in partially filling the heating units in accordance with demand. This method can be used on atmospheric or vacuum return systems.

2. Varying the pressure in the system while maintaining a constant differential pressure between the supply and return. This results in the heating units being filled with steam at a temperature which is proportional to demand. A vacuum pump maintaining a vacuum slightly below the supply pressure is required, and vacuums as high as 20 in. Hg during mild heating weather are common.

In *intermittent systems* steam at full pressure is supplied intermittently to the zone, the length of the *on* and *off* periods being varied in accordance with the demands of the control system. Two common arrangements are:

1. A timing device controlled by an outdoor thermostatic element which can be used to vary the on-off periods of boiler operation or the opening and closing of a steam valve as a function of outdoor temperature.

2. A control responding to an outdoor element and an element attached to a radiator or convector, so that it varies the length and frequency of the on-off intervals in such a way that the radiator or convector temperature is varied in accordance with outdoor temperature.

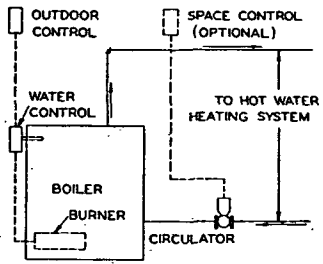

FIG. 7. CONTROL OF HOT WATER HEATING WITHOUT DOMESTIC HOT WATER SERVICE
(Limit and primary controls not shown)

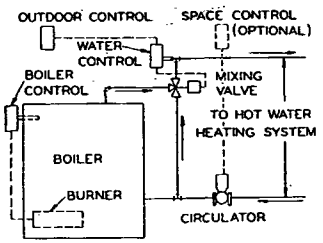

FIG. 8. CONTROL OF HOT WATER HEATING WITH PROVISIONS FOR DOMESTIC WATER HEATING
(Limit and primary controls not shown)

For proper operation of zone control equipment the heating system must be carefully designed and installed, and maintained in good operating condition. Vents, traps, vacuum pumps and valves must be given a careful inspection and repaired or replaced when required. Piping must be of adequate size graded and dripped. Return piping must be vented and any pockets or lifts removed.

Hot Water Heating Systems

A common method of obtaining zone control of hot water systems consists of varying the temperature of water supplied to the zone inversely as the outdoor temperature varies. This may be accomplished by a submaster thermostat in the zone supply line readjusted by an outdoor master thermostat, or by a single controller having one measuring element in the supply line and another compensating element outdoors. On single zone installations the controller may actuate the burner directly as shown in Fig. 7. If the boiler is also used for domestic hot water the controls may be arranged as in Fig. 8. In this case the boiler is controlled at a fixed temperature and the zone controller is arranged to operate a valve to proportion hot water from the boiler with cooler return water to obtain the desired zone water temperature. On multiple zone installations the boiler usually is controlled at a fixed temperature, and each zone is controlled by a separate valve and

outdoor compensated controller. Each zone should be equipped with a separate pump because in many cases the return water from some zones is warmer than the required supply water for other zones. By using individual zone pumps the returns can be separated and thus prevent overheating that would otherwise occur.

To compensate for variations in internal load, the action of the zone control may be modified by a room thermostat in each zone which either starts and stops the zone pump, modifies the relationship between outdoor temperature and water temperature, or operates an automatic valve in the zone supply or return line. Each zone may be further subdivided by providing a separate thermostat and valve for each subdivision.

Another zone control method for hot water systems consists of maintaining a constant water temperature and varying the volume of water supplied to the zone by means of a room thermostat which either starts and stops the zone pump or operates a two-position valve in the zone supply or return line.

Whenever flow control valves are employed in water circuits it is necessary to employ a relief valve or pressure-regulating valve in a bypass connection around the pump.

PANEL HEATING SYSTEMS

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 same control principles for hot water heating systems will also apply to panel heating.

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 cycling of 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, as described in the first paragraph under Hot Water Heating Systems in the section on Zone Control Systems. Controls indicated in Figs. 7 and 8 apply and, in addition, consideration should be given to preventing the introduction of excessively hot water in the event of control failure which might damage the panels, and to a manual boiler bypass or other means of reducing the water temperature to prevent too rapid drying out of new panels (see Chapter 23, Panel Heating). 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