

very wet solid as long as moisture is brought to the surface so rapidly that the surface remains thoroughly wet and evaporation can proceed at a constant rate, precisely as from a free water surface. The second stage, known as the *falling rate period*, is reached when the moisture in the material has been dried down to a point called the critical moisture content, below which the diffusion of moisture from the interior to the surface is no longer adequate to keep the surface thoroughly wetted. From this point on, the rate of drying will decrease until the operation is completed.

Constant Rate Period

During the constant rate period, the surface is kept saturated with water by diffusion from the interior and the operation is called *saturated surface drying*. The rate of drying is limited by the rate of diffusion of water vapor, through the surface air film surrounding the solid, out into the main body of the air. When the heat necessary for vaporization is supplied only by thermal conduction through the surface air film, the temperature of the solid is the wet-bulb temperature of the air. Heat gained by radiation or conduction from adjoining dry surfaces raises the temperature of the surface above the wet-bulb temperature. The vapor pressure of the water at the surface, therefore, increases and consequently the driving force causing diffusion through the surface air film becomes greater, causing a corresponding increase in the drying rate.

By placing the wet material in sight of hot surfaces during this constant rate period, the rate of drying may be increased several fold without overheating the material itself. Similarly, material placed on hot shelves, as well as material dried in shallow pans or on heated cylinders, will dry faster because of the heat received by conduction from the surfaces with which it is in contact. A controlling factor during this stage is the velocity of the air, affecting as it does the thickness of the surface air film through which the water vapor must diffuse. The higher the velocity, the faster will the drying proceed, the rate of drying varying approximately as the 0.6 power of the air velocity.

Falling Rate Period

After the critical moisture content of the material has been reached, two distinctly different forms of diffusion and evaporation are encountered. In both cases, the drying rate falls off rapidly with reduction of the moisture content. In the first type, known as *unsaturated surface drying*, the rate of evaporation per unit surface area is substantially constant and nearly independent of the thickness of the sheet or layer of the material. However, where the solid gains its heat only from the air around it and obtains none by radiation or conduction from adjacent surfaces, the transfer of heat from the air to the solid is, under constant drying conditions, found to be independent of the moisture content and 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

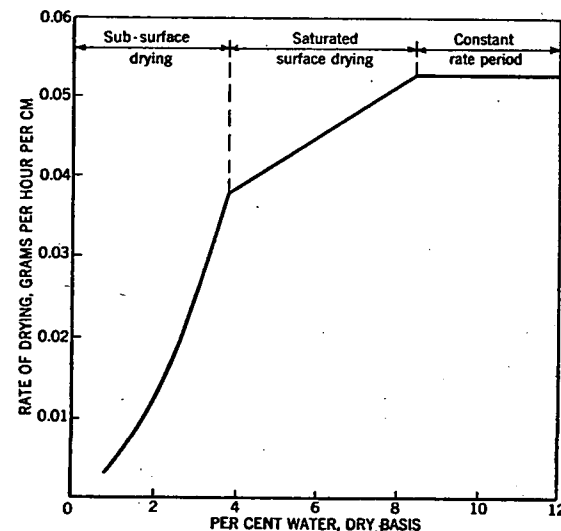


FIG. 1. RATE OF DRYING OF WHITING SLAB

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 so that no surface drying can take place, in which case only the final stage of sub-