

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

trol in relation to periods of use as related to outdoor conditions are the chief criteria by which a design for maintenance of indoor environment for learning may be judged.

Comfort, which may be defined as freedom from strain in accommodating to the environment, is a necessity. Fundamentals in this respect are discussed in Chapters 8 and 11 of the 1961 GUIDE AND DATA BOOK. Intermittent currents of air or air movement at varying velocities may result in discomfort. Similarly, variations in temperature may contribute more to discomfort than uniform maintenance of slightly higher or lower temperatures.

The temperature level maintained is of first importance. While temperatures must be raised to comfort levels, it is also essential that they be held to permissible maximums.

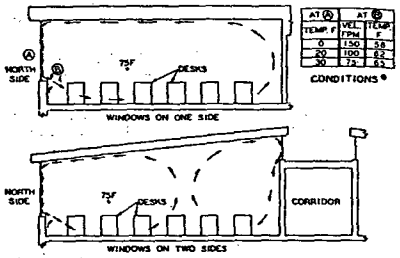
Odors, while they may not be deleterious to health, are disagreeable and distracting, even to the point of being nauseating. Odors should not be perceptible in schoolrooms.

Many local codes establish requirements for construction; glass areas, ventilation rates, etc., which exceed values found reasonable in consideration of knowledge gained since they were prepared.

Excessive glass areas increase distraction of students by outside activities and result in unnecessarily high heat gains. Many ventilation rates specified by codes are based on factors no longer considered valid.

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.



** 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

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 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.

Applicable ventilating systems are shown in Table 1. Natural ventilating systems are those relying on opening of

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[c]	Yes	Yes	72
7. Offices	Yes	Yes	Yes	Yes	Yes	72
8. Locker Rooms	No	Yes[c]	Yes[c]	Yes	No	75–80
9. Laboratories	No	No[c]	No[c]	Yes	No	72
10. Shops	If Code[c]	If Code[c]	If Code[c]	Yes	Yes	65–70
11. Toilet Rooms	Yes[d]	Yes[c]	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.

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 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.

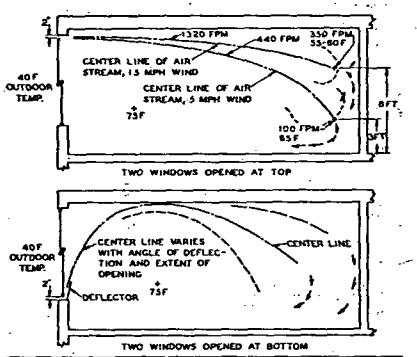
Temperature requirements of various spaces depend on occupancy, function, degree of activity, and type of clothing. Values generally accepted are listed in Table 1.

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 24, 25, and 26 of the 1961 GUIDE AND DATA BOOK. The performance requirements of the various parts of the system, whether combined or operating separately, according to use, are then established,



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