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CHAPTER 22

INDUSTRIAL DRYING SYSTEMS

Drying Terminology, Mechanism of Drying, Internal and External Conditions, Periods of Drying, Equilibrium Moisture Content, Application of Hygrometry to Drying, Determination of Drying Time, Commercial Drying Time, Dryer Calculations, Drying Methods and Equipment; Radiant, Conduction, and Convection Drying; Agricultural Drying, Solution of Drying Problem

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THE term *drying*, in a broad sense, encompasses the removal of water, and occasionally other liquids, from gases, liquids, or solids. However, the common usage of the word confines the meaning principally to the removal of water or solvent from solids by thermal means. *Dehumidification* is the term that is commonly assigned to the drying of gases. This is usually accomplished by condensation or adsorption by various drying agents (see Chapter 21 of the 1961 GUIDE AND DATA BOOK). *Distillation*, and particularly *fractional distillation*, is associated with the drying of liquids.

It is usually more economical to employ, whenever possible, mechanical means of separating as much water as is practicable from the solid materials before undertaking drying or dehydration steps. These mechanical methods such as filtration, screening, pressing, centrifuging, or settling usually require much less power, and frequently less capital outlay, thereby making the operation cheaper in terms of cost per pound of water removed.

DRYING TERMINOLOGY[1]

The generally accepted definitions of terms used in drying technology follow:

Adiabatic drying occurs in a dryer when all of the sensible heat given up by the air in cooling is used to evaporate water from the wet stock.

Batch drying is that type of drying operation in which the material is fed to and discharged from the drying chamber in batches at definite intervals of time.

Bone-dry basis indicates the moisture content of a wet solid as pounds of water per pound of bone-dry solid. The advantage of using this basis is that the absolute amount of moisture loss is obtained simply by subtracting the moisture contents before and after drying. (See definition of *Wet Basis*.)

Bound moisture refers to liquid (held by a solid) which exerts a vapor pressure less than that of the pure liquid at the same temperature. Liquid may become *bound* by retention in small capillaries, by solution in cell or fiber walls, by homogeneous solution throughout the solid, and by chemical or physical adsorption on solid surfaces. Bound moisture can be removed from a solid only under specific conditions of humidity in the external surroundings.

Capillary flow refers to the flow of liquid through the interstices and over the surface of a solid. It is caused by liquid-solid molecular attraction.

Commercial dry basis expresses the moisture content of a product as pounds of water per pound of solid as it leaves the dryer, i.e., per pound of commercially dry solid.

Commercial drying time is the residence time of the material being dried in a commercial dryer.

Constant-rate period is that drying period during which the rate of water removal per unit of drying surface is constant.

Continuous drying is that type of drying operation in which the material to be dried is fed and discharged continuously to and from the dryer. The operating conditions are independent of time.

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