elimination of air through air valves or traps. In two-pipe systems automatic control valves may also retard the supply of steam. Vacuum types of air venting valves may be used to reduce the length of the venting periods.

REFERENCES

[1] I=B=R Installation Guide No. 5, Baseboard Heating Systems (*Institute of Boiler and Radiator Manufacturers*, Second Edition, 1953).

[2] A Study of Radiant Baseboard Heating in the I=B=R Research Home, by Alonzo P. Kratz and Warren S. Harris (*University of Illinois, Engineering Experiment Station Bulletin* No. 358, 1945).

[3] A.S.H.V.E. Code for Testing Radiators (A.S.H.V.E. TRANSACTIONS, Vol. 33, 1927, p. 18).

[4] Commercial Standard for Testing and Rating Convectors, CS 140-47 (*U. S. Department of Commerce*, 1947.)

[5] The Heating Effect of Radiators, by Charles Brabbée (A.S.H.V.E. TRANSACTIONS, Vol. 33, 1927, p. 33).

[6] Investigation of Heating Rooms with Direct Steam Radiators Equipped with Enclosures and Shields, by A. C. Willard, A. P. Kratz, M. K. Fahnestock and S. Konzo (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929, p. 77 or *University of Illinois, Engineering Experiment Station Bulletin No. 192*). Investigation of Various Factors Affecting the Heating of Rooms with Direct Steam Radiators, by A. C. Willard, A. P. Kratz, M. K. Fahnestock and S. Konzo (*University of Illinois, Engineering Experiment Station Bulletin* No. 223).

[7] I=B=R Testing and Rating Code for Baseboard Type of Radiation (*Institute of Boiler and Radiator Manufacturers*, Second Edition, August 1952).

[8] I = B = R Testing and Rating Code for Finned-Type Radiation. (*Institute of Boiler and Radiator Manufacturers*, First Edition, 1951, with Addenda, 1954).

[9] Heat Emission from Radiators, by K. F. Rubert (*Cornell University, Engineering Experiment Station Bulletin* No. 24, 1937).

[10] Comparative Tests of Radiator Finishes, by W. H. Severns (A.S.H.V.E. TRANSACTIONS, Vol. 33, 1927, p. 41).

[11] Heat Loss from Direct Radiation, by J. R. Allen (A.S.H.V.E. TRANSACTIONS Vol. 26, 1920, p. 11).

[12] Heat Output of Concealed Radiators, by E. A. Allcut (*University of Toronto, School of Engineering Research Bulletin* No. 140, 1933).

[13] Humidification for Residences, by A. P. Kratz (*University of Illinois, Engineering Experiment Station Bulletin*, No. 230, p. 20).

[14] A.S.H.V.E. RESEARCH REPORT No. 1067—The Cooling and Heating Rates of a Room with Different Types of Steam Radiators and Convectors, by A. P. Kratz, M. K. Fahnestock and E. L. Broderick (A.S.H.V.E. TRANSACTIONS, Vol. 43, 1937, p. 389).

CHAPTER 24

PANEL HEATING

Definitions; Application Methods: Embedded Piping for Ceilings, Walls, or Floors; Warm Air and Electrically Heated Ceilings, Walls, or Floors; Output from Panel Surfaces: Radiation, Convection and Combined Heat Transfer; Floor Panel Design: Design Conditions, Calculation of Room Heat Loss, Determination of UMRT, Determination of Panel Output, Graphical Determination of Panel Input and Water Temperature; Ceiling and Wall Panel Design; Hot Water Piping, Installation and Control; Snow Melting: Design and Installation

IN this chapter the term, Panel Heating, is used to describe a method of space heating which employs large heated areas of interior room surfaces operating at relatively low surface temperatures (80 to 125 F). The heating elements usually consist of warm water piping, warm air ducts, or low temperature electrical resistance elements embedded in, or located behind, ceiling, wall, or floor surfaces.

Panel heating may be considered as another method of convenient and effective space heating. The heat loss requirements may be calculated in the conventional manner except that the heat loss through the area occupied by the heated panel need not be included. An assumed reverse heat loss from the panel, however, should be included in determining heating main size and the boiler load. The heat release from the panel is expressed in terms of hourly heat output per square foot of surface. The room air temperatures to be maintained are approximately the same as those maintained by heating systems employing cast-iron radiators, convectors, or warm air ducts.

This chapter does not include a separate discussion of such topics as the influence of radiation on human comfort, the mechanisms by which human beings release heat, and other similar topics that apply to all methods of heating interior spaces for human comfort. The reader is referred to Chapter 6 for a detailed discussion of these subjects.

APPLICATION METHODS

The great majority of panel installations of the past 50 years (which is the period of the modern utilization of this method of heating) have used warm water as the heating medium which is circulated in embedded piping. More recently, the use of warm air ducts, and embedded electrical heating elements, has come into favor, especially where specific local factors have influenced such use. Steam has been used only occasionally because of the problems which result from its higher temperature.

When the heating medium is warm water, both ferrous (steel or wrought iron) or non-ferrous (generally copper or aluminum) pipe or tube are used widely in ceiling, wall, or floor panel construction. Tube sizes used are $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$ and $\frac{7}{8}$ in. O.D., while piping is generally $\frac{1}{2}$, $\frac{3}{4}$ or 1 in. IPS. Where coils are embedded in concrete or plaster, no threaded joints should be used for either pipe coils or mains. The construction should be of all-welded type. Changes in direction should be made by bending the pipe itself, rather than by use of fittings. Solder-joint fittings are used for