levels of unit conditioners are generally somewhat greater than those of unit ventilators. Unit conditioners are described in Chapter 16, Unitary Air-Conditioning Equipment.

AUTOMATIC CONTROL

Discussion of automatic control in this chapter will be limited to general factors peculiar to school systems, and their effect on control or the need for it. Chapter 43, Automatic Control, provides a detailed discussion of the proper application of automatic control to the various system elements normally encountered.

Automatic temperature control equipment is justified in school systems because manual control will not maintain the temperature or environment within desirable limits.

Automatic control, made an integral part of the system design, can reduce the *initial cost* of the mechanical installation. Examples of this type of control include *warm-up clocks* or low-limit thermostats, which prevent the use of outdoor air until the building has been heated for a set period of time, or until a minimum space temperature is reached. Such controls permit selection of the minimum size of equipment such as boilers, furnaces, burners, coils, piping, etc., having the least excess capacity for warm-up purpose. Controls to prevent the heating of service water in large storage tanks during the warm-up period accomplish a similar result.

Controls which reduce the man-hours of attendance at the heating plant or reduce fuel costs, can reduce *operating costs*. Time clocks, relays, temperature and pressure control, which allow the starting of the heating plant without the presence of supervising personnel, are included in this category, together with controls to reduce the use of outdoor air during warm-up periods.

Where fans and extended surface coils are used to maintain the temperature in an occupied space having outside exposure, it is not possible to control the capacity of the equipment manually without producing alternately high and low space temperatures because of the rapid changes in load due to shifting occupancy, variation in solar intensity, and wind variation in speed or direction, and the relatively high capacity of this type of equipment. Where occupancy is particularly dense, the changes in load due to changes in occupancy alone are enough to make proper automatic control necessary in order to maintain space temperatures within acceptable limits. This applies to a large percentage of the spaces in a school building.

There are many other factors or conditions that make proper automatic control necessary in order to achieve acceptable environmental conditions. Those already discussed illustrate some basic considerations in applying temperature control to mechanical systems for schools.

OPERATION

The proper method of operation of a system depends upon its design and the automatic control applied to it and will vary with each individual system. To insure good operation throughout the life of a system, it is essential that adequate written instructions be prepared and made readily available to the operating personnel. There should be at least two copies of the instructions, one of which should be placed in a secure depository to insure its preservation in good condition during the life of the building.

The operating personnel should be thoroughly instructed regarding proper operation of the equipment upon completion of the installation. Someone having authority in the school administration, in addition to the operating personnel, should be instructed in the operating characteristics of the system, not only to insure that a change in the operating personnel does not result in the loss of knowledge required for the proper operation of the system, but also to insure that the operating personnel adheres to the instructions.

It is seldom that the personnel in charge of the operation of a school system has training particularly applicable to the characteristics of mechanical equipment or the automatic control applied to it. Therefore, it is essential that this type of operating personnel be made to understand the exact limits that must be observed in adjustment and operation of the system. Where temperature control is applied to a system, it must be realized that any instrument used for control purpose is of necessity very sensitive to any change or adjustment made in the setting of the instrument. Therefore, it is necessary that only personnel fully trained in the proper handling of the instruments should make adjustments other than those expressly designated as proper for the operating personnel.

It is common practice for officials in large school districts where there are many buildings to employ specialists acquainted with the adjustment of critical items of equipment such as temperature and automatic control. Where individual schools do not have such personnel available, it is necessary that the operating personnel be instructed to communicate with qualified service agencies to make changes in automatic control settings and instrument characteristics when they are found to be necessary by experience in the operation of the system. Continuing service contracts for proper maintenance of equipment can be had from companies in this field.

When systems are installed and designed on the basis of natural or gravity ventilation, the teacher or person in charge of the individual room or space must perform the functions of adjusting window openings or ventilator settings to provide the conditions of comfort and proper environment in the space. To accomplish efficient operation of the system and maintain a suitable environment, it is necessary that these people be instructed in detail regarding the techniques necessary to achieve the proper environment. It is necessary that the administrative authorities supervise the maintenance of such conditions by periodic checks on the efficiency of the people responsible for the spaces.

MAINTENANCE OF MECHANICAL SYSTEMS

The proper maintenance of a mechanical system will result in a minimum of repair and the extended life of the system equipment. As is the case with operating instructions, it is essential that written instructions for the maintenance of the system be prepared and given to the owner when the system is completed and placed in his charge. These instructions should include detailed information on the lubrication and care of each item of equipment. A schedule showing items of maintenance to be performed for each month of the year should be prepared.

Name plates and identification for each valve and item of equipment should be prepared. Manufacturers' catalogs and parts lists for the equipment should be obtained. One copy of each of these items should be placed in a secure depository, together with the operating instructions.

A list of the proper service agencies should be prepared and placed in the hands of the operating personnel. Any changes in service agencies should be recorded for the benefit of the administration as well as the operating personnel.

CHAPTER 48

TRANSPORTATION AIR CONDITIONING

Railway Passenger Car Air Conditioning; Passenger Bus Air Conditioning; Automobile Air Conditioning; Aircraft Air Conditioning; Ship Air Conditioning, Heating and Ventilating, Air-Conditioned Space Treatment, Systems and Controls

THE principles of air conditioning applying to stores, restaurants, hospitals, theaters, and homes are applicable to railway passenger cars, passenger buses, automobiles, streetcars, trolley coaches, airplanes, and ships. However, equipment used for mobile applications differs from that used for stationary purposes in that it must meet additional requirements. Equipment must be compact, accessible for quick inspection and servicing, light-weight and unaffected by vibration and impact. Freedom from vibration which could be transmitted to supporting vehicle and thus to passengers, is essential.

RAILWAY PASSENGER CAR AIR CONDITIONING

The railway passenger car represents a very difficult air-conditioning problem. Space is strictly limited so that all equipment and ducts must be reduced to minimum size. Electric power supply and water supply also are limited. All equipment must withstand severe vibration and shock, and must be very reliable since servicing points are frequently far apart.

During the heating season it is necessary to heat conventional cars with steam from the locomotive at pressures that may vary from 250 psig to only 5 or 10 psig on the last car in long trains. Passengers in window seats sit only a few inches from cold outside walls and windows, and are close to heating surfaces installed along sides of cars. Sudden changes in load may be caused by changes in sun, wind, or train movement. Even in coldest weather, outside doors must be opened frequently.

During the cooling season, the problem is further complicated by a highly concentrated internal load due to the passengers. Air distribution problems are increased by low ceilings and short air throws.

Heating

The heating of passenger cars is accomplished by using a split system consisting of an overhead air-circulating system with heating and cooling coils, and heating surfaces (floor heat) along car sides. The floor heaters, which usually consist of finned tubing, may be made more effective by addition of covers designed to increase gravity air circulation, and to direct the warm air from finned heating surface along cold outside walls and car windows. In some new cars, wall convector panels are used and extend the full length of the car, with air intakes along the floor and outlets at window sill height and at window head height in dead-light panels. The heated panel protects passengers from cold outside walls, and the chimney effect of the panel duct increases air flow and improves heating surface effectiveness.

Floor heat is supplied by introducing steam into an inner tube within a finned tube or by means of a separate steam-to-liquid heat exchanger. The liquid (usually an antifreeze) is mechanically circulated through plain finned tubing. When steam is used directly, the tube-within-a-tube construction makes it possible to obtain uniform distribution throughout the length of the car. It is achieved by means of heat transfer between the steam within the inner tube and the condensate returning in the annular space between the tubes.

The finned tubing at the floor must have sufficient capacity to offset effects of cold walls and windows during normal operation, and to heat the entire car to a minimum temperature of 60 during standby when the overhead system is not operating. The maximum capacity required (determined by standby requirements) varies with car construction and design temperatures, but is approximately 90,000 Btu per hour. This requires a heating capacity in finned tube of approximately 650 Btu per linear foot.

The overhead air heating coil must have sufficient capacity to heat the outdoor air brought into the car for ventilation, and to supply approximately 20 percent of the internal heat loss of the car so as to permit supply of floor heat at all times at an output that will not be objectionable to passengers sitting near it. The usual capacity of the overhead heating coil is approximately 100,000 Btu based on 2400 cfm of circulated air, with 600 cfm of this being outdoor air for ventilation. All Btu values are approximations of actual heating requirements, and do not include heat losses in the trainline (or leakage) or losses in the undercar piping. Present car designs have enabled the car builder to run the steam supply lines in recesses within the car body, thus greatly diminishing under-car losses.

Refrigeration

For cooling and dehumidification during summer, refrigeration may be obtained from ice bunkers, steam-jet systems, or mechanical compressors (driven directly from car axle by electric motors or by gas engines). Refrigeration required varies with load conditions, but 7½ tons per car is one capacity frequently used. Evaporative-type condensers are sometimes used in combination with the usual air condenser on either steam-jet or mechanical refrigeration.

When an electric motor (approx. 10 hp) is used to