of manual and automatic operation. When they are all manual, the exhaust fans are started from some remote point, the teacher controls the opening and closing of the windows, and the radiation is either left uncontrolled or is manually controlled, again by the teacher. When controls are *manual-automatic*, all of these functions are controlled as described except that an automatic valve is installed to control the steam or hot water flow to the radiation in an attempt to maintain room temperature conditions. With this system, odors and humidity are presumed to be controlled by increasing or decreasing the window opening to admit more or less outdoor air (up to the amount being exhausted). Cooling is provided in a similar manner. The results, while passable, are frequently haphazard, drafty, or stuffy, and depend to a great extent on the individual preference of the teacher.

Direct Radiation

Many schools employ direct radiation or, in some cases, convectors or continuous fin-type heating pipes in connection with all of the systems of ventilation described. The radiation should be well distributed along the outside wall. Where possible a radiator should be placed under each window or made practically continuous. Unless thermostatic control is to be installed, hand valves must be provided so that each teacher can regulate the amount of radiation being used.

The automatic control of these types of heating systems can be arranged by zones (where rooms have common orientation and common use) with the disadvantage of attempting to find the room with the average conditions, or by separate control for each room.

Forced Air Systems (Central Direct-Fired)

Since schools require forced ventilation in many areas, many different types of central systems have been utilized. All of the available warm air furnaces have been used. These systems for schools are divided into as many zones, each having its own control, as possible. In addition to the common central system similar to the type used in homes without zoning, the two types most frequently used in school building have been:

1. The type which takes a mixture of outdoor and return air through a fan and filter, and discharges it in either of two paths, over the surfaces of a warm air heater or through a by-pass around the heater, with mixing at the outlet of the heater to control the temperature of the air supplied to the rooms. This requires one supply duct from the heater to each room or zone so controlled.

2. The type of system known as the double duct system which has in it one main duct from the heater and another one which has by-passed the heater, both ducts being run parallel to each other to a point just behind the room supply outlet where dampers are installed to mix warm air and cool air to obtain the desired outlet temperature.

These systems usually operate with a fixed (manually variable) outdoor air quantity, the balance of the air being obtained by returning it from the spaces. The air is released into the spaces either through wall grilles, ceiling outlets, or outlets in the window sills discharging upward. Excess air is removed from the spaces, or rather is allowed to escape from the spaces in many instances, through relief grilles into the corridors, the corridors returning the air to central points where connections are made to the suction side of the central fan unit. In some states return of air is not permissible. Under these conditions the excess air is removed from the building through either gravity ventilators or power exhaust fans.

There have been some installations in which the return air is allowed to escape from the room, through wall grilles, into the corridors and thus back to the unit. While this arrangement is less expensive, it is not recommended because in case of fire all the smoke is drawn through the corridors which should be kept clear for the escape of the students and teachers. Corridor return is prohibited in many states and cities.

Proper design should avoid drafts from cold wall surfaces and from duct outlets. Air discharged toward cold surfaces should be designed for a terminal velocity of 50 fpm at approximately one-quarter the distance from a cold wall. Grille outlet velocities in excess of 600 fpm under 9 and 10 ft ceilings are likely to cause drafts at some points in the occupancy zone.

Forced Air Systems (Central Steam)

In these systems the air supplied for ventilation is tempered by automatically controlled steam coils and the normal heat loss for each room is supplied by direct radiators or convection. Provision is made for exhaust equal to the amount of outdoor air supplied. There are many variations of these systems, and they may include any features of central systems described in Chapter 29. Hot water may also be used as the heating medium.

This type of system can also be designed to provide the entire heating requirement without using any direct radiation. This arrangement is quite satisfactory, but must be controlled for zones of similar occupancy which have exactly the same orientation. Where used as a two-duct system as described under Forced Warm Air Systems in preceding section, much more satisfactory results can be expected.

Unit Ventilator Systems

Unit ventilators are used for supplying heat and ventilation for individual classrooms. These units and their controls are described in Chapters 24 and 38. They can be combined or furnished with storage cabinets, book shelves, extensions for additional direct radiation, and extended grilles to discharge upward along the window sills.

As in previous systems described, the excess air must be provided a means of escape.

Panel Heating Systems

A number of schools have employed panel heating of various designs. It is particularly adaptable in the *slab-on-ground* type of school to overcome the cold floor. It is also quite adaptable to the *open corridor* type of school using natural or window ventilation in the warmer climates. In the cold climates it should be augmented by a tempered-air ventilating system as previously described.

Design data are given in Chapter 23, but the designer must include ample thermostatic control which employs some means of varying the water temperature in inverse ratio to the outside temperature. With well-insulated walls and ceilings this feature usually results in an appreciable anticipation of the heating requirements. Several control systems are outlined in Chapter 38. Individual room control is desirable but not mandatory. A separate zone control for each exposure and for each floor is absolutely necessary for satisfactory results.