be actuated by outdoor temperature (load) to determine the basic temperature of the heating medium supplied to the radiant surface. To allow for variations in internal load, an inside thermostat should be used as a high limit to reduce further the heat input, if necessary. If a thermally *light* radiant surface is used, controls may be applied in the same manner as for typical convection heating.

The terms *thermally heavy* and *thermally light*, referring to capacity for heat storage, are comparative and descriptive rather than exact. For example, a concrete floor panel in a frame structure without insulation would represent a *heavy* panel in a *light* structure. A frame type (metal lath and plaster) panel in a concrete structure would represent a *light* panel in a *heavy* structure. As indicated previously, a *heavy* panel in a *heavy* structure provides comfortable conditions if outside controls are used in addition to the inside thermostat. But if a *heavy* panel is used in a *light* structure, rapid changes in outdoor conditions may cause discomfort in spite of outdoor controls, because the structure reacts so much more rapidly than the radiant heating surface.

Since thermally *heavy* radiant surfaces introduce considerable lag in the heating system, it is desirable that a control system be capable of maintaining the lag at a minimum. One method of reducing the lag in heat output is to utilize design water temperature in the panel, thus causing maximum rate of heat from the water in the pipe coils through the concrete slab to the surface of the panel, and into the space when heat is needed. Satisfactory control can be obtained only if the control system is sensitive enough to regulate the heat output of the panels with sufficient precision to prevent over-heating, and to anticipate heat demand as affected by outside weather conditions.

Circuit Balance

In addition to a thermostatically controlled device for modulating the temperature of the circulating water, it is advantageous to insert in each circuit a locked flow control or adjustable resistance to give uniform conditions throughout all rooms. Owing to unforeseen difficulties with varying frictional losses in pipes, emission factor, and exposures, it is an advantage to be able to regulate permanently the flow through each circuit by means of a key operated valve as indicated in Fig. 3.

Compensation for Increase of MRT

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 should theoretically be lowered to maintain comfort. In ordinary structures, with normal infiltration loads, the required reduction in air temperature is not great and a conventional fixed control point room thermostat may be used. If a large infiltration load exists, or if untempered mechanical ventilation is employed, a thermostat with variable control point should be considered. Because of the relationship between MRT and air temperature in the space (and the variable MRT from point to point in the space) a conventional type of room thermostat (either fixed or variable control point as previously determined) measuring principally air temperature, should provide simple and satisfactory control.

Lowered Night Temperature

In general, lowered night temperatures will produce very unsatisfactory conditions with any *panel heating* system. Heavy panels such as concrete floors cannot possibly respond to either increase or decrease in temperature within any reasonable time. Light panels such as plaster ceilings or walls may respond, with sufficient rapidity to changes in temperature, so that moderately satisfactory results can be expected from lowered night temperatures. However, very little fuel saving can be expected even with these light panels.

Typical Control Systems

There are many methods of control which are used in connection with panel heating systems. Some systems provide continuous circulation of the water and vary the water temperature to counteract variations in the outdoor temperature, space temperature, or a combination of these temperatures. Several systems of control depend upon intermittent circulation of the water, either by intermittent pump operation or the closing and opening of valves, in combination with either constant water temperature or with variations in the water temperature.

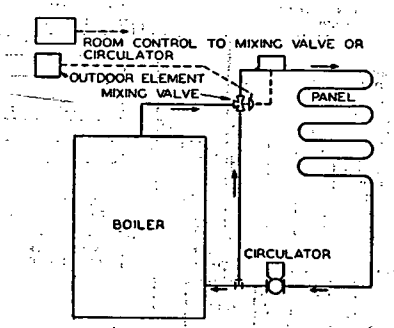

FIG. 3. PANEL HEATING CONTROL SYSTEM

Fig. 3 shows a typical arrangement of the essential parts of a simple panel heating system, which has several possible variations, depending upon the equipment used. The heating unit controls and safety devices are not shown. These devices are described under Residential Control Systems.

One system of control uses a self-contained three-way mixing valve operated by an outdoor thermostat to maintain the water temperature in inverse proportion to changes in the outdoor temperature. The indoor thermostat stops and starts the water circulator as required to maintain the space temperature. If more than one zone is to be controlled, a separate indoor thermostat is used to control operation of a separate circulator for each zone.

Another arrangement has a self-contained three-way water mixing valve controlled by an outdoor thermostat in conjunction with an indoor heat-sensitive element. This instrument may be a blackened copper sphere perhaps 8 in. in diameter that will overcome the outdoor thermostat influence on the mixing valve if the indoor temperature varies too much.

Another scheme employs a three-way water mixing valve operated by an electric motor. The impulses from the outdoor thermostat, indoor thermostat and an aquastat in the mixed water all are electronically coordinated to control the mixing valve motor.

Fig. 4 shows a typical electronic control system arranged for circulator