

of any variation in the drying rate due thereto. Furthermore, the drying rate is increased by greater air velocity and by lessened humidity of the drying air. These facts are explained by assuming that evaporation takes place on the surface of the solid, but that the concentration of moisture there is insufficient to saturate the whole surface, so that the surface behaves as though only a part of it were wet.

In the second type of diffusion, known as *sub-surface drying*, the rate of evaporation per unit surface area of the sheet of material is inversely proportional to the thickness and is uninfluenced either by the velocity or the humidity of the surrounding air. The heat-transfer from the air to the stock falls off rapidly as the moisture content and the drying rate decrease. This indicates that evaporation is taking place, not at the surface of the solid, but beneath the surface, so that water as vapor must diffuse not only through the gas film around the solid, but also through that layer of the solid itself between the zone of evaporation and the surface. Consequently, this type of evaporation is known as sub-surface drying, the limiting factor in the rate of drying being the speed of diffusion of the liquid water from the interior of the solid to the zone of evaporation.

The Drying Cycle

In the drying of a typical wet solid under constant conditions, saturated surface evaporation usually starts at a constant rate. This will continue until the critical moisture content of the stock is reached, after which there will follow a period of unsaturated surface drying, at a falling rate. This is finally superseded by sub-surface drying which continues at a decreasing rate until the operation is completed. The drying of a slab of whiting gives a typical illustration of this cycle, as shown in Fig. 1.

Omissions in the Cycle

Many solids such as lumber are so dry at the beginning of the drying operation that the constant rate period of free surface evaporation does not occur. Frequently the surface of the material is dry enough that no surface drying can take place, in which case only the final stage of sub-surface drying is involved. In other instances, the critical moisture content of a wet solid is sufficiently low that sub-surface drying starts almost immediately after the conclusion of the constant rate period. Thus the intermediate stage of saturated surface drying does not occur and the drying is of the sub-surface type during practically the whole of the falling rate period. With other kinds of material, particularly thin sheets such as newsprint paper, sub-surface drying may occur at such a low moisture content that it is not encountered in commercial work, the falling rate period being confined solely in practice, to unsaturated surface drying.

Capillary and Hygroscopic Moisture

Most solid materials to be dried are of a powdery, granular, cellular, or fibrous nature and contain water in two characteristic forms which have a direct relation to the rate and character of the drying operation. The first form is known as *free* or capillary moisture and comprises the water which is contained in the capillary spaces between the particles or fibers of the material. The second form is called *adsorbed* or hygroscopic

moisture and is intimately associated with the physical nature of the material, having a direct effect upon such physical properties as size, strength, electrical conduction, heat conduction, etc. Removal of the capillary water has little or no effect upon the material except to reduce its weight, while removal of the hygroscopic water causes definite changes in physical properties and characteristics.

Fiber Saturation Point

The total amount of adsorbed or hygroscopic moisture that a given amount of material can contain is definitely limited. This limit is known as the *fiber saturation point*¹ and corresponds roughly to the critical

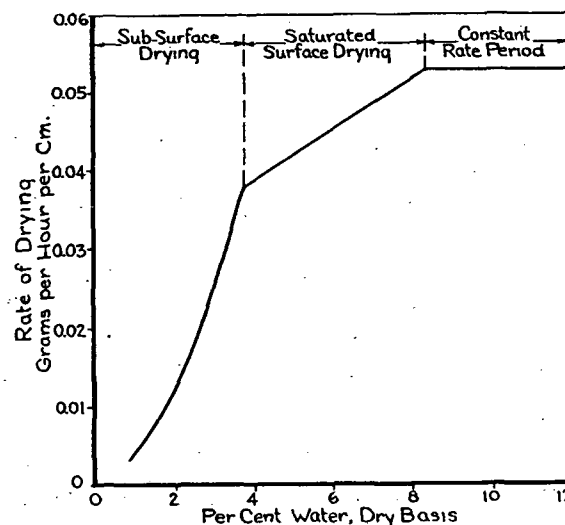


FIG. 1. RATE OF DRYING OF WHITING SLAB

moisture content. Beyond this point, any additional moisture must be in free or capillary form and the amount of such free water that the material can hold will depend upon the relative volume of capillary spaces that may be present. The fiber saturation point is of particular importance in the drying of thick, bulky materials having a more or less colloidal structure such as lumber and clay products, in which the removal of hygroscopic moisture is accompanied by shrinkage, stiffening, hardening, loss of plasticity, and other physical changes. Successful drying requires that these changes be controlled within safe limits in order to avoid injury to the material.

Removal of Free Water

In most commercial products which require a drying operation, the free water contained will flow readily from the interior to the surface by

¹U. S. Forest Service Bul. 70, p. 82, *Effect of Moisture on Strength*, Tiemann, 1907.