In any type of convection dryer the heat transfer and hence the drying depends primarily upon the surface area of material exposed to the air and the velocity of the air over the surfaces (see Dryer Calculations, later).

A general classification of several types of dryers is given in Table 1. The chief basis of classification in this table is that of intermittent or batch operation as opposed to continuous operation. Another important basis of classification would be the method of handling the material to be dried. In an effort to secure maximum contact of the air with the product, as well as uniformity of heating, the effectiveness of cascading the material in an inclined drum or of blowing heated air through a bed of granular or pre-formed material is at once apparent, and where continuous drying at high capacity is required, these types are preferred. Extensive experimental studies on both types are available, (see References).

Simple *drying ovens* are often used for drying smaller quantities of material.

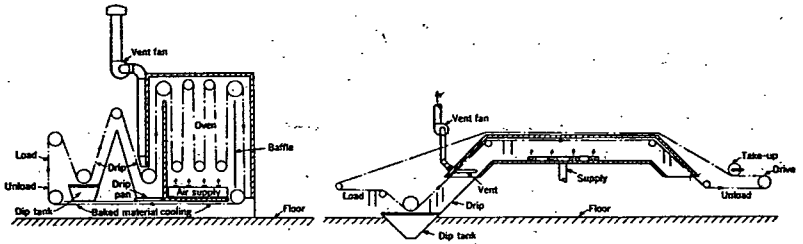

FIG. 3. SMALL PART MULTIPLE PASS OVEN

FIG. 4. INCLINED END ENAMELING OVEN

The heat and humidity supply for low temperature work up to 250 F is often steam; steam coils either in the oven or outside, heat the air used for drying. Circulation of heated oil is used to a limited extent, but the danger of leaks is serious, for if the oil is hotter than the flash point, a fire may start if the oil is released to the atmosphere. In many cases where steam is not available, direct or indirect-fired heaters are used with gas or oil as fuel. Indirect heaters should be carefully selected from a standpoint of long life and efficiency. The heat exchange surface should be adequate in area and easily accessible for cleaning and removal. For extremely high temperatures, alloy surface may be used. With direct-fired equipment care must be used in the selection of burners and sufficient combustion space allowed to insure complete combustion of fuel. Humidity can be obtained in dryers by the use of steam spray, humidifiers, or recirculation.

For low temperature work up to 200 F ovens and dryers are commonly built of two thicknesses of insulating board (fireproof preferred), with air space between. As the temperature increases materials better able to withstand the heat must be used. Metal lined ovens are easy to keep clean, and many high temperature dryers up to 1000 F are made of metal

panels with insulation between. Care should be taken to avoid *through metal* (metal extending through the oven wall from inside to out). Batch type ovens are entirely closed while in use and control of air leakage is easily taken care of. In the continuous dryer where the ends are open, heat and air leakage becomes important. Warm air leaking out of the ends of ovens means a heat loss, and often the temperature and humidity outside the oven becomes unbearable. For this reason, inclined or bottom entry ovens are used, as the warm air leakage can be more easily controlled. See Figs. 3 and 4.

MECHANISM OF DRYING

The modern theory of drying may be summed up as follows: Assuming uniform velocity and distribution of air at a constant temperature and

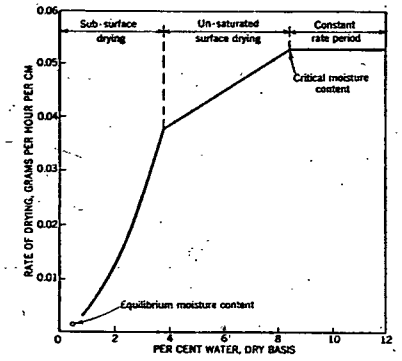

FIG. 5. RATE OF DRYING OF WHITING SLAB

humidity over the surface to be dried, the drying cycle will be divided into two distinct stages:

1. Constant rate period.
2. Falling rate period.

The *constant rate period* occurs while the material being dried is still very wet, and continues as long as the water in the material comes to the surface so rapidly that the surface remains thoroughly wet, and evaporation proceeds at a constant rate, precisely as from a free water surface. The material tends to assume a temperature corresponding to the wet-bulb temperature of the surrounding air. But the actual temperature is often slightly higher, due to radiation and conduction from dry surfaces adjoining the material. The constant rate period continues until a time is reached when the moisture no longer comes to the surface as fast as it is evaporated. This point is called the *critical moisture content* in the drying process.

As the drying proceeds, a period of *uniform falling rate* is entered. During this period, the surface of the material is gradually drying out, and