high water temperatures are desired. This is due to the fact that higher water outlet temperatures result in lower coefficients of performance.

For coefficients of performance of 4 or higher, the heat pump water heater may be more economical to operate than a conventional water heater.

Although the first cost of domestic hot water heat pumps is somewhat high, they have the advantages of eliminating products of combustion, odors and soot, and not needing a chimney. A further advantage is that they may be used for cooling purposes. With a coefficient of performance of 2½ to 3, water temperatures of 140 to 150 F may be obtained.[5]

REFERENCES

[1] Water Distributing Systems for Buildings, by R. B. Hunter (*National Bureau of Standards*, Report BMS79, p. 6–9). (Charts extended to flow of 0.39 gpm).

[2] Private communication from Howard E. Degler.

[3] Enough Hot Water—Hot Enough, by J. Stanford Setchell (*American Gas Association*, 1950).

[4] Plumbing Practice and Design, by Svend Plum (John Wiley and Sons, Inc., 1943)

[5] Progress Report on a Heat Pump Water Heater, by P. Sporn and E. R. Ambrose (*Heating and Ventilating*, February, 1949, Vol. 46, p. 78).

BIBLIOGRAPHY

Laundry, Kitchen and Hospital Equipment, by H. C. Russell (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929, p. 45).

Water Consumption, Cost and Savings, by G. C. St. Laurent (*American Hotel Association, Hotel Engineering*, Vol. 1, 1940).

Water-Supply Piping for the Plumbing System, by F. M. Dawson and A. A. Kalinske (Technical Bulletin No. 3, *National Association of Master Plumbers*).

Use of Solar Energy for Heating Water, by F. A. Brooks, *Smithsonian Institution*, Washington, D. C.

Methods of Estimating Loads in Plumbing Systems, by R. B. Hunter (*National Bureau of Standards*, Report BMS65, 1940). Plumbing Manual, Report of the Subcommittee on Plumbing, Central Housing Committee on Research, Design and Construction (*National Bureau of Standards*, Report BMS66, 1940). Water-Distributing Systems for Buildings, by R. B. Hunter (*National Bureau of Standards*, Report BMS79, 1941).

Hot Water Requirements, by M. B. Mackay (*Modern Sanitation*, August, 1949, Vol. 1, p. 30).

Urban Domestic Water Consumption, by M. A. Pond (*Journal of the American Water Works Association*, Vol. 31, No. 12, 1939, p. 2003).

CHAPTER 49

INSTRUMENTS AND MEASUREMENTS

Temperature Measurement, Pressure Measurement, Air Flow Measurement, Air Change Measurement, Humidity Measurement, Heat Transfer Through Building Materials, Evaluation of Thermal Environment, Combustion Analysis, Smoke Density Measurements, Determination of Air Contaminants, Sound and Vibration Measurements

HEATING and air conditioning engineers and technicians require instruments for both laboratory and field use and somewhat more precision is attainable and essential in the laboratory, where research and development are undertaken, than in the field, where acceptance and adjustment tests are conducted. Some instruments have attained an adequate state of development, while others fall far short of the desirable. For instance, temperatures can now be measured readily with ample accuracy for most purposes, while a convenient and precise method for determining or comparing the dustiness of atmospheres is lacking, and improvement in existing hygrometers and humidity controllers is essential.

Codes and standards covering different types of heating and air conditioning devices and apparatus have been promulgated by various authoritative organizations, and instruments essential for performance or compliance testing are enumerated in the relevant publications.[1, 2, 3, 4] The present purpose is to discuss the use and characteristics of the more important instruments.

TEMPERATURE MEASUREMENT[5, 6]

Thermometers

Any device capable of indicating temperature is a thermometer, but in common usage the term *thermometer* without qualification has come to signify the ordinary mercury-in-glass temperature indicating device. This type has a useful range from −40 F, the freezing point of mercury, to about 1000 F, at or near which the glass usually softens. Lower temperatures can be measured with alcohol-filled thermometers for which the range is about −94 F to +248 F. The better thermometers have their scales, either Fahrenheit or Centigrade, etched with acid into the glass which forms their stems. The probable error for etched stem thermometers is plus or minus one scale division, and calibration is desirable for much test work. Thermometers are calibrated during manufacture at not less than two temperatures—the freezing and boiling points of water—and calibration is often accomplished with the instrument completely immersed in a bath at the known temperature. The intervening scale divisions are then applied to the stem. When such a thermometer is used with the stem incompletely immersed, a correction known as the stem correction is necessary for accurate measurements, and its magnitude is usually computed by means of the following formula:

$$K = 0.00009\, D\, (t_1 - t_2) \qquad (1)$$

where

K = correction to be added, Fahrenheit degrees.