of the evaporative condenser have been started. In some cases, an automatic damper is used on the inlet of the evaporative condenser to provide proportional control of head pressure on the refrigeration system. See Chapter 43 for general information on controls.

REFERENCES

[1] W. D. Collins: *Temperature of Water Available for Industrial Use in the United States* (U. S. Geological Survey, *Water Supply Paper* No. 520F).

[2] R. F. Throne: Cooling performance of an industrialized lake surface (*Power*, September 1951).

[3] S. Hori, U. A. Patchett, and L. M. K. Boelter: Design of spray cooling ponds (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning*, October 1942, p. 624).

[4] W. H. Walker, W. K. Lewis, W. H. McAdams, and E. R. Gilliland: *Principles of Chemical Engineering* (McGraw-Hill Co., New York, 1937, p. 480).

[5] D. Q. Kern: *Process Heat Transfer* (McGraw-Hill Co., New York, 1950, p. 563).

[6] W. K. Lewis: The evaporation of a liquid into a gas (*ASME Transactions*, Vol. 44, 1922, p. 325).

[7] F. Merkel: Verdustungs kuhlung (*Forschungarbeiten*, No. 275, 1925).

[8] H. B. Nottage: Merkel's cooling diagram as a performance correlation for air-water evaporative cooling system (ASHVE TRANSACTIONS, Vol. 47, 1941, p. 429).

[9] W. H. McAdams: *Heat Transmission* (McGraw-Hill Co., New York, 1933, p. 157).

[10] A. L. London, H. B. Nottage, and L. M. K. Boelter: Determination of unit conductance for heat and mass transfer by the transient method (*Industrial and Engineering Chemistry*, April 1941, p. 467).

[11] Joseph Lichtenstein: Performance and selection of mechanical-draft cooling towers (*ASME Transactions*, 1943, p. 779).

[12] D. R. Baker and L. T. Mart: Analysing cooling tower performance by the unit-volume coefficient (*Chemical Engineering*, December 1952, p. 196).

[13] J. C. Albright and D. R. Baker: *Summer Weather Data* (The Marley Co., 1944).

[14] D. R. Baker: Studies relative to protection of cooling tower lumber (*ASME Oil, Gas and Power Division Proceedings*, June 1954).

CHAPTER 41

EVAPORATIVE AIR COOLING AND HUMIDIFICATION

Apparatus for Humidification, Spray Generation, Spray Distribution, Unit Humidifiers, Air Washers, Humidification with Air Washers, Dehumidification and Cooling with Air Washers, Evaporative Air Cooling, Types of Direct Evaporative-Cooling Equipment, Design Considerations, Controls, Maintenance

EVAPORATIVE air cooling and humidification increase the moisture content of an air stream or the air in a selected space, with or without a change in dry-bulb temperature.

Evaporative air cooling applies the well-known phenomenon of evaporating water at ambient temperature into an air stream. If no heat is added during the process, the dry-bulb temperature of the air stream is reduced along the thermodynamic wet-bulb temperature line with a consequent increase in latent heat and moisture content.

Humidification, used industrially and in residential air-conditioning and heating systems, may be accomplished by evaporative air-cooling apparatus, by the direct introduction of water spray into the air stream or space either by heated evaporating pans or steam jets. Some equipment can be used for both cooling and humidification.

APPARATUS FOR HUMIDIFICATION

Humidification may be direct or indirect, i.e., water in droplets or vapor form may be introduced directly into the humidified space, or previously humidified air may be circulated in or through the space. Evaporative air cooling is always indirect although the cooling may be accomplished by wetted surface or secondary cool surface.

The classification of apparatus used for humidification and evaporative air cooling is shown in Table 1.

HUMIDIFICATION SPRAY GENERATION AND DISTRIBUTION

Spray generation is obtained by (1) compressed air, (2) impact, (3) hydraulic separation, and (4) mechanical separation. Atomization can be accomplished by the use of a compressed air jet to reduce the water particles to a fine spray. With the impact method, a jet of water under pressure impinges directly on the end of a small round wire. Where hydraulic separation is employed, a jet of water enters a cylindrical chamber and escapes through an axial port with a rapid rotation which causes it to separate in a fine cone-shaped spray. In the mechanical separation process, water is thrown by centrifugal force from the surface of a rapidly revolving disc and separates into particles sufficiently small to be utilized in certain types of mechanical humidifiers.

Spray distribution is obtained by (1) air jet, (2) induction, and (3) fan propulsion.

Air-jet distribution utilizes the atomizing jet to distribute the spray through the space. Induction distribution utilizes the aspirating effect of an impact or centrifugal spray jet to induce air flow through a casing or duct for distribution of the spray. Fan propulsion uses a power-driven fan to distribute the spray.

Atomizing Humidifiers

In several types of atomizing humidifiers nozzles are placed within the room. Compressed air effects complete atomization of the water which is converted into vapor by the heat of the room air. In some of these nozzles an aspirating effect draws the water into the nozzle and atomizes it. Others are operated on a combined air and water pressure. It is usual for nozzles of the water-pressure type to be controlled by a diaphragm valve actuated by the pressure of the atomizing air.

High-Duty Humidifiers

Water is supplied at about 150 psig to an impact-type spray-generating nozzle located in a cylindrical casing. A drainage pan provides for the collection of unevaporated water which is returned to a filter tank. A powerful air current from a fan mounted above the unit, flows through the cylinder and is charged with moisture. Air discharges from an opening below at a high velocity in a complete and nearly horizontal circle. The spray is evaporated and the resulting vapor is diffused and distributed.

Spray Humidifiers

This type uses a spray nozzle in a cylindrical casing equipped with a drainage pan. The aspirating effect of the nozzle induces a moderate air current through the casing which distributes the entrained spray. The general method of circulating and returning the water is similar to that employed for high-duty humidifiers. A suitable pump and centrally-located filter tank are required.

Self-Contained Humidifiers

In this type mechanical or centrifugal means are used to generate and distribute spray. They may be used either singly or in groups. In large installations, where suitable connections are provided to permit the cleaning and servicing of individual units without affecting the room as a whole, group control of the water and power may be employed.

UNIT HUMIDIFIERS

The term unit humidifier denotes an assembly of elements the principal function of which is to humidify. The essential