For larger surfaces the conditions are different. If two parallel plane surfaces of considerable size are near each other, the rate of heat exchange between the two can be determined fairly accurately by means of the chart of Fig. 9. This is possible because the larger part of the heat radiated by one of the surfaces is intercepted by the other surface and only a small portion is radiated in such directions that it will not impinge upon the opposite surface.

As the distance between the two surfaces is increased, the proportion of the heat radiated by one of the parallel plane surfaces and intercepted by the other decreases almost as the square of the distance between the surfaces increases, because the intensity of heat radiation, like the intensity of light radiation, varies inversely as the square of the distance from the source of radiation.

For the purpose of designing radiant heating systems in which the heating panel is practically square and is radiating heat toward a parallel surface of equal size and shape, as shown in Fig. 11, the rate of heat exchange between the two surfaces will be equal to that shown in Fig. 9, multiplied by a factor, p, which depends upon the ratio of h to s (Fig. 11) as shown in the following table:

h/s =	1	2	3	4	5
p =	0.200	0.070	0.034	0.020	0.013

For example, if a panel 3 ft square is located parallel to, and 9 ft above, a bed in an open-air hospital, and if the temperature of the panel is 112 F and that of the bed is 70 F, the rate of heat transfer from the panel to a 9 sq ft section of the bed directly beneath the panel, will be 3.4 per cent of the rate shown in Fig. 9, or $0.034 \times 9 \times 44$, or 14 Btuh, approximately. The rate of heat transfer from the panel to a section of the bed other than the 9 sq ft directly beneath the panel will be lower than 14/9 Btuh per square foot.

This is a crude way of designing a radiant heating system for an open-air hospital, but it is sufficiently accurate, because the required temperature of the bed and the required rate of heat flow into it will vary with the temperature of the outdoor air, with the air movement over the bed, with the thickness and the character of the bedding, and with the physical condition of the patient.

A radiant heating system for an open-air school may be designed as described for the open-air hospital. The heating panel in such a case should be almost as large as the ceiling and, in order to keep the heat loss by radiation at a minimum, should be placed so that a maximum portion of the heat radiated by the panel will be directed toward the pupils and a minimum toward the outside walls and particularly the windows.

MEASUREMENT OF RADIANT HEATING

Radiant heating is intended to control the rate of radiant heat loss from the human body and should be measured by calorimetric methods.

The apparatus for this purpose consists essentially of a cylinder, maintained at the accepted mean surface temperature of the human body, together with an accurate (usually electrical) measuring of the varying rate of heat supply required to maintain this exact temperature. This instrument, the *eupatheoscope*, is readily adapted to function like a thermostat so as to turn heat on or off, when the desired temperature of 80 F, or any other predetermined surface temperature of the cylinder,

decreases or increases as a result of changes in the Operative Temperature.

For testing work, the *globe thermometer* is a useful instrument. It consists of an ordinary mercury thermometer, with its bulb placed in the center of a sphere from 6 to 9 in. in diameter, usually made of thin copper and painted black and sometimes covered with cloth. The temperature recorded by thermometer with its bulb in the center of the sphere is termed the *radiation-convection temperature*. See Chapter 11.

CONTROL OF PANEL AND RADIANT HEATING

The effectiveness of any type of control will depend largely on the time lag of the system. With warm air passing through floor ducts the time lag is usually too long for any kind of room thermostat, in fact a thermo-

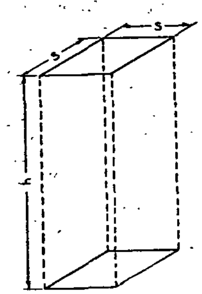

Fig. 11. Effect of Height Upon Radiation Received from a Panel

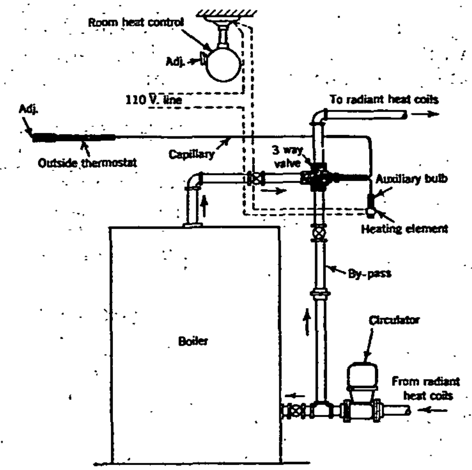

Fig. 12. Typical Panel and Radiant Heat Control System

stat will not prove suitable with any system if the building is constructed with massive brickwork and masonry, unless it operates in conjunction with a time control responsive to changes in outside conditions.

The heat emitted by hot water pipes imbedded in the plaster of the ceiling and walls or in the concrete base of a floor can be effectively controlled by an instrument designed to modulate the temperature of the water circulating in the system according to the outside conditions. Metal panels which can be installed in the ceiling or side walls may be either controlled by an instrument responsive to outside weather conditions or by a specially designed instrument responsive to both air temperature and radiation. Any purely *on or off* control system is not recommended for panel heating.

A typical control system operated from an outside thermostat and supplemented with a room heat control instrument is illustrated in Fig. 12. The outside thermostat modulates the temperature of the circulating water in the coils by mixing some of the hot water leaving the boiler with a proportionate amount of return water which is diverted to the three-way valve.