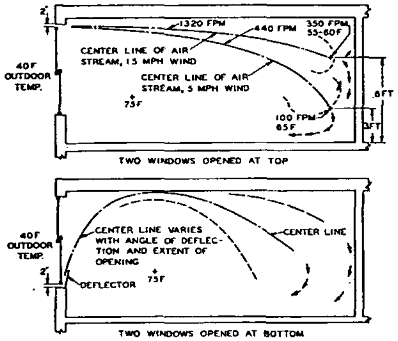


Wind[a] Mph	Air Volume Cfm	Cooling in MBh			
		40 F Outdoor Temp.		55 F Outdoor Temp.	
		Required[b]	Obtained	Required[b]	Obtained
0	0	19.0	0	27	0
5	730	19.0	25.3	27	14.5
15	2190	19.0	69.0	27	39.5

[a] Velocity vector normal to window. [b] South Classroom, Fig. 1.

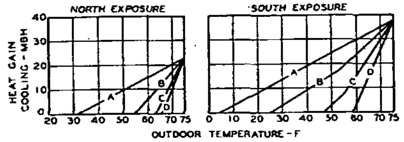
Based on wind normal to exposure; room 25 ft deep; windows double-hung, 5 ft wide, 2 windows opened as shown.

Fig. 3 . . . . Typical Air Flow in Classrooms with Natural Ventilation

Air Supply Methods

Windows are generally of double hung type or consist of metal architectural sections, the bottom section being arranged to swing inward to deflect air upward and the top section to swing outward from a hinge at its top or center. If double hung windows are used, a deflecting device, generally of glass, to prevent interference with light transmission, is provided at the bottom to deflect incoming currents upward, as illustrated in Fig. 3, and thereby prevent them from blowing directly on room occupants at desk level. Since windows require manual opening, proper control of air currents cannot be provided.

Mechanical air supply is generally provided by a central duct system, the air being delivered through wall grilles or ceiling diffusers, or by self-contained units within the rooms, such as unit ventilators and unit conditioners located at the outside walls. Grilles are generally located most conveniently at the inside or corridor wall. They must be of the deflecting type, deflecting upward in consideration of the drop in the air stream when air is introduced at lower than room temperature. Diffusers are generally located in ceilings of rooms in a pattern to provide proper air distribution. In location of both wall grilles and diffusers, it is important that the air-delivery path be free of obstructions, which might be light fixtures and crossbeams, since presence of obstacles will result in uncontrollable and turbulent currents of air extending into the occupied zone and causing drafts. Grilles and diffusers are generally selected to provide a terminal velocity of 50 fpm at approximately one-fourth the distance from an opposite wall or other obstacle to air flow.



Basis: Cooling requirements shown in Fig. 1.

A = Net heat gain with ventilation air controlled at room temperature of 75 F.

B, C, and D = Net heat gains using 525, 1000, and 1500 cfm, respectively, controlled to 55 F, minimum. Cooling air temperature will be higher as outdoor air temperature rises above 55 F.

Fig. 4 . . . Typical Cooling Capacities, Using Outdoor Air

Exhaust Methods

Windows, when used for exhaust, are opened at the top to take advantage of natural rise in the warm air to be exhausted. Windows are not fully effective for exhaust purposes, except in completely still weather. Typical conditions are shown in Fig. 3, indicating that, if the windows are on the windward side, air is introduced rather than exhausted.

Gravity exhaust ventilation is obtained through exhaust grilles in the ceiling (or in a wall away from the windows) connected to roof ventilators. Air is exhausted by wind effect and chimney effect due to differential pressure resulting from thermal head. This type of exhaust is used in conjunction with air supply obtained by admitting air at the windows. Satisfactory air changes can be obtained by this method within limits shown in Fig. 3, if the roof ventilators are adequately large. However, room conditions *cannot* be fully acceptable, since objectionable cold drafts are certain to occur in cold weather. Control of conditions depends on manual adjustment of window openings, a method that is reasonably satisfactory only in mild climates, but is not recommended where the design temperature is lower than 30 F. Gravity exhaust ventilation may be used with satisfactory results in combination with mechanical air supply systems.

In *mechanical exhaust systems* the roof ventilators described in preceding paragraph on *gravity exhaust ventilation* are replaced with motor-driven exhaust fans. If this system is used in conjunction with window supply of air, it should be remembered that when windows are closed, replacement air is drawn from the corridor or the ventilation rate is greatly reduced. At such times, negative pressures will prevail in the building, with adverse effects on incinerators, hooded equipment, and other local exhaust and fuel-firing equipment.

TYPES OF HEATING AND COOLING SYSTEMS

Systems may be classified according to methods of heating and cooling. Each may be combined with means for ventilation in various ways. Only a few states have specific requirements with respect to types of systems. Accordingly, except in these states, engineers and administrators of school construction are free to analyze and choose kinds of systems. The possible combinations of such systems are extremely numerous. A discussion of those encountered most often will follow.

Direct Radiation

This type of heating includes cast-iron radiators, cast-iron or nonferrous convectors, and continuous finned-pipe heating elements in connection with steam or water heating systems (see Chapters 14, 26, and 28). The radiation must extend the full length of the outside or window walls and the full width of high windows used in cross-lighted designs illustrated in Fig. 2. Control is obtained by manual valves, by individual automatic control valves for each room, or by an automatic valve or valves controlling zones of the system according to exposure.

Direct radiation may be used with natural ventilation, *natural ventilation with gravity exhaust*, and natural ventilation with mechanical exhaust. It is designed for the warm-up load and to provide a warm curtain of rising air to mix with the incoming cold air to temper it. However, it is inadequate for this purpose, because heating requirements are satisfied at relatively low outdoor temperatures as soon as classrooms are occupied and lighted, as illustrated in Fig. 1. The system requires the teacher to adjust openings for ventilation. Installation costs can be relatively low.

Electric Heating

This consists of electrical heating elements in baseboard type of radiation extending the full length of the window walls, electric ceiling panels, or panels formed of heating cable buried in the ceiling plaster. Control of heating is automatic by means of individual room thermostats. Any of the ventilating systems discussed previously can be combined with electrical heating, much as discussed under Direct Radiation. Electrical heating has the same shortcomings as direct radiation; namely, that when classrooms are occupied and lighted, heat is not available for counteracting downdrafts at windows. The system requires the teacher to adjust openings for ventilation. Generally, the cost of energy will be considerably higher than with systems using fossil fuels. Initial costs can be among the lowest.

Panel Heating

Floor panel heating is adaptable to the slab-on-ground type and to the open-corridor type of school, particularly in the warmer climates. Design data are given in Chapter 30, Panel Heating, which also describes features of panel heating control systems. (See also Chapter 43, Automatic Control.) The floor system lends itself well to individual room control, although zone control, including several rooms of the same exposure in the same zone, is practicable. Floor panel heating systems are adaptable in areas having design temperatures down to 0 F. Since the requirement for heating is materially reduced when the spaces are occupied and lighted, as illustrated in Fig. 1, the panels should be constructed to have minimum mass and thus minimum storage effect. This is accomplished by using a slab, only sufficiently thick to enclose the tubing or piping, underlaid by a slab of insulating concrete. Even with light concrete panels, there is enough storage effect to cause overheating after warm-up and to make it difficult to follow rapidly changing loads. Any of the types of ventilating systems already discussed may be combined with panel heating systems. However, the panel heating system cannot be effective in combating the natural condition of downdrafts at the windows. The system requires the teacher to adjust openings for ventilation. The panel system is well adapted for use in primary classrooms with slab-on-ground floor construction, where students spend much time on the floor.

Central Indirect Air Systems

In these systems, air is supplied for ventilation and heating. At a central point or points, outdoor ventilation air and recirculation air is mixed and heated by automatically controlled steam or hot water coils. Gravity or mechanical exhaust is coordinated with the air supply system. The *central system can be arranged to recirculate air from* window sills to intercept the flow of uncontrolled cold window drafts into the classroom. Such returns are fully effective only if the openings are located in the window sills; if located below the sills, the natural air currents will not be intercepted. There are many variations of the system, which may include features of central systems described in Chapter 19. Air supply may be controlled by zones of similar occupancy and identical orientation. Individually controlled booster or reheat coils may be located within ducts leading to each of the spaces. Individual room control may also be provided by a double duct system, equipped with mixing dampers for each room located within a short distance ahead of the supply grilles or diffusers serving the room. Central air conditioning can be included.

Split Systems

The central indirect air systems may be combined with direct radiation or convection units described in the previous section, Direct Radiation. In this combination, air may be supplied by the ventilating system at constant temperature, usually 55 F, when the outdoor temperature is less than 55 F. In this case direct radiation may be designed to take care of the building heat loss. In order to prevent window drafts, the temperature of the ventilation air *should be controlled to require operation of the direct* radiation when the outdoor temperature is below 55 F. The direct radiation is controlled by automatic valves operated by a room thermostat for the individual room and essentially provides reheat as required. These systems have wide flexibility but are usually higher in first cost than central indirect systems.

Central Direct-fired Air Systems

These systems are forced circulation warm air furnace systems. They may be arranged for single or double duct air distribution, as discussed under Central Indirect Air Systems. This type of system is further discussed in Chapter 18, Warm Air Heating. They are usually installed with zone controls and arranged to permit use of any desired proportion of outdoor air during periods of space occupancy. Mechanical cooling may be obtained by installation of cooling coils in the main supply ducts.

Unit Ventilators

Unit ventilators are used in classrooms to provide heating, controlled ventilation, and cooling, using outdoor air as the cooling medium. Auditorium unit ventilators are used in large rooms such as auditoriums, gymnasiums, and large lecture rooms. Classroom unit ventilators are often combined with matching storage cabinets or may be combined with ducts extending the full length of the windows and arranged either to discharge air upward along the window sills or withdraw air at the window sills and thereby prevent downdrafts from the windows. In order to effectively intercept natural downdrafts, the return grille must be located with the top of the unit at the level of the window sill. Classroom unit ventilators may also be combined with extended finned-pipe radiation at the window sills to combat cold window downdrafts. Electrical unit ven-