ical corrosion. A list of the materials which may be used to resist the action of certain fumes is given in Table 7. Hoods and ducts, when short, may frequently be constructed of wood and be quite effective. Rubberized paints are available and may be applied as protective coatings in handling such gases as chlorine and hydrochloric acid.

## REFERENCES


[1] Tentative Recommended Good Practice Code and Handbook on the Fundamentals of Design, Construction, Operation and Maintenance of Exhaust Systems, Page 21, Industrial Hygiene Codes Committee, *American Foundrymen's Association*.

[2] How to Design Exhaust Hoods, by J. M. DallaValle (*Heating and Ventilating*, Series of 12 articles March, 1943 to February, 1944).

[3] Industrial Exhaust Ventilation in Industrial Hygiene, by Allen D. Brandt (A.S.H.V.E. TRANSACTIONS, Vol. 50, 1944, p. 331).

[4] Fan Engineering, 1948, Buffalo Forge Co.

[5] Nature of Air Flow at Suction Openings, by A. D. Brandt, R. J. Steffy and R. G. Huebscher (A.S.H.V.E. TRANSACTIONS, Vol. 53, 1947).

[6] Energy Losses at Suction Hoods, by A. D. Brandt and R. J. Steffy (A.S.H.V.E. TRANSACTIONS, Vol. 52, 1946, p. 205).

[7] Industrial Health Engineering, by Allen D. Brandt (John Wiley & Sons, Inc., New York).

[8] For more detailed requirements refer to Fundamentals Relating to the Design and Operation of Exhaust Systems, Z9-1936 (*American Standards Association*). Industrial Code Bulletin Nos. 10 and 12 (New York State Labor Department). Principles of Exhaust Hood Design, by J. M. DallaValle (*U. S. Public Health Service*, 1939).

[9] Standards of the N.B.F.U. for Installation of Blower and Exhaust Systems for Dust Stock and Vapor Removal or Conveying, *National Board of Fire Underwriters*.

[10] National Electrical Code 1947, N.B.F.U. Pamphlet No. 70, *National Board of Fire Underwriters*.

[11] The Control of Industrial Dust, by J. M. DallaValle (*Mechanical Engineering*, Vol. 55, No. 10, October, 1933).

[12] Studies in the Design of Local Exhaust Hoods, by J. M. DallaValle and Theodore Hatch (*A.S.M.E. Transactions*, Vol. 54, 1932).

[13] Velocity Characteristics of Hoods under Suction, by J. M. DallaValle (A.S.H.V.E. TRANSACTIONS, Vol. 38, 1932, p. 387).

[14] Low Velocity Exhaust Systems, by Theodore Hatch (*Heating and Ventilating*, October, 1940, p. 27).

[15] Tank Ventilating Power Costs Cut by Low Velocity Systems, by William B. Harris (*Heating and Ventilating*, July, 1942, p. 42).

[16] Health Hazards in Chromium Plating, by J. J. Bloomfield and William Blum (*U. S. Public Health Report*, Vol. 43, No. 26, September 7, 1928).

[17] New Data for Practical Design of Ventilation for Electroplating, by W. P. Battista, Theodore Hatch and Leonard Greenburg (*Heating, Piping and Air Conditioning*, February, 1941, p. 81). Ventilation of Plating Tanks, by Allen D. Brandt (*Heating, Piping and Air Conditioning*, July, 1941, p. 434).

[18] Criteria for Industrial Exhaust Systems, by J. J. Bloomfield (A.S.H.V.E. TRANSACTIONS, Vol. 40, 1934, p. 353).

[19] Keeping Dust Under Control, by John M. Kane (presented to the 31st National Safety Congress, October 28, 1942, and reprinted in part in *National Safety News*, January, 1943). The Determination and Control of Industrial Dust, by J. J. Bloomfield and J. M. DallaValle (*Public Health Bulletin 217*, 1935), Engineering Control of Air Contamination of the Working Environment, by A. D. Brandt (In Manual of Industrial Hygiene, *U. S. Public Health Service*, 1943, p. 198–266).


CHAPTER 46

# DRYING SYSTEMS

Drying Terminology, Mechanism of Drying, Internal and External Conditions, Periods of Drying, Approximate Equations for Estimating Drying Time, Equilibrium Moisture Content, Applications of Hygrometry to Drying, Dryer Calculations, Drying Methods and Equipment; Radiant, Conduction and Convection Drying; Solution of Drying Problem

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, and is treated in Chapter 37. Distillation, and more 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:

*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.

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

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

*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*.)

*Dryer efficiency* is that fraction of the total heat, supplied by fuel, used to evaporate water. *Overall efficiency* is sometimes used to distinguish overall system efficiency from the *efficiency of the drying space* or *evaporative efficiency*.

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

*Evaporative efficiency* compares the amount of evaporation actually obtained in a dryer with that which would obtain by saturation of the air.

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