quantities are increased from a minimum, if the outdoor temperature as sensed by T_3 is low enough to provide cooling; and finally chilled water valve V_2 opens. Control T_2, however, operates, not at a constant temperature, but at a point varying from the minimum required in warm weather to the maximum required for heating. The variation is effected by T_1 in the return air, which raises and lowers the control point of T_2 until the proper return air temperature is obtained. During the heating and intermediate seasons, T_1 operates at a constant point, but in the cooling season it is readjusted by outdoor air thermostat T_4 to provide higher indoor temperatures. Room humidistat H opens valve V_3 on falling humidity to turn on the water sprays. As inside humidities in summer are normally higher than required in winter, the sprays are automatically kept closed.

Five diagrams of large central systems are shown in Chapter 21. The arrangement of coil and sprays diagrammed in Fig. 1 requires control as just described, except that if the cooling coil is of the direct expansion type, the refrigeration is controlled as explained in this chapter under

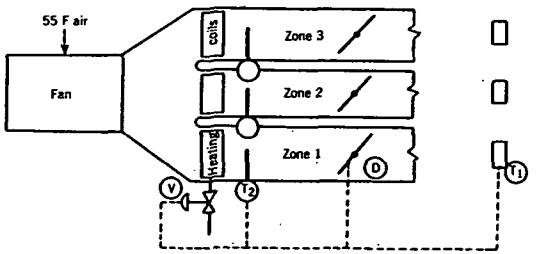

FIG. 6. ALL YEAR ZONE CONTROL WITH BOOSTER HEATING COILS AND VOLUME DAMPERS

Cooling Cycle. In Fig. 2, a dew-point thermostat near the eliminator plates, on a rising temperature first turns off the preheater and then turns on the water cooler. A return air or fan discharge thermostat controls the reheater coil, and the return air and by-pass dampers. Assuming that the coil is not heated in summer, the by-pass damper is opened and the return air damper closed to provide reheat. In winter, provision must be made to keep the by-pass damper closed, or to reverse its operation to prevent by-passing the coil when heat is required.

The temperature at the primary fan in Fig. 4 is maintained 10 F or more below desired zone temperatures throughout the year, to allow correction of overheating in winter. In summer this setting is further reduced, to cut down the amount of outside air required for cooling and to provide sufficient dehumidification. The zone thermostats thus call for more return air for reheat.

Where the internal cooling load is great, an arrangement as shown in Fig. 6, of this chapter, has some advantages. Air entering the fan is controlled at about 55 F by operation of a steam valve and outside and return air dampers, so long as weather permits. In summer the refrigeration is turned on at a somewhat higher temperature, as required. Booster heating coils, low limit thermostats, volume dampers and room,

or return air, thermostats are installed for all zones, as shown. Volume dampers are adjusted with a minimum position that will supply sufficient air quantities for heating. While a zone is too cold, T_1 holds D in minimum position and steam valve V wide open. On rising zone temperature, the steam is first gradually turned off, and if internal heat sources cause the temperature to build up, D gradually opens to increase the amount of cool air delivered. Control T_2 is set for the minimum temperature at which air can be introduced into its zone.

If heating as well as cooling is supplied only by the fan system, and zone control is by volume dampers, special instruments known as *summer-winter* thermostats are required to open the dampers on falling temperature in winter and on rising temperature in summer. Such instruments are also used similarly to operate valves which supply hot water in winter and chilled water in summer.

Economizer Controls. Although the saving of fuel or power is one of the reasons for using any automatic control equipment, there are some applications where this is the sole reason. For example, central fan systems are usually designed to use all outdoor air, or as much as required, while it has suitable characteristics, for economical operation. Except for cases such as chemical laboratories where return air cannot be economically used, dampers are placed in both the return air and outdoor air ducts to regulate the amount of air used from each. These may or may not be mechanically interconnected but are arranged so that as one opens the other closes. Where a minimum amount of outdoor air is needed for ventilation requirements, the control of dampers may include a relay to prevent closing the outdoor damper beyond a certain adjustable point or this damper may be divided into two sections, only one of which operates with the return air damper. Another relay connected to the fan motor circuit operates the minimum outdoor opening, in either case, as the fan is started and stopped. Usually it also places the remainder of the dampers in recirculating position when the fan stops and leaves them under control of their thermostats while the fan is running.

The control of recirculation is from thermostats. Since the outdoor air, in excess of the minimum required for ventilation, is used for cooling, the dampers are commonly interconnected with other cooling devices, so as to gradually increase the amount of outdoor air, and no refrigeration is turned on until the possibilities of natural cooling are exhausted. So long as the wet-bulb temperature outside is lower than that inside the more outdoor air used during the cooling cycle, the lower the operating cost. However, as soon as the wet-bulb temperature of the outdoor air exceeds that inside, its use should be reduced to the minimum. This is done automatically by the conditions of the outdoor air as sensed by:

1. A wet-bulb thermostat.
2. A dry-bulb thermostat readjusted by a humidistat to produce operation approaching wet-bulb control.
3. A dry-bulb thermostat and a humidistat working together, either one of which may throw the dampers to recirculating position.
4. A dry-bulb thermostat, alone.

These items are listed in order of importance, from a theoretical standpoint, but practical considerations reverse the order. A wet-bulb ther-