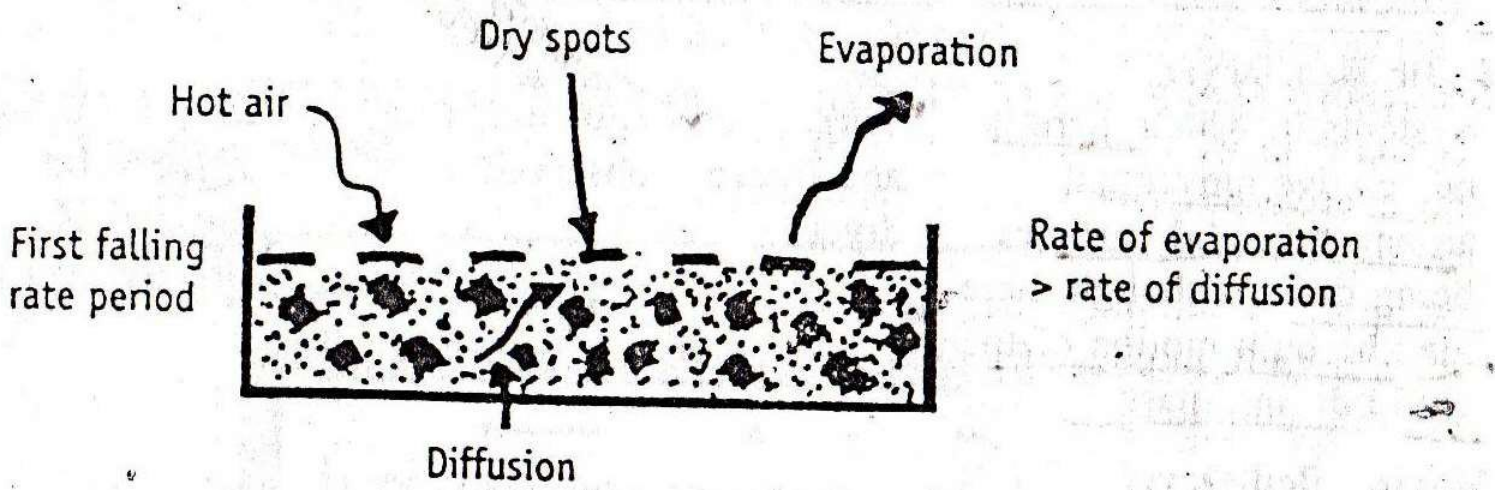
Drying Curve

(2) The time corresponding to BC represents the *constant rate period*. The temperature remains constant and rate of drying is constant. The moisture evaporating from the surface is replaced by the water diffusing from the interior of the solid. The rate of diffusion is equal to the rate of evaporation. The moisture content at the end of constant rate (point C) is referred to as the *critical moisture content* (CMC).



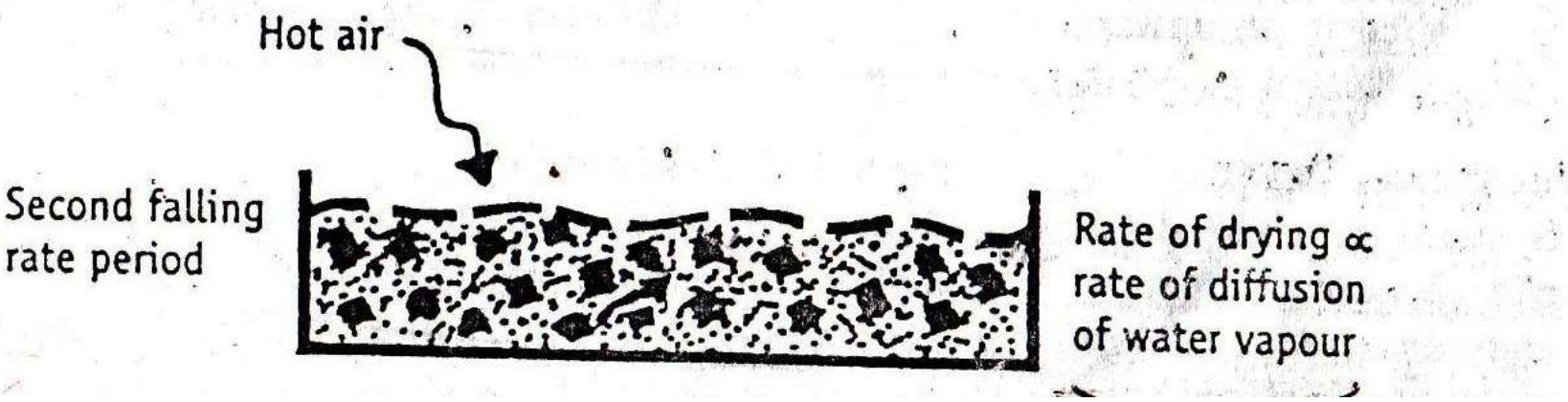
Drying Curve

(3) The time corresponding to CD represents the *first falling rate period* (or unsaturated surface drying). During this period, the surface water is no longer replaced at a rate fast enough to maintain a continuous film on the surface. Dry spots begin to appear and the rate of drying begins to fall off. The point D is referred to as the *second critical point.* At this point, the film of surface water is completely evaporated.



Drying Curve

(4) The time corresponding to DE represents the *second falling rate period.* During this period, the rate of drying falls even more rapidly than the first falling rate. During this period, the rate of drying is dependent on the rate of diffusion of vapour of moisture to the surface of the solid. Point E is referred to as the *equilibrium moisture content.*



Drying Curve

(5) Beyond E, the drying rate is equal to zero. Therefore, temperature and moisture content remain constant. Beyond, E, continued drying is waste of time and energy.

The curves may have different shapes for different levels of moisture.If the drying is carried above the level of CMC, only constant rate period occurs.