the drainage to the area expected to be drifted. The drainage will tend to wash away some of the snow.

Example 1: Design a snow melting system for an area of 10,000 sq ft in Pittsburgh, Pa. Assume an air temperature of 10 F and a wind velocity of 10 mph.

Solution: From Table 3 select a snowfall rate of 0.08. From Table 4 find the heat output of top of slab as $q_o = 168$ Btuh per sq ft and the anti-freeze average circulating temperature as $t_m = 117$ F.

For 10,000 sq ft and 40 percent loss from back of slab, the heat exchanger must deliver $10{,}000 \times 168 \times 1.40 = 2{,}352{,}000$ Btuh.

Using a 20 F deg temperature drop, the exit temperature from the exchanger must be 127 F and the entrance temperature must be 107 F.

The anti-freeze solution should be suitable for −20 F minimum temperature for Pittsburgh, and will therefore have a specific heat (see Table 5) of 0.832, and a weight of 65.3 lb per cu ft. The quantity of solution to be circulated with 20 deg temperature drop will then be

$$\frac{2{,}352{,}000}{20 \times 0.832} = 141{,}300 \text{ lb. per hr,}$$

which equals 270 gpm, or 0.601 cu ft per sec.

Assume that the coil circuit of longest equivalent length is 250 ft and has a flow of 4 gpm. The coil is ¾ in. *IPS*, having an internal diameter of 0.824 in. or 0.0687 ft. The velocity is therefore

$$\frac{4 \times 231}{60\ (0.824)^2\ (\pi/4)\ 12} = 2.41 \text{ fps}$$

From Table 5 the kinematic viscosity μ is 1.46×10^{-5} ft² per sec.

The Reynolds number $N_{Re} = \frac{Vd}{\mu} = \frac{2.41\ (0.0687)}{1.46 \times 10^{-5}} = 11340.$

From Fig. 4 of Chapter 4, using a roughness factor e = 0.00015, whence e/d = 0.00218, the value of the friction factor f is found to be 0.0335.

Substituting in Equation 14 for f, l, V and d

$$h_t = \frac{0.0335\ (250)\ (2.41)^2}{2(32.2)\ (0.0687)} = 11 \text{ ft.}$$

The head against which the pump must operate is therefore 11 ft of the circulating liquid.

REFERENCES

[1] Standard Specifications for Gypsum Plastering, including Requirements for Lathing and Plastering (*American Standards Association*, A42.1, 1946).

[2] Code and Manual for the Design and Installation of Warm Air Ceiling Panel Systems (Manual 7-A of the *National Warm Air Heating and Air Conditioning Association*).

[3] Various investigations of W. Nusselt (1915-1928) as discussed in Chap. 23 and Chap. 25, and tabulated in Author Index of *Heat Transfer*, by Max Jakob, Vol. I, 1949 (John Wiley and Sons, New York).

[4] The Transmission of Heat by Radiation and Convection, by Ezer Griffiths & A. H. Davis (*Special Report No.* 9, 1922, *Department of Scientific & Industrial Research*, His Majesty's Stationery Office, London, England).

[5] Radiation and Convection from Surfaces in Various Positions, by G. B. Wilkes and C. M. F. Peterson (ASHVE Transactions, Vol. 44, 1938, page 513).

[6] Design Conditions for Snow Melting, by W. P. Chapman (*Heating and Ventilating*, November, 1952, p. 88).

[7] Design of Snow Melting Systems, by W. P. Chapman (*Heating and Ventilating*, April, 1952, p. 95).

[8] Anti-Freeze Protection for Snow Melting Systems, by P. B. Gordon (*Official Bulletin, Heating, Piping and Air Conditioning Contractors National Association*, February, 1950, p. 21).

[9] Properties of Ethylene Glycol and Its Aqueous Solution, by C. S. Cragoe (*National Bureau of Standards CRC Report No. 9, Society of Automotive Engineers*).

BIBLIOGRAPHY

Trend Curves for Estimating Performance of Panel Heating Systems, by B. F. Raber and F. W. Hutchinson (A.S.H.V.E. Transactions, Vol. 48, 1942, p. 425).

A.S.H.V.E. Research Report No. 1192—Panel Heating and Cooling Performance Studies, by B. F. Raber and F. W. Hutchinson (A.S.H.V.E. Transactions, Vol. 48, 1942, p. 35).

A.S.H.V.E. Research Report No. 1193—Radiation as a Factor in the Feeling of Warmth in Convection Radiator and Panel Heated Rooms, by F. C. Houghten, Carl Gutberlet and E. C. Hach (A.S.H.V.E. Transactions, Vol. 48, 1942, p. 55).

Panel Heating and Cooling Analysis, by B. F. Raber and F. W. Hutchinson (A.S.H.V.E. Transactions, Vol. 47, 1941, p. 285).

Operating Results of a Residence Radiant Wall Heating System, by E. J. Rodee (A.S.H.V.E. Transactions, Vol. 47, 1941, p. 123).

Performance of a Residential Panel Heating System, by H. F. Randolph and J. B. Wallace (A.S.H.V.E. Transactions, Vol. 49, 1943, p. 235).

Radiant Heating (*Heating and Ventilating*, March, 1941, p. 35).

Radiant Heating and Cooling, by F. E. Giesecke (*Heating, Piping and Air Conditioning*, June, July, August, September and October, 1940).

Calculations for Radiant Heating, by T. Napier Adlam (*Heating and Ventilating*, October, 1931).

Radiant Heating and Cooling, Part I, by C. O. Mackay, L. T. Wright, Jr., R. E. Clark, and N. R. Gay (*Cornell University Engineering Experiment Station*, Bulletin No. 32, 1943).

Design Method for Panel Heating Systems Using Copper Tubing, by R. G. Vanderweil (A.S.H.V.E. Journal Section, *Heating, Piping and Air Conditioning*, Nov. 1947, p. 123).

Air Temperature Gradients in a Panel Heated Room, by J. M. Ayres and B. W. Levy (A.S.H.V.E. Transactions, Vol. 54, 1948, p. 131).

Graphical Solution of Radiant Panel Areas, by W. P. Chapman and R. E. Fischer (*Heating and Ventilating*, Jan. 1948, p. 88).

Embedding Coils in Radiant Heating Panels, by D. L. Mills and L. J. LaTart (*Heating and Ventilating*, Dec. 1947, p. 75).

Radiant Heat with Copper Tubing, by D. L. Mills and L. J. LaTart (*Heating and Ventilating*, Nov. 1947, p. 95).

Panel Heat with Copper Tubing—Experiment in Practice, by D. L. Mills and L. J. LaTart (*Heating and Ventilating*, Oct. 1947, p. 65).

Experimental Studies on Panel Heating Tube Spacing, by B. F. Raber and F. W. Hutchinson (A.S.H.V.E. Transactions, Vol. 53, 1947, p. 369).

Panel Heating—A Basic Discussion, by S. Konzo (*American Artisan*, Oct. 1946, p. 68).

Solar House Heated by a Warm Air Floor Panel, by John E. Peterson (*American Artisan*, Dec. 1946, p. 83).

Design Data for a Warm Air Floor Panel, by Axel B. Algren (*American Artisan* Jan. 1947, p. 141).

The Mechanism of Heat Transfer, Panel Cooling, Heat Storage, by Charles S. Leopold (*Refrigerating Engineering*, July 1947, p. 33)

Radiant Heating—Simplified Design and Installation (*Copper and Brass Research Association*, 1949).

Research Report No. 1387—Laboratory Studies on Heat Flow Within a Concrete Panel, by C. M. Humphreys, H. B. Nottage, C. V. Franks, R. G. Huebscher, L. F. Schutrum and D. W. Locklin (A.S.H.V.E. Transactions, Vol. 56, p. 175).

Research Report No. 1388—Heat Flow Analysis in Panel Heating or Cooling Sections, by L. E. Hulbert, H. B. Nottage and C. V. Franks (A.S.H.V.E. Transactions, Vol. 56, 1950, p. 189).

Electric Analogger Studies on Panels with Imbedded Tubes, by Carl F. Kayan (A.S.H.V.E. Transactions, Vol. 56, 1950, p. 205).

Books

Hot Water Heating, Radiant Heating and Radiant Cooling, by F. E. Giesecke (Technical Book Co., P. O. Box 62, Austin, Tex. 1947).