The control of air-handling units in a hot water heating system requires careful consideration. Where the piping required is within economical limits, it is advisable to use a three-way mixing valve and a pump in the coil circuit (see Fig. 19, Chapter 28) to achieve control. This arrangement provides a constant flow to the coil while the temperature of the water to the coil is varied by changing the mixture of supply water and return water. If impracticable to use separate three-way valves and pumps for each coil, it is necessary when varying the flow to a hot water coil to use control valves with plugs or discs designed for close control of flow. They should also be sized accurately for the flow required by the coil at a pressure drop as large as the pump and the piping system will permit. Face and bypass dampers to vary the flow of air over a coil with constant water flow can be used in the control of air-handling units.

Precautions should be taken to prevent the freezing of water in a hot water heating system whenever design outdoor temperatures are lower than approximately 20 F, particularly if the system is to be operated on an intermittent basis as in schools where normal operation is not required on Saturdays or Sundays or during vacation periods. In selecting a means of freeze protection, consideration should be given to the type of system as well as outdoor temperature. For instance, an air-handling unit to heat outdoor air must have the coil protected for 32 F, whereas supply mains and radiation usually are not subjected to freezing temperatures until the outdoor temperature drops considerably below 32 F for extended periods. Intake dampers on air-handling units that heat outdoor air should be interlocked with the fan motor so as to close whenever the fan is not running. Provision should be made to close the outdoor-air intake and/or stop fan operation if the water circulating in the coil drops below a safe temperature level. The possibility of water freezing in the mains can be minimized by using an outdoor thermostat to provide continuous circulation of the water whenever the outdoor temperature drops below approximately 30 F. Another arrangement uses an interval timer and outdoor thermostat to provide intermittent cycling of the circulating pump whenever the outdoor temperature drops below some predetermined temperature. A thermostat in the return water at the boiler can be used to start the burner or other heat source if the temperature of the return water drops to about 40 F. See Chapter 43 for general information on controls.

ZONE CONTROL OF STEAM AND WATER SYSTEMS

This section is concerned with zone controls for steam or hot water heating systems. Refer to Part II of this chapter for a general discussion of zoning.

Most zone control systems are designed to supply heat to a zone at a rate equal to the heat loss. This rate of heat input may be established by room thermostats, by controllers responsive to outdoor conditions, or by a combination of both. The outdoor controller responds to temperature and may respond to solar radiation and wind velocity and direction. Features which may be added to the basic zone control system include:

1. Means for automatically or manually varying the heat input to the zone to compensate for variations in internal heat gain. The automatic arrangement requires a thermostat at a representative location within the zone. The manual arrangement usually consists of a switch located where convenient.

2. Means for maintaining a lowered economy temperature or shutting off the heat completely at night or at other times when the zone is unoccupied. This may be accomplished manually or by means of a clock.

3. An arrangement providing rapid warm-up following a period at the nonoccupancy temperature. During this warm-up period full heat may be admitted to the system or the heat input may be controlled at a higher-than-normal rate. The warm-up may be accomplished by a manual switch or may be part of the clock program. A warm-up thermostat located within the zone may be arranged to terminate the warm-up period independently of the switch or clock when the zone approaches the desired occupancy temperature.

4. A manual switch to provide full heat or no heat independently of other controls and to permit manual selection of the various clock functions.

5. Means for shutting off the heat completely when the outdoor temperature reaches a point where heat no longer is needed.

6. A high-limit thermostat in the zone to shut off the heat completely when the zone becomes overheated.

Steam: Zone Distribution

In *continuous-flow steam systems* the quantity of steam supplied to the zone is varied in accordance with the demands of the control system. To obtain equalized distribution of the steam, metering orifices are generally required on the inlets to all radiators or convectors. Supplementary controls for low heat output are often desirable. The following two arrangements are common:

1. Varying the difference in pressure between the supply and return which results 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. This 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.

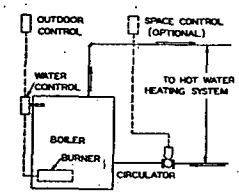
2. A control responding to an outdoor element and an element attached to a radiator or convector. This control varies the length and frequency of the on-off intervals in such a way that the radiator or convector temperature is varied in accordance with outdoor temperature.

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.

Water: Zone Distribution

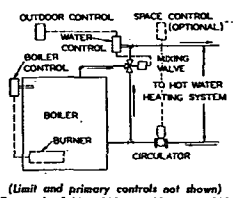
A common method of obtaining zone control of hot water systems consists of varying the temperature of water supplied to the zone inversely as the outdoor temperature varies. This may be accomplished by a submaster thermostat in the zone supply line readjusted by an outdoor master thermostat, or by a 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. 25. If the boiler is also used for domestic hot water the controls may be arranged as in Fig. 26. 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



(Limit and primary controls not shown)

Fig. 25 .... Control of Hot Water Heating Without Domestic Hot Water Service



(Limit and primary controls not shown)

Fig. 26 .... Control of Hot Water Heating With Provisions for Domestic Water Heating

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.

TERMINAL EQUIPMENT

Control applications to the following types of terminal equipment are described in their respective chapters:

Radiant Panels—Warm Air Ceiling Panels, Chapter 18
—Hot Water Panels, Chapter 30
—Electric, Chapter 30 and 17
Snow Melting, Chapter 49
Unit Heaters, Chapter 15
Unit Ventilators, Chapter 15
Unit Air Coolers, Chapter 16
Induction Units, Chapter 19
Dual-Duct Mixing Units, Chapter 19
Room Fan-Coil Units, Chapter 19
Reheat Coils for Individual Spaces, Chapter 19

Classroom Heating and Cooling Units

Controls for winter heating and ventilating are essentially the same as for classroom unit ventilators as described in Chapter 15, Unit Ventilators and Unit Heaters, except that face and bypass dampers are usually added. The supply hot water temperature should be varied inversely with outdoor temperature for best results. The space thermostat operates the face and bypass dampers, coil valve, and the outdoor- and return-air dampers.

When the system water is changed from hot to chilled water the controls are reversed. For summer cooling the outdoor-air damper opens to a fixed position to admit the required percentage of outdoor air when the fan motor is started. The space thermostat is now reverse-acting and operates only the face and bypass dampers at the cooling coil while the valve remains open.

Radiators and Convectors

When individual room control is used each radiator and convector is equipped with an automatic control valve. Depending upon the size of the room one thermostat may control one or several valves in unison.

Volume Damper or Single-Duct Units

When individual room control is used each volume damper is equipped with an operator. Often several air outlets are supplied through one damper. The damper operation is usually controlled by a room-type thermostat. The volume damper is usually set to provide for minimum ventilation requirements regardless of thermostat demand. When the air-supply system is used for heating as well as cooling it is necessary to use a heating-cooling thermostat.

RESIDENTIAL HEATING AND AIR CONDITIONING

The control equipment function in the residence may vary from the regulation of a coal-fired heating plant to the completely automatic control of a year-around heating and cooling system. Regardless of the type of heating or air-conditioning system used, the control system should be selected carefully to insure safety and comfort of the occupants as well as economy of operation.

The simplest type of domestic control is one in which the room thermostat starts and stops the burner, as described in the preceding section. It may be used on gravity or forced-warm air, hot water or steam systems. In forced