

Step 9. Design Panel Area

Follow the procedure for slab-on-grade construction, Step 9.

Step 10. Total Panel Output

Follow the procedure for slab-on-grade construction, Step 10, substituting heat flow downward (q_d) for the apportioned downward and edgewise heat flow (q_{ed}).

Step 11. Fluid Circuit

Follow the procedure for slab-on-grade construction, Step 11.

Step 12. Boiler Size

Follow the procedure for slab-on-grade construction, Step 12.

Installation Details and Accessories

The design of the two-pipe, direct return forced circulation system which is used in a panel heating system is described generally in Chapter 28, Hot Water Heating Systems. In addition to the usual valves, a balancing valve should be installed in the supply or return connection of each panel in order to permit the heat output of the panel to be balanced with other panels in the same zone.

While all piping should be designed to minimize trapping of air or water, few panel heating systems can be installed to be completely free of air traps. For that reason, panel heating systems cannot usually be filled by flooding nor drained by gravity alone. The system can be filled and the air removed if the system is flushed with a sufficient flow of water. To empty the system a flow of compressed gas is used to assist gravity drainage of the water. Provisions for both flushing and blowing should be included in the piping. Devices for the collection and venting of the gases that will appear during operation should also be provided.

Controls

Automatic controls for panel heating differ somewhat from those described for convective heating because of the thermal inertia characteristics of the panel heating surface and the increase in the mean radiant temperature within the space under increasing loads for panel heating. However, many of the control principles for hot water heating systems described in Chapter 28 will also apply to panel heating. (See also Chapter 43.)

Panels such as concrete slabs have large heat storage capacity and continue to emit heat long after the room thermostat has shut off the supply of heating medium. In addition, there is a considerable time lag between thermostat demand and heat delivery to the space due to the large part of the heat which must first be stored in the thermally heavy radiant surface. This inertia will cause uncomfortable variations in space conditions unless controls for detecting load changes as early as possible are provided.

In general, the temperature of the heating medium supplied to the panel surface should be varied in accordance with outdoor temperature but precautions must be taken to prevent the introduction of excessively hot water which might damage the panels in the event of control failure. A manual boiler bypass or other means of reducing the water temperature may be necessary to prevent too rapid drying out of new panels (see section, Embedded Piping for Ceiling Panels, in this chapter).

Due to the increase in MRT (mean radiant temperature) within a panel-heated space which necessarily takes place as the heating load increases, the air temperature under such conditions, theoretically, should be lowered in the order of 1 or 2 degrees to maintain comfort. In ordinary structures with

normal infiltration loads the required reduction in air temperature is small and, consequently, a conventional room thermostat may be used.

In panel heating systems, lowered night temperatures will produce unsatisfactory results with heavy panels such as concrete floors. These panels cannot respond to either quick increase or decrease in heating demand within the relatively short time required, with the result that there will be a very slow reduction of space temperature at night and a correspondingly slow pickup in the morning. Panels of light weight construction, such as plaster or metal ceilings and walls, may respond to changes in demand with sufficient rapidity to obtain moderately satisfactory results from lowered night temperatures. However, very little fuel saving can be expected even with the light panels unless the lowered temperature is maintained for long periods. If reduced non-occupancy temperatures are employed, some means of providing a higher-than-normal rate of heat input for rapid warm-up is necessary, or a long warmup period should be provided, as explained in Chapter 28.

Warm Air Panels

The first three steps in the design of warm air panels are the same as those outlined for warm water panels and the same performance curves can be used. The balance of the design can be determined from the data in the Chapter on Forced Warm Air Systems and Manual 7-A of the National Warm Air Heating and Air Conditioning Association.

Electric Panels

Electric panel heating systems can be designed by using part of the procedure for warm water panels as a guide. See also Chapter 17, Electric Heating.

Step 1. Heat Loss

Follow the procedure for warm water panels, Step 1.

Step 2. Required Panel Output

Follow the procedure for warm water panels, Step 2.

Step 3. Panel Surface Temperature

Follow the procedure for warm water panels, Step 3.

Step 4. Panel Heat Loss

Determine the heat loss from the panel, using the panel surface temperature found in Step 3 and the factors in Chapter 9, Heat Transmission Coefficients of Building Materials.

REFERENCES

- ¹ Standard Specifications for Gypsum Plastering, Including Requirements for Lathing and Plastering (American Standards Association, A 42.1, 1946).
- ² Manual 7A Design and Installation of Warm Air Ceiling Panel Systems (National Warm Air Heating and Air Conditioning Association).
- ³ W. H. McAdams: Chapters 4 and 7 (*Heat Transmission*, McGraw-Hill Book Co., New York, 1954, 3rd ed.).
- ⁴ T. C. Min, L. F. Schutrum, G. V. Parmelee, and J. D. Vouris: ASHAE Research Report No. 1576—Natural convection and radiation in a panel heated room (ASHAE Transactions, Vol. 62, 1956, p. 337).
- ⁵ Cyril Tasker, C. M. Humphreys, G. V. Parmelee, and L. F. Schutrum: ASHAE Research Report No. 1444—The ASHVE Environment Laboratory (ASHVE Transactions, Vol. 58, 1952, p. 139).
- ⁶ L. F. Schutrum, G. V. Parmelee, and C. M. Humphreys: ASHAE Research Report No. 1473—Heat exchanges in a ceiling panel heated room (ASHVE Transactions, Vol. 59, 1953, p. 197).

Panel Heating

¹ L. F. Schutrum, G. V. Parmelee, and C. M. Humphreys: ASHAE Research Report No. 1490—Heat exchanges in a floor panel heated room (ASHVE Transactions, Vol. 59, 1953, p. 495).

² L. F. Schutrum and C. M. Humphreys: ASHAE Research Report No. 1499—Effects of non-uniformity and furnishings on panel heating performance (ASHVE Transactions, Vol. 60, 1954, p. 121).

³ L. F. Schutrum and J. D. Vouris: ASHAE Research Report No. 1516—Effects of room size and non-uniformity of panel temperature on panel performance (ASHVE Transactions, Vol. 60, 1954, p. 455).

⁴ H. H. Macey: Heat loss through a solid floor (*Institute of Fuel Journal*, 22-128, p. 369).

⁵ E. L. Sartain and W. S. Harris: Performance of covered hot water floor panels, Part I—Thermal characteristics (ASHAE Transactions, Vol. 62, 1956, p. 55).

⁶ A Subcommittee of the TAC on Panel Heating and Cooling, R. L. Maher, Chairman; W. P. Chapman; H. T. Gilkey; P. B. Gordon; E. F. Snyder; and J. M. Van Nieuwerkerken; and by ASHAE Laboratory Staff Members, L. F. Schutrum, G. V. Parmelee, and C. M. Humphreys: ASHAE Research Report No. 1600—Thermal design of warm water concrete floor panels (ASHAE Transactions, Vol. 63, 1957, p. 239).

⁷ A Subcommittee of the TAC on Panel Heating and Cooling, R. L. Maher, Chairman; W. P. Chapman; H. T. Gilkey; P. B. Gordon; E. F. Snyder; and J. M. Van Nieuwerkerken; and by ASHAE Laboratory Staff Members, L. F. Schutrum, G. V. Parmelee, and C. M. Humphreys: ASHAE Research Report No. 1559—Thermal design of warm water ceiling panels (ASHAE Transactions, Vol. 62, 1956, p. 71).

BIBLIOGRAPHY

- B. F. Raber and F. W. Hutchinson: Trend curves for estimating performance of panel heating systems (ASHVE Transactions, Vol. 48, 1942, p. 425).
- B. F. Raber and F. W. Hutchinson: ASHAE Research Report No. 1192—Panel heating and cooling performance studies (ASHVE Transactions, Vol. 48, 1942, p. 55).
- F. C. Houghten, Carl Gutberlet, and E. C. Hach: ASHVE Research Report No. 1193—Radiation as a factor in the feeling of warmth in convection radiator and panel heated rooms (ASHVE Transactions, Vol. 48, 1942, p. 55).
- B. F. Raber and F. W. Hutchinson: Panel heating and cooling, analysis (ASHVE Transactions, Vol. 47, 1941, p. 285).
- E. J. Rodie: Operating results of a residence radiant wall heating system (ASHVE Transactions, Vol. 47, 1941, p. 123).
- H. F. Randolph and J. B. Wallace: Performance of a residential panel heating system (ASHVE Transactions, Vol. 49, 1943, p. 235).
- Radiant heating (*Heating and Ventilating*, March 1941, p. 35).
- F. E. Giesecke: Radiant heating and cooling (*Heating, Piping and Air Conditioning*, June, July, August, September and October 1940).
- T. N. Adlam: Calculations for radiant heating (*Heating and Ventilating*, October 1931).
- C. O. Mackay, L. T. Wright, Jr., R. E. Clark, and N. R. Gay: Radiant Heating and Cooling (Cornell University, Engineering Experiment Station Bulletin No. 32, 1943).
- R. G. Vanderweil: Design method for panel heating systems using copper tubing (ASHVE JOURNAL SECTION, Heating, Piping and Air Conditioning, November 1947, p. 123).
- J. M. Ayres and B. W. Levy: Air temperature gradients in a panel heated room (ASHVE Transactions, Vol. 54, 1948, p. 131).
- W. P. Chapman and R. E. Fischer: Graphical solution of radiant panel areas (*Heating and Ventilating*, January 1948, p. 88).
- D. L. Mills and L. J. LaTart: Embedding coils in radiant heating panels (*Heating and Ventilating*, December 1947, p. 75).
- D. L. Mills and L. J. LaTart: Radiant heat with copper tubing (*Heating and Ventilating*, November 1947, p. 95).
- D. L. Mills and L. J. LaTart: Panel heat with copper tubing—experiment in practice (*Heating and Ventilating*, October 1947, p. 66).
- B. F. Raber and F. W. Hutchinson: Experimental studies on panel heating tube spacings (ASHVE Transactions, Vol. 53, 1947, p. 369).
- S. Konzo: Panel heating—a basic discussion (*American Artisan*, October 1946, p. 68).
- John E. Peterson: Solar house heated by a warm air floor panel (*American Artisan*, December 1946, p. 83).
- A. B. Algren: Design data for a warm air floor panel (*American Artisan*, January 1947, p. 141).
- C. S. Leopold: The mechanism of heat transfer, panel cooling, heat storage (*Refrigerating Engineering*, July 1947, p. 33).
- Radiant Heating—Simplified Design and Installation* (Copper and Brass Research Association, 1949).
- C. M. Humphreys, H. B. Nottage, C. V. Franks, R. G. Huebscher, L. F. Schutrum, and D. W. Locklin: ASHVE Research Report No. 1387—Laboratory studies on heat flow within a concrete panel (ASHVE Transactions, Vol. 56, p. 175).
- L. E. Hulbert, H. B. Nottage, and C. V. Franks: ASHVE Research Report No. 1388—Heat flow analysis in panel heating or cooling sections (ASHVE Transactions, Vol. 56, 1950, p. 189).
- C. F. Kavan: Electric analog studies on panels with imbedded tubes (ASHVE Transactions, Vol. 56, 1950, p. 205).
- A. B. Algren: ASHVE Research Report No. 1345—Ground temperature distribution with a floor panel heating system (ASHVE Transactions, Vol. 54, 1948, p. 321).
- F. W. Hutchinson, D. L. Mills, and L. J. LaTart: Losses from a floor-type panel heating system (ASHVE Transactions, Vol. 57, 1951, p. 37).
- C. M. Humphreys, C. V. Franks, and L. F. Schutrum: ASHVE Research Report No. 1418—Field studies of heat losses from concrete floor panels (ASHVE Transactions, Vol. 57, 1951, p. 221).
- N. S. Billington: Losses from heated floors (*Journal of the Institution of Heating and Ventilating Engineers*, June 1953).
- E. L. Sartain and W. S. Harris: Heat flow characteristics of hot water floor panels (ASHAE Transactions, Vol. 60, 1954, p. 103).
- F. C. Houghten, S. I. Taimuty, Carl Gutberlet, and C. J. Brown: ASHVE Research Report No. 1213—Heat loss through basement walls and floors (ASHVE Transactions, Vol. 48, 1942, p. 369).
- R. S. Dill, W. C. Robinson, and H. E. Robinson: *Measurements of Heat Losses from Slab Floor* (National Bureau of Standards, Building Materials and Structures Report BMS 103).
- H. A. Bareither, A. N. Fleming, and B. E. Alberty: Temperature and heat loss characteristics of concrete floors laid on ground (*American Artisan*, March 1950).
- N. S. Billington: Heat loss through solid ground floors (*Journal of the Institution of Heating and Ventilating Engineers*, November 1951).
- J. R. Jamieson, R. W. Roose, and S. Konzo: Warm-air perimeter heating: Part III—Heat losses from floor slab (ASHVE Transactions, Vol. 58, 1952, p. 217).
- M. Baker, J. M. O'Byrne, and A. M. Levy: Estimating the heat loss from slab floors and basements (*Heating, Piping and Air Conditioning*, November 1952).
- N. S. Billington and E. W. Shaw: Experiments with intermittently operated floor panels (*Journal of the Institution of Heating and Ventilating Engineers*, June 1952).
- N. S. Billington: Heat loss through solid ground floors—II (*Journal of the Institution of Heating and Ventilating Engineers*, November 1952).
- H. R. Martin, P. R. Achenbach, and R. S. Dill: *Effect of Edge Insulation Upon Temperature and Condensation on Concrete Slab Floors* (National Bureau of Standards, Building Materials and Structures Report No. 138, October 1953).
- Aydin Umur, G. V. Parmelee, and L. F. Schutrum: ASHAE Research Report No. 1528—Measurement of angular emissivity (ASHAE Transactions, Vol. 61, 1955, p. 111).
- C. M. Humphreys, C. V. Franks, and L. F. Schutrum: ASHVE Research Report No. 1426—Laboratory studies of the thermal characteristics of plaster panels (ASHVE Transactions, Vol. 57, 1951, p. 363).
- L. F. Schutrum and C. M. Humphreys: ASHVE Research