[14] See pp. 130–132 of Reference 7.

[15] Heat Transmission through Glass, by G. V. Parmelee (A.S.H.V.E. RESEARCH BULLETIN No. 1, July 1947).

[16] *Research in Home Humidity Control*, by S. C. Hite and J. L. Dray (*Purdue University, Engineering Experiment Station, Research series* No. 106, November 1948).

[17] Permeance Measurement Improved by Special Cell, by F. A. Joy and E. R. Queer (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, June 1949, p. 103).

[18] *Water Vapor Transfer Through Building Materials*, by F. A. Joy, E. R. Queer and R. E. Schreiner (*Pennsylvania State College, Engineering Experiment Station Bulletin* No. 61, December 1948).

[19] *Remedial Measures for Building Construction*, by L. V. Teesdale (*Report* R1710 of *U. S. Forest Products Laboratory* 1947).

[20] *Condensation Control in Dwelling Constructions* (*U. S. Housing and Home Finance Agency*, 1949).

[21] The Diffusion of Water Vapor Through Various Building Materials, by J. D. Babbitt (*Canadian Journal of Research*, Vol. 17, February, 1939, p. 15).

[22] Methods of Moisture Control and Their Application to Building Construction, by F. B. Rowley, A. B. Algren and C. E. Lund (*University of Minnesota, Engineering Experiment Station Bulletin* No. 17).

[23] *The Relation of Wall Construction to Moisture Accumulation in Fill-Type Insulation* by Henry J. Barre *Iowa State College of Agriculture and Mechanic Arts Agricultural Experiment Station Bulletin* No. 271, 1940.)

[24] Moisture Migration: A Survey of Theory and Existing Knowledge, by P. F. McDermott (*Refrigerating Engineering*, August 1941, p. 103).

[25] Permeability of Paint Films to Moisture by R. I. Wray and A. R. Van Vorst (*Industrial and Engineering Chemistry* Vol. 25, p. 842, *1933*).

[26] *Water Vapor Transmission of Building Materials Using Four Different Testing Methods*, by R. R. Britton and R. C. Reichel, (*U. S. Housing and Home Finance Agency Technical Bulletin* No. 12, January 1950).

[27] Water-Vapor Permeability of Building Papers and Other Sheet Materials, by E. R. Bell, M. G. Seidl, and N. T. Krueger (A.S.H.V.E. JOURNAL SECTION *Heating, Piping and Air Conditioning*, December 1950).

BIBLIOGRAPHY

A.S.H.V.E. RESEARCH REPORTS:

No. 852—Effects of Air Velocities on Surface Coefficients, by F. B. Rowley, A. B. Algren and J. L. Blackshaw (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930, p. 123).

No. 895—Wind Velocity Gradients Near a Surface and Their Effect on Film Conductance, by F. C. Houghten and Paul McDermott (A.S.H.V.E. TRANSACTIONS, Vol. 37, 1931, p. 301).

No. 914—Surface Coefficients as Affected by Direction of Wind, by F. B. Rowley and W. A. Eckley (A.S.H.V.E. TRANSACTIONS, Vol. 38, 1932, p. 33).

No. 915—Conductivity of Concrete, by F. C. Houghten and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 38, 1932, p. 47).

No. 964—The Heat Conductivity of Wood at Climatic Temperature Differences, by F. B. Rowley (A.S.H.V.E. TRANSACTIONS, Vol. 39, 1933, p. 329).

No. 996—Insulating Value of Bright Metallic Surfaces, by F. B. Rowley (A.S.H.V.E. TRANSACTIONS, Vol. 40, 1934, p. 413).

No. 1026—Thermal Properties of Concrete Construction, by F. B. Rowley, A. B. Algren and Clifford Carlson (A.S.H.V.E. TRANSACTIONS, Vol. 42, 1936, p. 33).

No. 1048—Thermal Properties of Concrete Construction, by F. B. Rowley, A. B. Algren and Robert Lander (A.S.H.V.E. TRANSACTIONS, Vol. 43, 1937, p. 33).

A.S.H.V.E. Research Report—Overall Coefficients for Flat Glass Determined under Natural Weather Conditions, by G. V. Parmelee and W. W. Aubele (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, December 1948, p. 111).

Insulating Effect of Successive Air Space Bounded by Bright Metallic Surfaces, by L. W. Schad (A.S.H.V.E. TRANSACTIONS, Vol. 37, 1931, p. 285).

Thermal Conductivity of Wood, by J. D. MacLean (A.S.H.V.E. TRANSACTIONS, Vol. 47, 1941, p. 323).

The Specific Heat of Thermal Insulating Materials, by G. B. Wilkes and C. O. Wood (A.S.H.V.E. TRANSACTIONS, Vol. 48, 1942, p. 493).

Heat Loss Studies in Four Identical Buildings to Determine the Effect of Insulation, by D. B. Anderson (A.S.H.V.E. TRANSACTIONS, Vol. 48, 1942, p. 471).

Effect of Ceiling Insulation upon Summer Comfort, by T. D. Phillips (*National Bureau of Standards*, Report BMS52, July 1, 1940).

Thermal Insulation Made of Wood-Base Materials, Its Application and Use in Houses, by L. V. Teesdale (*U. S. Forest Products Laboratory Report* No. R1740, October 1949).

Heat Transmission Through Building Materials, by F. B. Rowley and A. B. Algren (University of Minnesota, *Engineering Experiment Station Bulletin* No. 8).

Building Insulation, by P. D. Close (*American Technical Society*, Chicago, 1945).

Moisture Condensation in Building Walls, by H. W. Wooley (*National Bureau of Standards*, Report BMS63, December 14, 1940).

Condensation of Moisture and Its Relation to Building Construction and Operation, by F. B. Rowley, A. B. Algren and C. E. Lund (A.S.H.V.E. TRANSACTIONS, Vol. 45, 1939, p. 231).

A Theory Covering the Transfer of Vapor Through Materials, by F. B. Rowley (A.S.H.V.E. TRANSACTIONS, Vol. 45, 1939, p. 545).

Simultaneous Heat and Vapor Transfer Characteristics of an Insulating Material, by F. G. Hechler, E. R. McLaughlin and E. R. Queer (A.S.H.V.E. Transactions, Vol. 48, 1942, p. 505).

Comparative Resistance to Vapor Transmission of Various Building Materials, by L. V. Teesdale (A.S.H.V.E. TRANSACTIONS, Vol. 49, 1943, p. 124).

Permissible Relative Humidities in Humidified Buildings, by Paul D. Close (A.S.H.V.E. JOURNAL SECTION, *Heating, Piping and Air Conditioning*, December, 1939, p. 766).

Condensation Within Walls, by F. B. Rowley, A. B. Algren and C. E. Lund (A.S.H.V.E. TRANSACTIONS, Vol. 44, 1938, p. 95).

CHAPTER 10

INFILTRATION AND VENTILATION

Causes of Infiltration, Infiltration Due to Wind Pressure, Infiltration Due to Temperature Difference, Sealing of Vertical Openings, Natural Ventilation, Wind Forces, Temperature Difference Forces, Heat Removal, Effect of Unequal Openings, Combined Wind and Temperature Forces, Types of Openings, General Ventilation Rules, Ventilation of Animal Shelters, Garage Ventilation

THE air leakage which takes place through various apertures in buildings must be considered in heating and cooling calculations, and properly evaluated. This *infiltration*, as it is sometimes designated, takes place through cracks around doors and windows, through solid walls, and through fireplaces and chimneys. Although the latter sources of leakage may be considerable, they are often neglected on the assumption that dampers would be closed during periods of extreme cold weather, or that the fireplace will be in use at such times, and will therefore contribute to the heat supplied and lessen the heating load.

CAUSES OF INFILTRATION

The displacement of heated air in buildings by unheated outside air is due to two causes, namely, (1) the pressure exerted by the wind, and (2) the difference in density of outside and inside air because of differences in temperature. The former is generally referred to as *infiltration* and the latter as *stack* or *chimney effect*.

In either case an exact estimate of the amount of infiltration under design conditions is difficult to make. The complicating factors include (1) variations in building construction, particularly as to width of crack or size of openings through which air leakage takes place; (2) the variations in wind velocity and direction; (3) the exposure of the building with respect to air leakage openings, and with respect to adjoining buildings; (4) the variations in outside temperatures which influence the chimney effect; (5) the relative area and resistance of openings on the windward and leeward sides, and on the lower floors and on the upper floors; and (6) the influence of a planned air supply and the related outlet vents. Tight construction is essential for preventing large heat loss due to infiltration.

INFILTRATION DUE TO WIND PRESSURE

The wind causes a pressure to be exerted on one or two sides of a building. As a result, air comes into the building on the windward side through cracks or porous construction, and a similar quantity of air leaves on the leeward side through like openings. In general, the resistance to air movement is similar on the windward to that on the leeward side. This causes a building up of pressure within the building, and a lesser air leakage than that experienced in single wall tests as determined in the laboratory. It is assumed that actual building leakages, owing to this building up of pressure, will be 80 per cent of laboratory test values. While there are cases where this is not true, tests in actual buildings substantiate the factor for the gen-