*Critical moisture content* is that obtaining when the constant-rate period ends and the falling-rate period begins.

*Equilibrium moisture content* is that to which a given material can be dried under specific conditions of air temperature and humidity.

*Evaporative load* is the total amount of water evaporated per hour in the dryer.

*Falling-rate period* is that drying period during which the instantaneous drying rate continually decreases.

*Fiber saturation point* is the moisture content of cellular materials (wood, etc.) at which the cell walls are completely saturated while the cavities are liquid-free. It may be defined as the equilibrium moisture content as the humidity of the surrounding atmosphere approaches saturation.

*Final moisture content* is the percentage by weight of moisture remaining in the solid at the end of the drying operation.

*Free moisture content* is that liquid content which is removable at a given temperature and humidity. Free moisture may include both bound and unbound moisture.

*Fuel economy* is the number of units of fuel (cubic feet of gas, pounds of steam, gallons of oil, etc.) required to remove 1 lb of water from the solid being dried.

*Humidity* denotes the amount of water vapor actually present in a gas, and is generally expressed as weight of vapor per unit weight of any gas.

*Hygroscopic material* is material that may contain bound moisture.

*Initial moisture content* is the percentage by weight of moisture in the solid at the start of the drying operation.

*Initial moisture distribution* refers to the moisture distribution throughout a solid when drying begins.

*Moisture gradient* refers to the internal distribution of water in a solid at a given moment in the drying process, the nature of which depends on the characteristics of the solid involved.

*Non-hygroscopic material* is material that can contain no bound moisture.

*Test drying time* is the drying time of a relatively small and representative sample of the material which is dried in a laboratory dryer under conditions simulating commercial operation.

*Through-circulation drying* is that method of drying in which the air flow is directed through a permeable bed of solids.

*Unbound moisture* in a hygroscopic material is that moisture in excess of the equilibrium moisture content corresponding to saturation humidity. All water in a non-hygroscopic material is unbound water.

*Wet basis* expresses the moisture in a material as a percentage of the weight of the *wet* solid. This basis is less satisfactory than the dry-weight basis on which the percentage change of moisture is constant for all moisture contents.

## MECHANISM OF DRYING[1]

When a solid dries, two fundamental processes are involved: (1) the transfer of heat to evaporate the liquid, and (2) the transfer of mass as vapor and internal liquid. These two processes occur simultaneously, and the factors governing the rate of each process determine the rate of drying.

In any commercial drying problem, a principal objective is to supply the required heat in the most efficient manner. Consequently, heat transfer may occur by convection, conduction, or radiation, or by any combination of these mechanisms. The various types of industrial dryers may be shown to differ fundamentally with respect to the method used for transferring heat to the solid. In general, heat must flow first to the outer surface of the solid and then into the interior. An important exception is drying with high frequency electrical currents where heat is *generated within the solid*, producing a higher temperature at the interior than at the surface, and consequently, causing heat to flow from inside the solid to the outer surfaces.

Mass transfer in drying occurs as liquid or vapor flow, or both, within the solid, and as vapor flow from the external wet surfaces. The nature of liquid concentration gradients in solids during drying depends on the mechanism of internal liquid flow, and this mechanism, in turn, depends to a large extent upon the physical and chemical characteristics of the solid being dried.



### Internal vs. External Conditions

A study of how a solid dries may be based on the *internal* mechanism of liquid flow, or on the effect of the *external conditions* of temperature, humidity, air flow, state of subdivision, etc., on the drying rate of the solid. The former procedure involves a fundamental study of the liquid flow conditions within a solid during drying. The latter procedure, although less fundamental, is more generally used because the effects are easier to establish and the results have greater immediate application in dryer design and operation.

*Internal Mechanism of Liquid Flow.* Internal liquid flow may occur by several mechanisms, depending on the structure of the solid. Several mechanisms of flow are as follows:

1. *Diffusion* in continuous, homogeneous solids.
2. *Capillary flow* in granular and porous solids.
3. Flow caused by *shrinkage* and *pressure* gradients.
4. Flow caused by a *vaporization-condensation* sequence.
5. Flow caused by *gravity*.
6. Flow caused by an electrical potential, *electro-osmosis*.
7. Flow caused by temperature gradients, *thermal diffusion*.

Although more than one of these mechanisms of flow may be effective at one time, only one predominates as a rule at a given time in a solid during drying. However, a different mechanism may predominate at a different time in the cycle. The mechanism of moisture flow is usually established experimentally from a study of moisture gradients.

*External Variables.* The principal external variables involved in any drying problem are: *temperature, humidity, air flow, state of subdivision* of the solid, *agitation* of the solid, *method of supporting the solid*, and the *contact* between hot surfaces and wet solid. All these variables do not necessarily occur simultaneously in one problem.

### Periods of Drying[1]

A typical drying time curve for a wet solid is shown in Fig. 1. This curve is a plot of the moisture content at any time in a solid undergoing drying. It is the usual method of presenting experimental drying data. Although Fig. 1 shows that the moisture content is subject to a continuous variation with time, a more precise illustration of the nature of this variation can be obtained by differentiating the curve and plotting the drying rate in pounds of water per (hour) (pound of dry material) against the moisture content in pounds of water per pound of dry material as shown in Fig. 2. The *rate curve* shows that the drying process is not a smooth, continuous one in which a single mechanism controls throughout.

Section BA on each curve represents a *constant-rate period.* In Fig. 1, it is shown by a straight line of constant slope $dw/d\theta$, which becomes a horizontal line on the rate curve in Fig. 2.

The curved portion of Fig. 1 is termed the falling-rate period, and, as shown in Fig. 2, it is typified by a continuously changing rate. Point A,