

Electric Heating

Any of the heating systems (direct radiation, panel heating, central indirect air systems, split systems, or unit ventilators) discussed for schools has an electrical counterpart using electric heating equipment. For complete air conditioning systems, heat pumps may be used.

Careful design and evaluation of structure, insulation and heating system are essential to attain a competitive annual owning and operating cost of the electrically heated school because of the usually higher cost of electrical energy for heating compared to combustion fuels. The cost of energy will depend on the local electrical rates. Since schools are sometimes served on different rates than other uses, the utility serving the school should be contacted to determine the most advantageous applicable electric rate.

Electric heating is discussed in Chapter 11. Heat Pumps are discussed in Chapter 4 of this volume and Chapter 58 of the 1961 GUIDE AND DATA BOOK.

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 13 of the 1961 GUIDE AND DATA BOOK 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

To assure good operation, adequate written instructions should be prepared and made readily available to the operating personnel. A copy should be placed in a secure depository to assure 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 assure that a change in the operating personnel does not result in the loss of knowledge required for proper operation, but also to assure 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 automatic 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.

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.

SURFACE TRANSPORTATION AIR CONDITIONING

AUTOMOBILE AIR CONDITIONING: General Design Requirements, Capacity Requirements, Air Distribution, Temperature and Humidity Control, Space Limitations, Engine Performance and Operation, Design Requirements for Compressors, Condensers, Drives, Evaporators, and Controls; **RAILROAD AIR CONDITIONING:** Passenger Car Construction, Equipment Selection Consideration and Design Limitations, System Design; **BUS AIR CONDITIONING:** Design Considerations, Capacity Requirements, Air Distribution, Equipment Location, Drives, Controls

THIS chapter discusses the special considerations affecting the design and application of air-conditioning systems for automobiles, railroad passenger cars, and buses.

PART I: AUTOMOBILE AIR CONDITIONING

Comfort cooling of the automobile with mechanical refrigeration equipment is rapidly becoming one of the most popular major accessory features. The units are available as factory installed systems or can be added to the cars in the field by automotive dealers or various air conditioning dealers who feature automobile air conditioning.

The numerical growth has been accompanied by a large amount of design and development work that constantly strove to provide the best comfort value, i.e., the greatest cooling comfort in the automobiles for the least money. The industry has passed through several basic stages of development and has investigated many more that were found to be impractical from the standpoint of bad applications, poor performance, or high cost.

TYPES OF UNITS

The basic types of automobile air-conditioning units are: (1) the trunk unit, (2) the combined car heater-air conditioner, and (3) the under-dash type.

The trunk unit mounted under the rear deck, with air intake and discharge above and behind the rear seat, was successfully used as a factory- or field-installed system, and is still provided in some cars either as a single system or an auxiliary unit.

The combination of air conditioning with the car heater has become popular among automobile manufacturers because: (1) it provides a complete year-round system in one assembly and (2) it can be pre-charged and pre-tested, and installed conveniently either at the factory or in the field.

The under-dash type is popular for field installation and is being considered for factory installation. This system also can be charged and tested prior to installation and provides effective cooling performance.

GENERAL DESIGN REQUIREMENTS

Like most air-conditioning systems the auto air conditioner must provide adequate comfort cooling to the passengers in the conditioned space under a wide variety of ambient conditions. The cooling load is affected by many of the usual factors such as outdoor temperature and humidity, air leakage into the conditioned space, quantity of outdoor air brought in, the number of occupants, and sun load. These load factors, however, are constantly and rapidly changing as the automobile moves over the highways at different speeds and in different directions, and over various types of road surfaces and through all kinds of surroundings. For example, the faster

the car moves the greater the amount of infiltration into the car, and the better the heat transfer coefficient between the outdoor air and the car surface. The sun baking down on a black-top road will raise its temperature to approximately 135-150 F, and thus increase the amount of heat transmitted into the car through the floor. When driving through a grassy or wooded terrain, much less indirect or radiant heat is experienced in the car than when passing through sandy flats or rocky hills. The sun can shine in through the side windows, windshield, or rear window as the car follows turns in the road, thus varying the amount and location of the sun load in the car. The fact that the car is moving and changing direction very definitely complicates the determination of actual design load.

The variation in car speed from idle or very slow moving traffic conditions to high speed open highway driving for extended periods also complicates the unit basic design specifications necessary to match the cooling load. The unit capacity is the lowest at idle speeds with no car movement because the compressor is driven directly from the engine, and the amount of air available to cool the condenser is at a minimum. The slow compressor speed combined with the high condensing temperatures result in a low and unusual inadequate capacity at idle conditions. Operation in slow moving traffic is only slightly better than at idle. The intermittent increases in engine speed give corresponding increases in compressor capacity and condenser (and radiator) air flow. This provides more cooling during the running periods. If the car can move for some distance between stops, the cooling capacity can be adequate. Some improvement can be gained if the car is kept in low gear during the short running distances. This keeps the engine and fan speed at a maximum for a given car speed. Satisfactory performance at idle and slow speeds is one of the major design and development challenges facing those engineering and applying automotive air conditioning. Fig. 1 shows representative variations in car temperature when changing from open road driving to city traffic (15 mph and idle).

There are also considerable variations in cooling load requirements between the multitude of automobile models. A system designed for a 4-door sedan, for example, may have considerable difficulty in maintaining comfort conditions in the rear section of a station wagon. The rapidly increasing number of station wagons sold will focus more attention to their cooling problem in the future.

The discussion so far on Design Requirements has described some basic factors to be considered in starting out on an auto air conditioner design or application. It is readily apparent that much of the design approach rests upon empirical tests because of the multitude of variables that are almost impossible to calculate with any accuracy. It is possible though to establish some specific parameters for unit design based upon