Radiant Heating Serves War Plant

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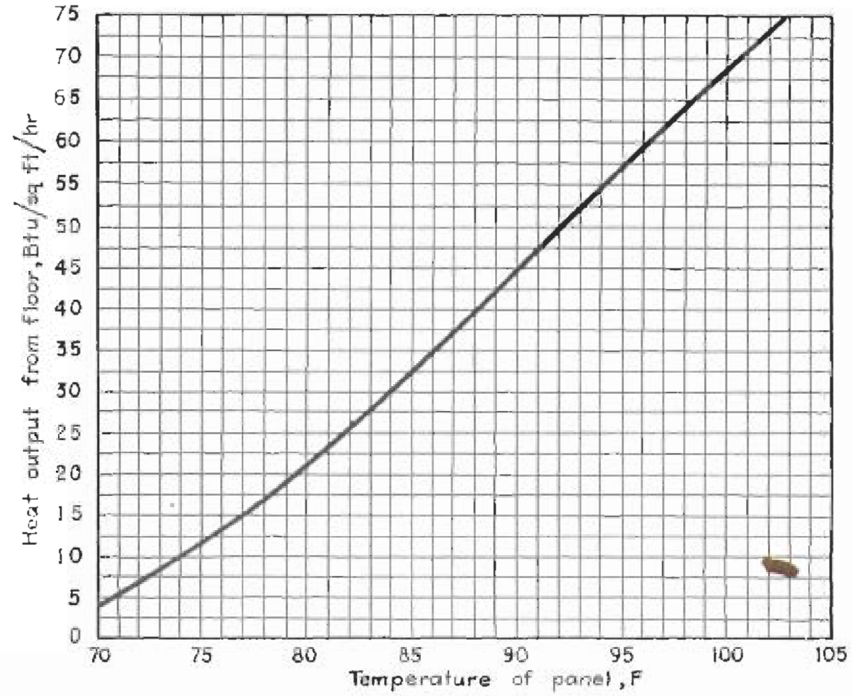
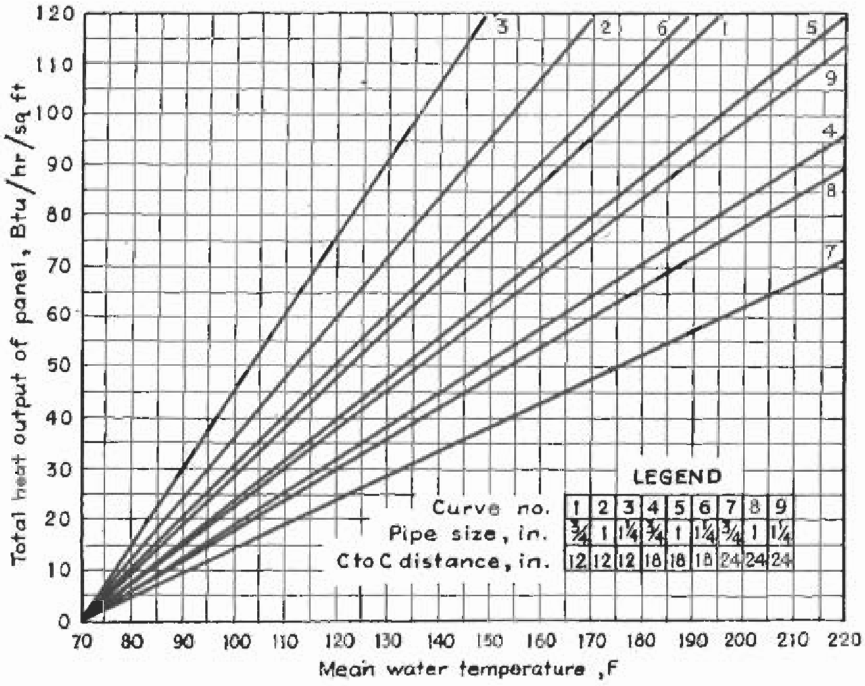


Fig. 1—Calculated heat output from floor panels at various temperatures, based on air at 70 F and assuming average wall and ceiling temperatures of 65 F



▶ In recent years, the possibilities of radiant heating have intrigued many engineers. Its merits have often been extolled in print, but actual installations are comparatively few and the buildings are in general small, or radiant-heating equipment is supplemental only. The few reports of large jobs have usually given little information about design and installation.

We look with interest, then, at a recently completed one-story building without basement, 80 ft by 280 ft long. One of a group of industrial buildings, designed and constructed by Stone & Webster Engineering Corp to provide additional war-production facilities, this building uses a minimum of critical materials and is essentially utilitarian. Walls are brick, sash is wood, columns wood, roof trusses prefabricated plywood, roof insulated plywood and floor concrete.

Selection of radiant heating gives certain practical advantages: 1. Building's entire interior width is available for desk and working space. 2. Eliminating exposed radiation and piping makes interior more attractive. 3. Radiant heating eliminates trenches for return lines, a number of which would have been required at the several exterior doors even if return lines had been exposed on the walls.

Building Arrangement

The personnel department occupies the building's west end, which comprises 6400 sq ft and is divided into reception and waiting rooms, interview, examination and medical-analysis rooms. Remainder of the building, comprising 16,000 sq ft, includes two cafeterias, each seating 450 people, and a kitchen centrally located between the cafeterias.

As floors were to be concrete, heating coils were installed in the floor slab. Small areas, which need more

Fig. 2—Relation between heat dissipated per sq ft of panel surface, mean water temperature, and size and spacing of ferrous pipe. Based on 3.5 Btu per hr per sq ft of pipe surface per deg F temperature difference, water to air

heat than the slab could give off, required a few panels in partitions. Hot water was chosen as the heating medium because of the low temperatures possible and the convenience of distribution control with forced circulation. The floor slabs were divided into four sections, comprising the building's four areas. Perimeter of each slab was separated from the building's side walls and from each other by expansion joints, which were inserted around the columns so that the slab in each section was free to move as the concrete temperature changed.

Heat losses from the building, which were calculated in the conventional manner, assuming air temperatures of 70 F for office space and 65 F for cafeteria space, were as follows (Btu per hr):

West-end personnel zone	157,000
Center cafeteria zone	120,000
Kitchen zone	94,000
East-end cafeteria zone	160,000
Total	531,000

Sufficient pipe surface was installed to overcome this total loss of 531,000 Btu, plus an allowance of 149,000 Btu to compensate for heat loss into the ground. Total installation included 15,000 linear ft of pipe, of which 13,500 ft was 1 in. and the balance ¾ in., 1¼ in. and 1½ in. Total calculated heat loss represented 1.85 Btu per hr per cu ft of heated space, which compares with a reported amount of 1.1 Btu per hr per cu ft heated space for buildings in Europe where lower temperatures are maintained and weather conditions are not so severe.

Design was based on a mean water temperature of 105 F at 0 F outside temperature and a temperature drop in the system of 20 F. Maximum temperatures of floor slabs in constantly occupied areas were calculated not to exceed 85 F. Floor temperatures for entrances, toilets, etc, were calculated up to 96 F because length of occupancy is limited and physical discomfort would not result by foot contact with surfaces at this temperature for short periods.

Basis for required temperatures of the floor slabs in the different areas and size and spacing of pipe coils to furnish this were determined from data originally published in an article in September, 1941, *Plumbing and Heating Business:* "A Working Method for Calculating a Floor Type Radiant Heating System." Fig. 1 and 2 are adapted from this article. For the east-end cafeteria, which has an open area of 5,520 sq ft with three wall exposures, calculation was as follows:

Heat output required of the floor panel:

$$\frac{160{,}000 \text{ Btu heat loss}}{5{,}520 \text{ sq ft}} = 29 \text{ Btu/sq ft/hr}$$

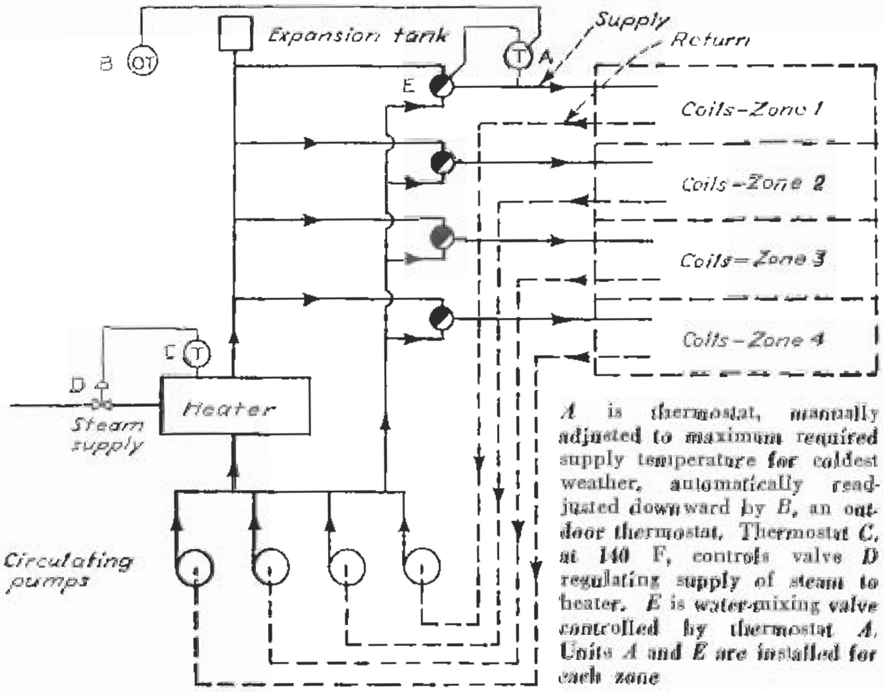
Required floor temperature: Fig. 1 calls for a floor temperature of 83 F, which is below the 85 F desirable maximum for this occupancy

Amount of heat required to offset flow of heat into ground: Allow 30% (floor slab to be installed directly on tamped earth) 29 × 0.3 = 8.7 Btu per sq ft per hr

Total input to be supplied to floor:

$$29 + 8.7 = 37.7 \text{ Btu/sq ft/hr}$$

Size and spacing of coils to supply this amount: Assuming 105 F mean water temperature, Fig. 2 shows that 1



A is thermostat, manually adjusted to maximum required supply temperature for coldest weather, automatically readjusted downward by *B*, an outdoor thermostat. Thermostat *C*, at 140 F, controls valve *D* regulating supply of steam to heater. *E* is water-mixing valve controlled by thermostat *A*. Units *A* and *E* are installed for each zone

Fig. 3—Four-zone radiant-heating hookup with forced circulation of hot water

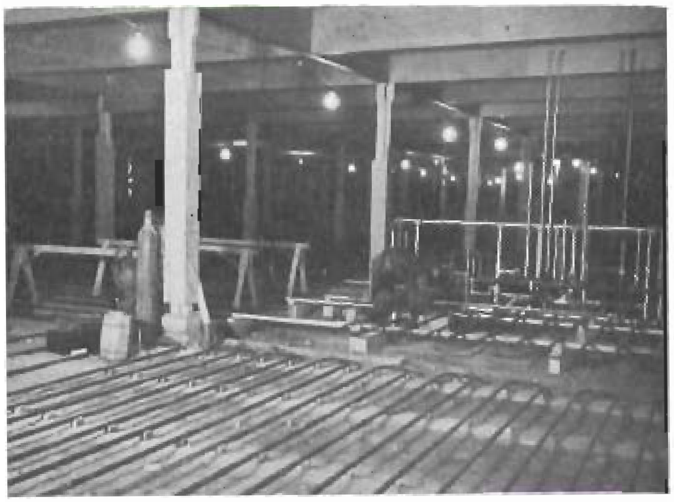


Fig. 4—Pipe coils in place before pouring concrete slab

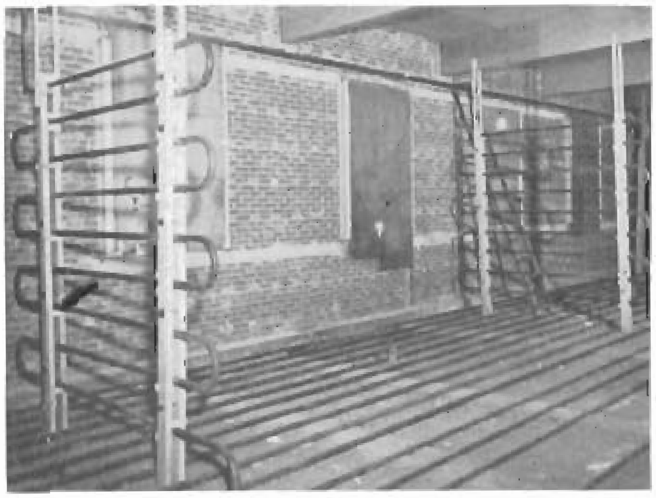


Fig. 5—Typical arrangement of pipe coils for wall panels

in. pipe 12 in. on centers would supply 42 Btu/sq ft, and 1¼ in. pipe 18 in. on centers would supply 35.5 Btu/sq ft. In this case, 1-in. pipe was selected as this size was to be most generally used and as a slight adjustment of mean water temperature would permit securing the required heat input.

Total input required to be supplied to this zone:

37.7 Btu/sq ft × 5520 = 208,000 Btu/hr.

Amount of water to be circulated:

$$\frac{208{,}000 \text{ Btu}}{20 \text{ F} \times 60 \text{ min} \times 8 \text{ lb/gal.}} = 21.7 \text{ gpm}$$

Calculations for each separate room were made in a similar manner. Where small offices at exterior walls required an excessive floor temperature if all heating were to be done by the floor panel, a wall panel supplemented it and reduced the floor temperature to below 85 F maximum. Fig. 5 shows typical wall-panel construction.

Zoning Arrangement

As calculated above, the east cafeteria has a designed floor temperature of 83 F, with 1-in. pipes spaced generally 12 in. on centers. The 5200 linear ft of pipe in this area is divided into four circuits. It was attempted in each of the four zones to design the circuits so that a rational balance between the small quantities of water handled and the pumping head of the pumps would be obtained. With approximately 22 gpm in this area, a 1½-hp motor was required for 68 ft head. The other three zones have pumps with 1-hp motor handling 14 to 20 gpm at 62 to 65 ft head.

Kitchen zone includes a number of rooms such as toilets, locker room, entrance and office. Main kitchen area has a designed floor-slab temperature of 77 F with 1-in. pipes 24 in. on centers. Toilet rooms and vestibule have designed floor temperatures of 90 F with 1¼-in. pipe 12 in. on centers. This zone is divided into three pipe circuits.

The west cafeteria with two exposed walls has a designed floor-slab temperature of 80 F with approximately 3600 linear ft of 1-in. pipe, 18 in. on centers. Three pipe circuits are used.

Most difficult problem was the personnel-examination area as it was subdivided into many different-sized rooms. Interview rooms and offices had 8-ft partitions separating them from the main office space. Ratio of floor area to heat loss made it impossible to install sufficient piping in the floor for adequate heat without extremely high floor temperatures. Partitions being open at the top, part of the heat loss was allocated to the main office area and additional pipe was installed there to take care of the extra loss. In addition, four separate wall coils of 1¼-in. pipe, 12 in. on centers, were installed. Other than the above, all pipes are in the floor slab. The main personnel area has a designed floor-slab temperature of 77 F with 1-in. pipes 24 in. on centers. Interview rooms and offices have designed slab temperatures of 85 F with 1-in. pipes generally 12 in. on centers. Toilet rooms and main entrance have designed slab temperatures of 96 F with 1¼-in. and 1½-in. pipe, 12 in. on centers. Because of the cut-up area of the surface, this zone was divided into six circuits.

Piping Circuit Design

To save installing a large number of lockshield balancing valves which, by the nature of the system, would be difficult of access, great care was taken to design each circuit with equal pressure drop. This care was justified by results of initial tests. Most of the 16 circuits were sufficiently in balance so that it was necessary to install valves in only a few circuits.

Operation has not been of sufficient duration to determine whether a less liberal allowance would have compensated for the downward heat loss into the ground. Preliminary tests indicate that possibly a smaller allowance would have been adequate as inside temperatures have been comfortable in severe weather with slightly lower water temperatures than calculated.

Relative assembly of circulation and heating equipment serving the heating installation is diagrammed in Fig. 3.

Hot-Water Supply System

Hot water converter, circulating pumps and controls are located in an equipment room in an adjacent manufacturing building because of lack of space in the personnel building. The four hot-water supplies and returns run underground in a trench and thence underfloor to the various zones. Throughout care was taken to allow for expansion and contraction in the connections from the underfloor mains to the piping in the slabs. Steam is supplied to the converter at 10 psi. A self-contained temperature regulating valve maintains a constant water temperature in the converter.

A 125-gal. closed expansion tank with water-fill line, and combination pressure-reducing and relief valve provides for expansion. Four hot-water circulating pumps operating continuously handle the circulating water.

Zone Control

Each of the four zones is controlled by a 3-way mixing valve. An adjustable immersion thermostat with remote control located on a main panel board is installed to operate each 3-way valve. The basic water temperature for these thermostats is regulated by an outdoor pilot thermostat. The remote-control adjustable feature of these thermostats permits increase or decrease of basic water temperature to meet possible variable demands in the different zones. As a case in point, the personnel area has an asphalt tile floor, while the rest of the areas have monolithic floors. Asphalt tile floors require 10 to 15 deg. higher water temperature than monolithic floors. Moreover, during busy hours the kitchen requires lower water temperatures than the other zones. Immersion thermostats can take care of these variations through manual operation from the panel board.

Piping Installation

All the piping is genuine, standard weight, wrought iron. It was bent cold at the job and assembled in sections above the spot in which it was to be located. After welding, the coils were laid in position and final connections were welded in place. A 500-psi hydrostatic test was made for each circuit. Length of test period was 12 to 24 hr.

The photograph of a portion of the installation, Fig. 4, before pouring the floor slab gives a vivid idea of the general piping arrangement of this type of heating system.

Before the concrete slab was poured the pipes were laid approximately level and 2 in. above the finished grade to the center of the pipe. This left approximately 4½ in. of concrete above the greater portion of the piping. When the slab was ready for pouring, a temporary warm water connection was made to the pumps and water at 100 F was circulated through all pipes while the concrete was poured, and until it had thoroughly set. This allowed piping and concrete to attain an approximate average point of expansion. The rather unusual scheme seems to have been fully justified because during the first two operating months no cracks have been observed on the finished surface of the concrete floor slab.