CHAPTER 6

EDUCATIONAL FACILITIES

THIS chapter contains technical and environmental factors and considerations to assist the design engineer in the proper application of heating, ventilating, and air-conditioning systems and equipment for educational facilities. For further information on the HVAC systems mentioned in this chapter, see the 2000 *ASHRAE Handbook—Systems and Equipment*.

GENERAL CONSIDERATIONS

All forms of educational facilities require an efficiently controlled atmosphere for a proper learning environment. This involves the selection of heating, ventilating, and air-conditioning systems, equipment, and controls to provide adequate ventilation, comfort, and a quiet atmosphere. The system must also be easily maintained by the facility's maintenance staff.

The selection of the HVAC equipment and systems depends upon whether the facility is new or existing and whether it is to be totally or partially renovated. For minor renovations, existing HVAC systems are often expanded in compliance with current codes and standards with equipment that matches the existing types. For major renovations or new construction, new HVAC systems and equipment can be installed if the budget allows. The remaining useful life of existing equipment and distribution systems should be considered.

HVAC systems and equipment energy use and associated life-cycle costs should be evaluated. Energy analysis may justify new HVAC equipment and systems when a good return on investments can be shown. The engineer must take care to review all assumptions in the energy analysis with the school administration. Assumptions, especially as they relate to hard-to-measure items such as infiltration and part-load factors, can have a significant influence on the energy use calculated.

Other considerations for existing facilities are (1) whether the central plant is of adequate capacity to handle the additional loads of new or renovated facilities, (2) the age and condition of the existing equipment, pipes, and controls, and (3) the capital and operating costs of new equipment. Educational facilities usually have very limited budgets. Any savings in capital expenditures and energy costs may be available for the maintenance and upkeep of the HVAC systems and equipment and for other facility needs.

When new facilities are built or major renovations to existing facilities are made, seismic bracing of the HVAC equipment should be considered. Refer to Chapter 54, Seismic and Wind Restraint Design, for further information. Seismic codes may also apply in areas where tornados and hurricanes necessitate additional bracing. This consideration is especially important if there is an agreement with local officials to let the facility be used as a disaster relief shelter.

The type of HVAC equipment selected also depends upon the climate and the months of operation. In hot, dry climates, for instance, evaporative cooling may be the primary type of cooling; some school districts may choose not to provide air conditioning. In hot, humid climates, it is recommended that air conditioning or dehumidification be operated year-round to prevent the growth of mold and mildew.

ENERGY CONSIDERATIONS

Most new buildings and renovated portions of existing buildings must comply with the energy codes and standards enforced by local code officials. Use of energy-efficient equipment, systems, and building envelope materials should always be considered and evaluated. Methods of reducing energy usage should be discussed by the design team.

Outdoor air economizer cycles use cool outdoor air to accommodate high internal loads for many hours of the year, as dry- and wet-bulb temperatures permit. A relief air system sized to remove up to 100% of the outdoor air that could be supplied is required. Some packaged rooftop air-conditioning units do not have adequate relief air outlets, which could lead to overpressurization of the space. Additional relief vents or an exhaust system may be necessary.

Night setback, activated by a time clock controller and controlled by night setback thermostats, conserves energy by resetting the heating and cooling space temperatures during unoccupied hours. Intermittent use of educational facilities sometimes requires that individual systems have their own night setback control times and settings.

Coupled with night setback is **morning warm-up and cool-down**. This allows the space temperatures to be reset for normal occupancy at a predetermined time. This can be achieved either by setting a time clock for approximately one hour before occupancy or through the optimization program of a central energy management system. Such a program determines the warm-up or cool-down time based on the mass of the building, the outdoor air temperature, and a historical log of building occupancy.

Hot water temperature reset can save energy by resetting the building hot water temperature based upon outdoor air temperature. Care must be taken to not lower the water temperature below that recommended by the boiler manufacturer.

During cool weather, **cooling-tower free cooling** uses the cooling towers and either chiller refrigerant migration or a heat exchanger to cool the chilled water system without using the chillers. This system is useful for facilities with high internal heat loads.

Heat recovery systems can save energy when coupled to systems that generate a substantial amount of exhaust air. A study must be performed to determine whether a heat recovery system is cost-effective. Various heat recovery systems include runaround loops, heat wheels, and heat exchangers.

Boiler economizers can save energy by recovering the heat lost in the stacks of large boilers or in central plants. The recovered heat can be used to preheat the boiler makeup water or combustion air. Care should be exercised not to reduce the stack temperature enough to cause condensation. Special stack materials are required for systems in which condensation may occur.

The preparation of this chapter is assigned to TC 9.8, Large Building Air-Conditioning Applications.

Variable-speed drives for large fans and pumps can save energy, especially if coupled with energy-efficient motors. The HVAC systems should be evaluated to determine whether there is enough variation in the airflows or water flows to justify the application of these devices. A cost analysis should also be performed.

Passive solar techniques, such as the use of external shading devices at fenestrations, can be incorporated into the building design. Coordination with the owner and design team is essential for this strategy. A life-cycle cost analysis may be necessary to evaluate the cost-effectiveness of this method.

Solar energy systems can either supplement other energy sources or be the sole energy source for an HVAC system. A life-cycle cost analysis should be performed to evaluate the cost-effectiveness of such a system.

DESIGN CONSIDERATIONS

Climate control systems for educational facilities may be similar to those of other types of buildings. To suit the mechanical systems to an educational facility, the designer must understand not only the operation of the various systems but also the functions of the school. Year-round school programs, adult education, night classes, and community functions put ever-increasing demands on these facilities; the environmental control system must be designed carefully to meet these needs. When occupied, classrooms, lecture rooms, and assembly rooms have uniformly dense occupancies. Gymnasiums, cafeterias, laboratories, shops, and similar functional spaces have variable occupancies and varying ventilation and temperature requirements. Many schools use gymnasiums as auditoriums and community meeting rooms. Wide variation in use and occupancy makes flexibility important in these multiuse rooms.

Design considerations for the indoor environment of educational facilities include heat loss, heat gain, humidity, air movement, ventilation methods, ventilation rates, noise, and vibration. Winter and summer design dry-bulb temperatures for the various spaces in schools are given in Table 1. These values should be evaluated for each application to avoid energy waste while ensuring comfort.

Sound levels are also an important consideration in the design of educational facilities. Typical ranges of sound design levels are given in Table 2. Whenever possible and as the budget allows, the design sound level should be at the lower end of these ranges. For additional information, see Chapter 47, Sound and Vibration Control.

Proper ventilation can control odors and inhibit the spread of respiratory diseases. Refer to ASHRAE *Standard* 62 for the ventilation rates required for various spaces within educational facilities.

Equipment for school facilities should be reliable and require minimal maintenance. Equipment location is also an important consideration. The easier equipment is to access and maintain, the more promptly it will be serviced. Roof hatches, ladders, and walkways should be provided for access to rooftop equipment.

Controls. Controls for most educational facilities should be kept as simple as possible because a wide variety of people need to use, understand, and maintain them. The different demands of the various spaces indicate the need for individual controls within each space. However, unless each space is served by its own self-contained unit, this approach is usually not practical. Many times, a group of similar spaces will be served by a single thermostat controlling one heating or cooling unit. Rooms grouped together should have similar occupancy schedules and the same outside wall orientation so that their cooling loads peak at approximately the same time.

Because most facilities are unoccupied at night and on weekends, night setback, boiler optimization, and hot water temperature reset controls are usually incorporated. When setbacks are used, morning warm-up and cool-down controls should be considered. After morning warm-up, automatic controls should change systems from heating to cooling as spaces heat up due to light and occupancy loads.

Table 1 Recommended Winter and Summer Design Dry-Bulb Temperatures for Various Spaces Common in Schools[a]

Space	Winter Design, °F	Summer Design, °F
Laboratories	72	78[d]
Auditoriums, libraries administrative areas, etc.	72	78
Classrooms		
Pre-K through 3rd	75	78
4th through 12th	72	78
Shops	72	78[b]
Locker, shower rooms	75[d]	[c,d]
Toilets	72	[c]
Storage	65	[c,d]
Mechanical rooms	60	[c]
Corridors	68	80[b]

[a]For spaces of high population density and where sensible heat factors are 0.75 or less, lower dry-bulb temperatures will result in generation of less latent heat, which may reduce the need for reheat and thus save energy. Therefore, optimum dry-bulb temperatures should be the subject of detailed design analysis.
[b]Frequently not air conditioned.
[c]Usually not air conditioned.
[d]Provide ventilation for odor control.

Table 2 Typical Ranges of Sound Design Levels

Space	A-Sound Levels, dB	Desired NC (Noise Criteria)
Libraries, classrooms	35-45	30-40
Laboratories, shops	40-50	35-45
Gyms, multipurpose corridors	40-55	35-50
Kitchens	45-55	40-55

Computerized systems are desirable. They can do much more than start and stop equipment; capabilities include resetting water temperatures, optimizing chillers and boilers, and keeping maintenance logs. See Chapter 39, Computer Applications, for more information about computerized management systems. For further information on controls, see Chapter 46.

Preschools

Commercially operated preschools are generally provided with a standard architectural layout based on owner-furnished designs. This may include the HVAC systems and equipment. All preschool facilities require quiet and economical systems. The equipment should be easy to operate and maintain. The design should provide for warm floors and no drafts. Radiant floor heating systems can be highly effective. Consideration should be given to the fact that the children are smaller and will play on the floor, while the teacher is taller and will be walking around. The teacher also requires a place for desk work; the designer should consider treating this area as a separate zone.

Preschool facilities generally operate on weekdays from early in the morning to 6:00 or 7:00 P.M. This schedule usually coincides with the normal working hours of the children's parents. The HVAC systems will therefore operate 12 to 14 hours per work day and be either off or on night setback at night and on weekends.

Supply air outlets should be located so that the floor area is maintained at about 75°F without the introduction of drafts. Both supply and return air outlets should be placed where they will not be blocked by furniture positioned along the walls. Coordination with the architect about the location of these outlets is essential. Proper ventilation is essential for controlling odors and helping prevent the spread of diseases among the children.

The use of floor-mounted heating equipment, such as electric baseboard heaters, should be avoided, as children must be prevented from coming in contact with hot surfaces or electrical devices.

Elementary Schools

Elementary schools are similar to preschools except that they have more facilities, such as gymnasiums and cafeterias. Such facilities are generally occupied from about 7:00 A.M to about 3:00 P.M. Peak cooling loads usually occur at the end of the school day. Peak heating is usually early in the day, when classrooms begin to be occupied and outdoor air is introduced into the facility. The following are facilities found in elementary schools:

Classrooms. Each classroom should at a minimum be heated and ventilated. Air conditioning should be seriously considered for school districts that have year-round classes in warm, humid climates. In humid climates, serious consideration should be given to providing dehumidification during the summer months, when the school is unoccupied, to prevent the growth of mold and mildew. Economizer systems during the winter months, to provide cooling and ventilation after morning warm-up cycles, should also be considered.

Gymnasiums. Gyms may be used after regular school hours for evening classes, meetings, and other functions. There may also be weekend use for group activities. The loads for these occasional uses should be considered when selecting and sizing the systems and equipment. Independent gymnasium HVAC systems with control capability allow for flexibility with smaller part load conditions.

Administrative Areas. The school's office area should be set up for individual control because it is usually occupied after school hours. As the offices are also occupied before school starts in the fall, air conditioning for the area should be considered or provisions should be allowed for the future.

Science Classrooms. Science rooms are now being provided for elementary schools. Although the children do not usually perform experiments, odors may be generated if the teacher demonstrates an experiment or if animals are kept in the classroom. Under these conditions, adequate ventilation for science classrooms is essential along with an exhaust fan with a local on-off switch for the occasional removal of excessive odors.

Libraries. If possible, libraries should be air conditioned to preserve the books and materials stored in them. See Chapter 3, Commercial and Public Buildings, for additional information.

Middle and Secondary Schools

Middle and secondary schools are usually occupied for longer periods of time than elementary schools, and they have additional special facilities. The following are typical special facilities for these schools:

Auditoriums. These facilities require a quiet atmosphere as well as heating, ventilating, and in some cases, air conditioning. Auditoriums are not often used with exception for special assemblies, practice for special programs, and special events. For other considerations see Chapter 4, Places of Assembly.

Computer Classrooms. These facilities have a high sensible heat load due to the computer equipment. Computer rooms may require additional cooling equipment such as small spot-cooling units to offset the additional load. Humidification may also be required. See Chapter 17, Data Processing and Electronic Office Areas, for additional information.

Science Classrooms. Science facilities in middle and secondary schools may require fume hoods with special exhaust systems. A makeup air system may be required if there are several fume hoods within a room. If there are no fume hoods, a room exhaust system is recommended for odor removal, depending on the type of experiments conducted in the room and whether animals are kept within the room. Any associated storage and preparation rooms are generally exhausted continuously to remove odors and vapors emanating from stored materials. The amount of exhaust and the location of exhaust grilles may be dictated by local or National Fire Protection Association (NFPA) codes. See Chapter 14, Laboratories, for further information.

Auto Repair Shops. These facilities require outdoor air ventilation to remove odors and fumes and to provide makeup air for exhaust systems. The shop is usually heated and ventilated but not air conditioned. To contain odors and fumes, return air should not be supplied to other spaces, and the shop should be kept at a negative pressure relative to the surrounding spaces. Special exhaust systems such as welding exhaust or direct-connected carbon monoxide exhaust systems may be required. See Chapter 30, Industrial Local Exhaust Systems, for further information.

Ice Rinks. These facilities require special air-conditioning and dehumidification systems to keep the spectators comfortable, maintain the ice surface at freezing conditions, and prevent the formation of fog at the surface. See Chapter 4, Places of Assembly, and Chapter 34 of the 2002 *ASHRAE Handbook—Refrigeration* for further discussion of these systems.

School Stores. These facilities contain school supplies and paraphernalia and are usually open for short periods of time. The heating and air-conditioning systems serving these areas should be able to be shut off when the store is closed to save energy.

Natatoriums. These facilities, like ice rinks, require special humidity control systems. In addition, special materials of construction are required. See Chapter 4, Places of Assembly, for further information.

Industrial Shops. These facilities are similar to auto repair shops and have special exhaust requirements for welding, soldering, and paint booths. In addition, a dust collection system is sometimes provided and the collected air is returned to the space. Industrial shops have a high sensible load due to the operation of the shop equipment. When calculating loads, the design engineer should consult the shop teacher about the shop operation, and where possible, diversity factors should be applied. See Chapter 30, Industrial Local Exhaust Systems, for more information.

Locker Rooms. Model building codes in the United States require that these facilities be exhausted directly to the outside when they contain toilets and/or showers. They are usually heated and ventilated only. Makeup air is required; the exhaust and makeup air systems should be coordinated and should operate only when required.

Home Economics Rooms. These rooms usually have a high sensible heat load due to appliances such as washing machines, dryers, stoves, ovens, and sewing machines. Different options should be considered for the exhaust of the stoves and dryers. If local codes allow, residential-style range hoods may be installed over the stoves. A central exhaust system could be applied to the dryers as well as to the stoves. If enough appliances are located within the room, a makeup air system may be required. These areas should be maintained at negative pressure in relationship to adjacent classrooms and administrative areas. See Chapter 31, Kitchen Ventilation, for more information.

Colleges and Universities

College and university facilities are similar to those of middle and secondary schools, except that there are more of them, and they may be located in several buildings on the campus. Some colleges and universities have satellite campuses scattered throughout a city or a state. The design criteria for each building are established by the requirements of the users. The following is a list of major facilities commonly found on college and university campuses but not in middle and secondary schools:

Administrative Buildings. These buildings should be treated as office buildings. They usually have a constant interior load and additional part-time loads associated with such spaces as conference rooms.

Animal Facilities. These spaces are commonly associated with laboratories, but usually have their own separate areas. Animal facilities need close temperature control and require a significant amount of outdoor air ventilation to control odors and prevent the spread of disease among the animals. Discussion of animal facilities is found in Chapter 14, Laboratories.

Dormitory Buildings. A discussion of dormitories can be found in Chapter 5, Hotels, Motels, and Dormitories.

Storage Buildings. These buildings are usually heated and ventilated only; however, a portion of the facility may require temperature and humidity control, depending upon the materials stored there.

Student and Faculty Apartment Buildings. A discussion of these facilities can be found in Chapter 5.

Large Gymnasiums. These facilities are discussed in Chapter 4, Places of Assembly.

Laboratory Buildings. These buildings house research facilities and may contain fume hoods, machinery, lasers, animal facilities, areas with controlled environments, and departmental offices. The HVAC systems and controls must be able to accommodate the diverse functions of the facility, which has the potential for 24-hour, year-round operation, and yet be easy to service and quick to repair. Variable air volume (VAV) systems can be used in laboratory buildings, but a proper control system should be applied to introduce the required quantities of outdoor air. Significant energy savings can be achieved by recovering the energy from the exhaust air and tempering the outdoor makeup air. Some other energy-saving systems employed for laboratory buildings are (1) ice storage, (2) economizer cycles, (3) heat reclaim chillers to produce domestic hot water or hot water for booster coils in the summer, and (4) cooling-tower free cooling.

The design engineer should discuss expected contaminants and concentrations with the owner to determine which materials of construction should be used for fume hoods and fume exhaust systems. Backup or standby systems for emergency use should be considered, as should alarms on critical systems. The maintenance staff should be thoroughly trained in the upkeep and repair of all systems, components, and controls. See Chapter 14, Laboratories, for additional information.

Museums. These facilities are discussed in Chapter 21, Museums, Libraries, and Archives.

Central Plants. These facilities contain the generating equipment and other supporting machinery for campus heating and air conditioning. Central plants are generally heated and ventilated only. Central plants are covered in Chapter 11 of the 2000 *ASHRAE Handbook—HVAC Systems and Equipment*.

Television and Radio Studios. A discussion of these facilities can be found in Chapter 3, Commercial and Public Buildings.

Hospitals. Hospitals are discussed in Chapter 7, Health Care Facilities.

Chapels. A discussion of these facilities can be found in Chapter 4, Places of Assembly.

Student Unions. These facilities may contain a dining room, a kitchen, meeting rooms, lounges, and game rooms. Student unions are generally open every day from early in the morning to late at night. An HVAC system such as VAV cooling with perimeter heating may be suitable. Extra ventilation air is required as makeup air for the kitchen systems and due to the high occupancy of the building. See Chapter 3, Commercial and Public Buildings, and Chapter 31, Kitchen Ventilation, for additional information.

Lecture Halls. These spaces house large numbers of students for a few hours several times a day and are vacant the rest of the time, so heat loads vary throughout the day. The systems that serve lecture halls must respond to these load variations. In addition, because the rooms are configured such that students at the rear of the room are seated near the ceiling, the systems must be quiet and must not produce any drafts. Coordination with the design team is essential for determining the optimal location of diffusers and return grilles and registers. Placement of the supply diffusers at the front of the room and the return air grilles and registers near the front and rear of the room or under the seats should be considered. An analysis of the system noise levels expected in the hall is recommended. See Chapter 47, Sound and Vibration Control, for further information.

EQUIPMENT AND SYSTEM SELECTION

The architectural configuration of an educational building has a considerable influence on the building's heating and cooling loads and therefore on the selection of its HVAC systems. Other influences on system selection are the budget and whether the project is to expand an existing system or to integrate an HVAC system into the design of a new building. ASHRAE *Standard* 100 has recommendations for energy conservation in existing institutional buildings. ASHRAE *Standard* 90.1 should be followed for the energy-efficient design of new buildings. ASHRAE *Standard* 62 addresses the criteria necessary to meet indoor air quality requirements.

The only trend evident in HVAC design for educational facilities is that air-conditioning systems are being installed whenever possible. In smaller single buildings, systems such as unit ventilators, heat pumps, small rooftop units, and VAV systems are being applied. In larger facilities, VAV systems, large rooftop units with perimeter heating systems, and heat pump systems coupled with central systems are utilized. When rooftop units are used, stairs to the roof or penthouses make maintenance easier.

Single-Duct with Reheat

Reheat systems are restricted from use by ASHRAE *Standard* 90.1 unless recovered energy is used as the reheat medium. Booster heating coils should be considered if the heat is to be applied after mechanical cooling has been turned off or locked out (e.g., during an economizer cycle). The booster heating coil system can use recovered energy to further reduce energy costs.

Multizone

The original multizone design, which simply heated or cooled by individual zones, is seldom used because mixing hot and cold airstreams is not energy-efficient. Multizone system units can be equipped with reset controllers that receive signals from zone thermostats, allowing them to maintain optimum hot and cold temperatures and minimize the mixing of airstreams.

Another energy-conserving technique for a multizone design is the incorporation of a neutral zone that mixes heated or cooled air with return air, but does not mix heated and cooled airstreams. This technique minimizes the energy-wasting practice of simultaneously producing both heating and cooling.

Multizone systems are also available that have individual heating and cooling within each zone, therefore avoiding simultaneous heating and cooling. The zone thermostats energize either the heating system or the cooling system as required.

Replacement multizone units with the energy-saving measures (see the section on Energy Considerations) are also available for existing systems. The replacement of multizone units with VAV systems described in the next section has been successful.

Variable Air Volume

Types of variable air volume systems include single-duct, single-duct with perimeter heating, and dual-duct systems. The supply air volumes from the primary air system are adjusted according to the space load requirements. VAV systems are most often zoned by exposure and occupancy schedules. The primary system usually provides supply air to the zones at a constant temperature either for cooling only or, in the case of dual-duct systems, for heating or cooling. To conserve energy, heating and cooling should not be provided simultaneously to the same zone. Heating should be provided only during economizer cooling or when mechanical cooling has been turned off or locked out.

Perimeter heating can be provided by duct-mounted heating coils, fan terminal units with duct- or unit-mounted heating coils, perimeter fin tubes, baseboard heaters, cabinet unit heaters, or convectors. Radiant ceiling or floor heating systems can also be applied around the perimeter. Each zone or exposure should be controlled to prevent overheating of the space. Perimeter air-distribution systems should be installed so that drafts are not created.

Fan terminal units are utilized when constant air motion is required. These units operate either constantly or only during heating periods. Noisy units should be avoided. A system of fan terminal units with heating coils allows the primary heating system to be shut off during night setback or unoccupied periods.

Packaged Units

Unit ventilators or through-the-wall packaged units with either split or integral direct-expansion cooling may serve one or two rooms with a common exposure. Heat pumps can also be used. When a single packaged unit covers more than one space, zoning is critical. As is the case for VAV systems, spaces with similar occupancy schedules are grouped together. If exterior spaces are to be served, exterior wall orientation must also match.

For water-source heat pumps, a constant flow of water is circulated to the units. This water is tempered by boilers for heating in the winter or by a fluid cooler provided for heat rejection (cooling). Heat rejection may be necessary for much of the school year, depending upon the internal loads. Certain operating conditions balance the water loop for water-source heat pumps, which could result in periods in which neither primary heating nor cooling is required. There may be simultaneous heating and cooling by different units throughout the facility, depending upon exposure and room loads. A water storage tank may be incorporated into the water loop to store heated water during the day for use at night.

Air-to-air heat pumps are also used in schools, as are small rooftop and self-contained unit ventilators featuring heat pump cycles.

REFERENCES

ASHRAE. 2001. Energy standard for buildings except low-rise residential buildings. ANSI/ASHRAE *Standard* 90.1-2001.

ASHRAE. 2001. Ventilation for acceptable indoor air quality. ANSI/ASHRAE *Standard* 62-2001.

ASHRAE. 1995. Energy conservation in existing buildings. ANSI/ASHRAE *Standard* 100-1995.