analysis of owning and operating costs for the various systems being considered, as well as any other special considerations for the particular store.

Unitary systems generally are used where a multiplicity of small stores with varying hours of operation would make a central station system both inconvenient and costly to operate. This type of design is normally encountered in the smaller shopping centers.

Larger department stores and shopping centers are usually served by one or more central station systems distributing chilled water to the various areas requiring heating or cooling. As in the case of unitary systems, the store hours, load variations, and size of load will affect the final selection of equipment.

Every effort should be made to minimize the use of sales space for air conditioning equipment, with consideration being given to ceiling and roof locations wherever practicable. However, the added structural and architectural requirements must be considered, as well as possible increases in wiring and rigging costs. In selecting locations for equipment, the designer should keep in mind the maintenance and operation of the system after installation.

Air Distribution

All buildings must be studied for orientation, wind exposure, construction and floor arrangement. These factors not only affect load calculations but also zone arrangements and duct locations. In addition to planning for entrances, wall areas with significant glass, roof areas, and population densities, the expected locations of various departments such as the lamp department should be considered. Certain areas such as beauty parlors may require cooling when the other store areas are operating on ventilating or heating. Certain flexibility must be left in the duct design to allow for future movement of various departments and, in the modern store, a possible increase in lighting intensity. The preliminary duct layout should also be checked from the standpoint of winter heating to determine any special situations to be considered. In the case of entrances, it sometimes becomes necessary to design for separate air systems, particularly in northern areas. This would also be true for storage areas where cooling is not contemplated.

Air Quantity

Supply air quantities should be selected to provide an air change rate of approximately 10 to 12 min in normal load densities, and as much as 5 to 6 min for heavy load densities, with diffusion (supply) temperatures adjusted accordingly. Care should be taken to avoid drafts by proper design of the distribution system. Lower rates of change, up to 15 min or more, may be used for economy, for areas with low occupancy and load density, or for areas with high ceilings.

First floor areas with high ceilings frequently have mezzanine balconies, with supply ducts located beneath the balcony approximately 10 ft above the floor, serving the main floor area. A stratifying effect occurs which permits supply air quantities to be based on a 10 to 12 min air change (diffusion and load density permitting) for the space volume represented by this lower 10 ft strata rather than for the entire ceiling height volume of the space. Adequate air movement to satisfy optimum comfort requirements can be obtained with such an air distribution arrangement.

Duct Design

The design of duct systems should be in accordance with the methods discussed in Chapter 12 of the 1961 GUIDE AND DATA BOOK.

The use of higher duct velocities is increasing for air-conditioning systems in both existing stores and new installations. The reduction in space requirements for duct risers and branches using high velocities (4000 to 6000 fpm in trunk ducts and approximately 3000 fpm in branches) has permitted the installation of central station systems which might not have been possible with lower velocities.

Temperature Control

Control requirements are more or less similar to general air conditioning practice and are discussed in Chapter 13 of the 1961 GUIDE AND DATA BOOK and Chapter 1 of this volume. The extent of automatic control will depend on the type of installation and particularly the extent to which it is zoned. Each zone must have its own thermostat operating controls on equipment serving that particular area. The central station system supplying air to the zones must be controlled so that air of the correct condition is delivered to the zones. Master thermostats which lower or raise the settings of zone thermostats with the variations of outdoor summer dry-bulb temperatures are often desirable from the standpoint of transient customer occupancy. The use of outdoor air for cooling during intermediate seasons should be under automatic control so that this function can be provided at minimum operating cost. Exhaust air controls, when necessary, permit venting or relieving the excess air to the outside, thus keeping pressure in the building at unnoticeable levels.

Partial, or full, automatic control should be placed on the refrigeration system to permit plant capacity variation to compensate for load fluctuations. This will, of course, be a function of the plant design, the size of the installation and the possible savings in operating cost as a consequence of the additional controls. Completely automatic refrigeration plants are now practical at little additional cost and should be given careful consideration.

In general, a blow-through type system is recommended for small department stores where the comparatively small air quantities used to do not create serious physical arrangement and space problems. The system is excellent in providing zoning flexibility, is economical, and is considered generally superior to systems which compensate for load fluctuations by varying air supply volumes, with consequent disturbances to the air system balance and variation in ventilation air. Multi-zone blow-through units are often used even in larger stores.

REFERENCES

[1] *Cooling Load Estimate Forms for Self-Contained Air Conditioners* (ARI Standard No. 2-20, Air-Conditioning and Refrigeration Institute, 1953).

[2] Arthur Rose and S. L. Sloan, Jr.: Air conditioning the variety store (*Air Conditioning, Heating and Ventilating*, February 1960, p. 79).

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CHAPTER 15

PUBLIC BUILDING AIR CONDITIONING

MULTIROOM BUILDINGS: General and Special Factors in Design, Zoning Requirements, Solar Heat Gains, Internal Loads, Cooling Load Distribution, Installation and Operating Costs, Local System Details, Choice of Systems; CHURCHES, THEATERS, AND AUDITORIUMS: Cooling Load Factors, Ventilation, Precooling, Types of Systems, Design Calculations, System Operation, Economics; EATING AND AMUSEMENT PLACES: Survey, Analysis and Division of Zones, Load Calculations, Selection of Equipment

THIS chapter deals with current practice in air conditioning public buildings. It is divided into three parts: Part I, Multiroom Buildings; Part II, Churches, Theaters, and Auditoriums; and Part III, Eating and Amusement Places.

PART I—MULTIROOM BUILDINGS

In Part I practice will be described for (1) office building, (2) hotels (guest rooms), (3) hospitals (patient rooms) and (4) apartment buildings.

Air-conditioning for human comfort was still largely limited to large spaces (such as theaters) around 1930—and thereafter for a period progress was retarded by economic conditions in the United States. During the same period, however, *self-contained* room units and unit systems were developed and installed for individual rooms and parts of buildings. Although misapplied in many instances, units and unit systems were comparatively low in first cost and, being suited to partial installation, they contributed in a large measure to wider acceptance and increased demand for air conditioning. During these early stages, with systems differing widely, experience was gained which can now be a guide to the types of systems appropriate for multiroom buildings, considering the size, load characteristics, and economic factors involved.

Air conditioning of multiroom buildings is different from practices which apply successfully to theatres, department stores, or similar buildings which have large open areas with a small external heat gain as compared with the internal load.

Multiroom buildings have a large percentage of outside rooms. The solar heat gain alone may amount to from 30 to 50 percent of the total heat load. This external load is constantly changing throughout the day and therefore, zoning of the building according to exposure is required. However, the internal load may also vary from room to room, and since a central zoning system is capable of maintaining, at best, only an *average* temperature throughout the zone (with compromise results in many spaces), the results in some spaces may be most unsatisfactory.

In a theater the occupant has no choice but to accept an average comfort level. In an office building, however, each tenant rightfully expects acceptable comfort conditions in each room. In a hotel or apartment the temperature level should be subject to selection and adjustment by the occupants of each room.

GENERAL FACTORS IN DESIGN

Special design requirements. To satisfy the requirements of multiroom buildings, aside from the usual functions of year-round air conditioning which include ventilation, cleaning, dehumidifying, humidifying, heating, cooling, and air circulation, equipment must provide capacity and flexibility (1) (to meet variations in external and internal loads, including adequate *simultaneous* heating and cooling capacity; (2) means of obtaining individually selected temperatures (within a reasonable range); and (3) maintenance of these temperatures in each room, independent of the others during all seasons.

Simultaneous capacity for heating or cooling has not always been given sufficient consideration in the past. At the end of the so-called cooling season, some systems are stopped or switched over to the winter heating cycle. As an examination of weather records will disclose, there are a great many days during the intermediate seasons of spring and fall when both heating and cooling are needed on different facades, or at different times on the same facade. Also, buildings of this type frequently have large window areas with correspondingly high solar heat gains. Hence on cloudy, humid days in summer when this solar heat is lacking, some reheating may be required. Conversely, in winter on bright days, the effect of sun may necessitate cooling of exposed areas. For example, in November, the south exposure may require heating in the morning, cooling during midday and heating again in the afternoon. Such reversals of load cannot be met by the average conventional system. Under certain conditions, even when the building as a whole may require heating, a few rooms (due to concentrated internal loads) may require cooling. This condition makes it necessary to have capacity for simultaneous heating and cooling available at each room, independently of the others, and to have provision for individual room control. The failure of early systems to meet these conditions was at first condoned but now, with greater experience and improved practices, no system will be acceptable that does not fulfill these requirements.

SPECIAL DESIGN FACTORS

While the four types of buildings mentioned have many similar requirements (as distinguished from auditoriums or other large spaces), there are also important differences which affect their proper air-conditioning. The factors affecting design for each type will be discussed.

1. *Office Buildings.* Office buildings generally include *both peripheral*, and *interior zone* spaces. The peripheral zone may usually be considered as extending from 12 to 18 ft *inward* from the outer wall toward the center-line of the building and will have windows, frequently of large area. This zone is apt