Table 3 . . . . Water Usage for Water-Cooled Equipment

Summer Water Temperature, Normal Extremes F	Gallons Per (Hour) (Ton)	Summer Water Temperature, Normal Extremes F	Gallons Per (Hour) (Ton)
55	34	75	58
60	39	80	70
65	44	85	88
70	50		

continuous fan operation the number of hours of compressor operation should be subtracted from the number of hours in the cooling season to obtain the extra hours of fan operation. This value may then be used with the appropriate value of power consumption and power cost for the fan motor only, to find the added power cost for continuous fan operation and the result should then be added to the power cost during compressor operation.

For water-cooled condenser applications the water cost, as determined from the operating hours, water rate, and manufacturer's data on equipment water usage, is added to the power cost to obtain the estimated total operating cost.

Another method has been developed using cooling degree days above 70 F as a criterion but tabulated values of cooling degree days for various localities are not available.[9] Approximate values can be obtained from degree-day maps.[10, 11] The daily range of temperatures for various localities is also required with this method.[12] It is important that the method used in estimating operating cost be consistent with the method used in calculating the heat gain of the structure.

EFFECTS ON FUTURE HOUSE DESIGN

Air conditioning, like automatic heating, has brought about improved practice in residential construction, particularly in those regions where cooling is of primary importance. Although it is true that construction practices which reduce the heating load also reduce the cooling load, there are certain considerations that are unique in their effect upon the cooling load. Special attention should be paid to window orientation and shading. South windows may be shaded by awnings or roof overhangs, but it is not practicable to shade large window areas having an east or west orientation except by exterior solar screening of some type. The use of insulation in the walls and ceiling of the residence will reduce the cooling load appreciably. In addition, attention should be paid to adequate ventilation of the attic. Double-glazed and weather-stripped windows, heat-absorbing glass, planned shade tree locations, and light-colored exterior wall and roof surfaces, also help to reduce the cooling load.

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CHAPTER 47

SCHOOL SYSTEMS

General Considerations, Criteria for Design, Design Considerations, Preliminary Design, Mechanical Plant Design, Types of Ventilating Systems, Types of Heating and Cooling Systems, Automatic Control, Operation, Maintenance

THE purpose of this chapter is to outline the factors affecting the selection of heating, ventilating, and air-conditioning systems for schools. The components of these systems are the same as used for other types of buildings. Their combination in school systems, in some cases, will be the same as for other buildings, but may differ considerably in others in order to provide optimum conditions for effective school work and to comply with local regulations.

GENERAL CONSIDERATIONS

The proper criteria for heating, ventilating, and in many instances air conditioning, of school buildings, particularly classrooms, are often not recognized fully.

Many designers and school administrators approach the problem as one of heating, whereas analysis may show that cooling, rather than heating, is required during periods of occupancy throughout most of the year. Ventilation systems are frequently designed to supply air at 72 F for ventilation. Generally, they should be designed to supply air at 55 F to 60 F to provide all cooling possible during occupancy.

With regard to ventilation, code requirements vary from acceptance of natural ventilation, such as obtained by opening of windows, to a requirement of mechanical supply of a specified quantity of air, which sometimes is as high as 30 cfm of outdoor air per occupant. The variations in quantity of outdoor air specified usually are due to the lack of a uniform understanding of the *reason* for ventilation. Research has established that ventilation air is required, *not* to replace oxygen for breathing, but to *dilute body odors*, which become intensified in densely occupied spaces. A discussion of air requirements will be found in Chapter 6.

When planning for introduction of ventilation air into rooms, careful consideration should be given to air distribution and circulation within the occupied space, as well as the natural convection and temperature effects.

Elementary schools of recent design are generally single-story buildings, often placed at considerable distance from each other. Windows 7 ft or more in height and extending the full length of one or more classroom walls, often raise great problems in maintenance of an optimum indoor atmospheric environment and in prevention of eye strain.

Secondary or high schools are more often two- and three-story structures but present problems only slightly less severe than grade schools. Separation of school buildings results in increased cost of the mechanical systems.

A further characteristic of school buildings is a wide variation in use and occupancy. Classrooms (the largest single group of occupancies), lecture rooms, assembly rooms, auditoriums, and other similar areas have uniformly dense occupancies. Gymnasiums, cafeterias, laboratories, shops, and similar functional spaces have lighter occupancies and also have different and varying ventilation temperature requirements. Many schools include multipurpose rooms serving as auditoriums, gymnasiums, and community centers.

The normal periods of operation are five days per week for nine months per year, with complete shutdown during week-ends and vacation periods. Where schools are not operated during the summer months school boards may not find complete air conditioning justified except in southern climates. Systems for administration areas, gymnasiums, auditoriums, and multipurpose rooms, *suitable for community activities*, will often be operated at times when the systems for classrooms and other general educational areas may not be in operation.

Automatic control of temperature and system equipment is a necessity if comfortable conditions are to be obtained. Proper application of controls may return the cost of investment by savings in labor and fuel within a year or two.

Frequently, insufficient consideration is given to provisions for access and maintenance with the idea that the mechanical system is a fixed part of the structure and should last as long as the structure, without attention.

School boards are often criticized by their constituents for spending large sums of money for so-called luxury items, with the result that economy in construction and design becomes a paramount factor. This often tends to limit the mechanical equipment selected below that required to maintain a proper indoor atmospheric environment. However, many schools in areas having warm spring and fall climates are now being designed to include air conditioning, at least in spaces of densest occupancy and greatest use.

CRITERIA FOR DESIGN

Comfort, cleanliness, reduction of odors, maintenance of alertness, compliance with codes, installation cost, ease and cost of upkeep, cost of operation, and adaptability to control 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. Uniformity of air movement and temperature within the space is required to provide a comfortable environment. Fundamentals in this respect are discussed in Chapter 6, Physiological Principles, and Chapter 20, Air Distribution. 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.

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