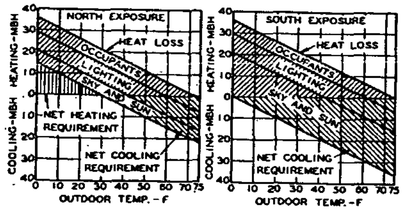


Basis: Floor area—1000 sq ft. Windows on one side only—240 sq ft. Heat transmission factors, U; roof—0.15, wall—0.25, glass—1.13. No infiltration. Heat gains based on artificial lighting at 2.3 watts per sq ft of floor area. Occupants, 35. Solar intensity and incidence at 45 deg N. latitude, December 1. Windows shaded by venetian blinds. Since the consideration is cooling, a room temperature of 75 F, instead of the 72 F shown in Table 1, was used in the above charts. Net cooling requirement for the south exposure approaches that of the north exposure on a day when the sky has a heavy cloud cover.

Fig. 1 . . . . Typical Net Heating and Cooling Requirements of Classrooms

Local codes may establish requirements for construction, glass areas, ventilation rates, etc., which exceed values found reasonable in consideration of knowledge gained since they were prepared. This is natural because codes usually are brought up to date only periodically when need for revision is made obvious.

Installation cost is a prime consideration in design. It should be considered in relation to the overall cost of school operation. The cost of maintenance is reflected in man hours required to provide proper operation and reasonable life of the equipment. Proper location, access, and working space for the equipment are reflected in reduced operator or custodian time. Some systems require more frequent attention, overhaul, or replacement than others. Operating costs may be held to a minimum by: (1) selection of the proper fuels for system requirements based on fuel economics in a particular area; (2) providing flexibility for operation of sections of systems according to use; (3) provision of adequate automatic temperature control and system control.

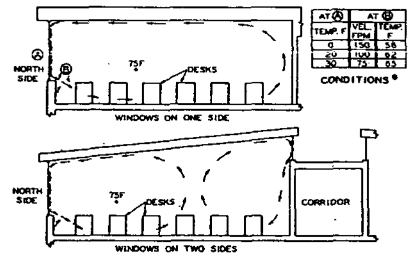
Periods of use contemplated for the entire school building, or sections of it, due to summer school, or community use of an auditorium throughout the summer or during spring and fall months (in a region where these are mild) may influence a decision to include air-conditioning systems.

DESIGN CONSIDERATIONS

Engineering advice is essential during *preliminary design* on the effect of fenestration and orientation on room conditions; the advisability of outside shading on glass exposures; construction of the building, including insulation for most economical operating conditions and desirable room temperatures; and costs of the mechanical plant.

Design for the required indoor environment for learning must be made in consideration of the heat losses, heat gains, and air movements; ventilation means and ventilation rates; space temperature requirements; variability of occupant density; independent operation of various spaces; practicability of cooling; means of cooling (if it is to be included in the design); and automatic control of the environment.

A typical illustration of heat losses and heat gains in classrooms is presented in Fig. 1, applicable for sun effect



* *Conditions shown at windows are conservative; vary with number and shape of cross-members. Temperatures are often lower; velocities often higher.*

Fig. 2 . . . . Natural Air Currents in Classrooms

to about 45 deg north latitude and design temperature for heating of 0 F. For the classrooms shown and based on the construction and conditions described in the footnote, heat gains in the classroom with north exposure equal the heat losses at 32 F. In the south classroom, practically no heating is required after the room is occupied and lighted. Accordingly, heat is required in the south classroom only for warm-up. Cooling is required in north classrooms at outdoor temperatures above 32 F and, in south classrooms, at all temperatures above 0 F. Conditions shown for the north classroom would apply to a south classroom when the sky is fully overcast.

Natural air movements or air currents prevailing in the space must be taken into account in design. Fig. 2 illustrates two conditions: the first having windows located along one side, the second having windows for cross-lighting. Measured conditions are shown for classrooms of the first type. It is significant, as will be noted in these illustrations, that, even though the room temperature at the control point may be at the desired level, uncomfortable conditions with such impairment of health as may be due to cold drafts could be expected for the students in the first or second rows paralleling the windows. Direct radiation installed at the glass exposures cannot be fully effective in warming the descending currents of cold air unless it extends the full length of the windows, is located close to the window sill, and is in operation whenever the outdoor temperature is low enough to cause these downdrafts.

Ventilation means and rates are largely fixed by state and municipal codes and vary considerably with type and intended use of any building. Applicable ventilating systems are shown in Table 1. Natural ventilating systems are those relying on opening of windows to admit and exhaust air. Mechanical supply or exhaust systems are those using fans to supply or exhaust air. Natural ventilating systems are not suitable for spaces such as gymnasiums, auditoriums, cafeterias, and meeting rooms, because of size or density of occupancy; nor for laboratories, large toilet rooms, locker rooms, or kitchens in which intense odors are common; nor in shower rooms where high vapor concentrations are likely to occur. It is not possible to obtain consistently good room conditions in classrooms by means of any ventilating system that depends on openable windows for introduction of air. This is the case with each of the natural ventilation

Table 1 . . . . Applicable Ventilating Systems and Room Temperatures

Space	Natural	Natural with Gravity Exhaust	Natural with Mechanical Exhaust	Mechanical Supply and Exhaust	Mechanical Supply, Gravity Exhaust	Room Temp F
1. Classroom	No[a]	No[a]	No[a]	Yes	Yes	72
2. Gymnasium	No	No	No	Yes	Yes	60–70
3. Auditorium	No	No	No	Yes	Yes	72
4. Kitchen	No	No	No	Yes	No	65–70
5. Cafeteria	No	If Code[b, c]	If Code[c]	Yes	Yes	65–72
6. Meeting Rooms	No	No	If Code[a]	Yes	Yes	72
7. Offices	Yes	Yes	Yes	Yes	Yes	72
8. Locker Rooms	No	Yes[c]	Yes[a]	Yes	No	75–80
9. Laboratories	No	No[a]	No[a]	Yes	No	72
10. Shops	If Code[c]	If Code[a]	If Code[a]	Yes	Yes	65–70
11. Toilet Rooms	Yes[d]	Yes[a]	Yes[d]	Yes	No	70
12. Showers	No	No	No	Yes	No	75–80

[a] Subject to conditions. See text. [b] If permitted by code [c] Unless rooms are interior. [d] If rooms are small and have openable windows.

systems shown in Table 1. The problems are due to the following factors:

1. At low outdoor temperatures, the windows are kept closed, resulting in high odor intensities.
2. As outdoor temperatures rise, up to temperatures of 60 F, uncontrolled, uncontrollable, and variable drafts will occur in the occupied zone. Typical conditions are shown in Fig. 3.
3. Frequent adjustment of window openings by the instructor, with consequent distraction from teaching duties, will be necessary to provide adequate ventilation without excessive drafts and to maintain proper room temperature.
4. Manual readjustment of window openings is an erratic method of controlling ventilation.
5. The advantages of saving time and obtaining greater accuracy of temperature control are lost.

Temperature requirements of various spaces depend on occupancy, function, degree of activity, and type of clothing. Values generally accepted are listed in Table 1.

In meeting spaces such as auditoriums, cafeterias, gymnasiums, and the like, the variability of occupant density may warrant the use of separate units or systems for the several spaces in order to permit their individual operation without operating the entire school system.

It may be practicable to counteract the net heat gains shown in Fig. 1 or some of them by cooling with ventilation air or other means besides refrigeration. This would require the use of mechanical air supply with sufficient cooling capacity at a 55 F outdoor air temperature to offset the net heat gains. If the amount of air required results in an excessive cost of the mechanical system, a study should be made of means of reducing the various cooling load sources, particularly the solar load. When outdoor temperatures are in excess of 65 F, windows with ample opening to produce rapid changes of air in the space are necessary to maintain comfortable conditions, unless cooling by refrigeration is installed. When the outdoor temperature is above 65 F, relatively high velocity air movement in the space is not objectionable from the standpoint of comfort. Even under the most favorable conditions, ventilation systems cannot maintain comfort when the outdoor temperature exceeds 72 F.

DESIGN OF THE MECHANICAL PLANT

Heating, ventilating, and cooling loads are computed according to the procedures given in Chapters 9, 11, 12, and 13. The performance requirements of the various parts of the system, whether combined or operating separately, according to use, are then established, with due consideration being given to the method of control and operation of the entire school project. Heating requirements should be determined for design conditions and for warm-up periods, the heaviest warm-up load being that which occurs after a weekend shutdown when the outdoor temperature is at design value.

The load applicable during occupancy, considering net heating and cooling loads, is determined and evaluated as shown in Fig. 1. If planned use of the building extends through the summer, cooling design dry-bulb temperatures used are those established by the ASHAE Technical Advisory Committee on Weather Design Conditions which are shown in Column 6 of Table 2, Chapter 13, and referred to as "TAC 2½% Basis." Design temperatures in common use, both dry- and wet-bulb, may also be found in the same table in Columns 7 and 8. For detailed analysis of frequency of occurrence of extreme conditions by months, reference may be made to *Region Climate Analyses and Design Data*, published in 1951 by the American Institute of Architects. These analyses are available for all United States areas.

The requirements of each of the mechanical systems incorporated in a school plant are as follows:

1. An adequate warm-up rate for heating, the ability to raise room temperatures to required conditions shown in Table 1 within an acceptable interval of time when the outdoor temperature is at design value. Usually, warm-up requirements after a weekend shutdown are used as a basis.
2. Maintenance of indoor design temperature when cooling is required. Considering the heat gains shown in Fig. 1, a typical analysis of ability to provide cooling with outdoor air is shown in Fig. 4.
3. Uniformity of air motion, discussed under Criteria for Design. Generally this requirement is satisfied by a system providing constant air flow, with proper distribution of the air supplied.
4. Uniformity of temperature of supply air, discussed under Criteria for Design.
5. Introduction of ventilation air, according to applicable codes; otherwise on a rational basis, as discussed in Chapter 6 for quantity and Chapter 20 for distribution.
6. Interception or deflection of window drafts in rooms having extensive fenestration, such as classrooms. (See Fig. 2.)
7. Acceptable noise levels which will depend on location of the school and on the equipment provided.

TYPES OF VENTILATING SYSTEMS

Any ventilating system provides air circulation and thus includes means of supply and exhaust. Ventilation systems may be classified by the type of supply (window or mechanical) or exhaust (window, gravity, or mechanical).