tem, a detailed study of (1) first cost, (2) owning and operating cost, (3) space requirements, and (4) effect on total building or remodeling costs, should be conducted. Some of the pertinent factors of the major systems will be listed.

Indirect Systems

The indirect or chilled water system is common in this application particularly on large projects or when the space is part of a larger system, such as an auditorium in an industrial plant or a church in an office building. Savings can be made in the total installed equipment, because the space may have a peak load at a different time than the rest of the building. In the case of auditoriums, containing an ice rink, the air conditioning compressor may also be a part of the ice-making system.

Indirect systems usually make use of reciprocating liquid chilling units, hermetic electrical centrifugals, steam turbine driven centrifugals, or absorption liquid chilling units. The choice depends on the availability of steam, high temperature water, or power, and relative costs.

Direct Expansion Systems

Direct expansion systems employ central station fan and coil units, a reciprocating compressor and air, water, or evaporative condensers. Within the tonnage range of these systems, they are usually the lowest in first and operating cost. Broad industry usage of this type of system makes it the easiest to engineer, install, and maintain. The direct expansion system is the one normally used in churches.

Factory Assembled Self-Contained Units

Self-contained or packaged units are finding increasingly greater acceptance in these applications. They have all the advantage of the field assembled systems and are usually lower in first cost. Their compact size is an advantage when air-conditioning existing buildings. High salvage value, ease of operation and low maintenance are other advantages. These units are offered in sizes from approximately 2 to 100 tons, using water, air, or evaporative, integral or remote condensers.

Ice or Water Storage Systems

In many churches the system used combines the chilled water system with a storage tank for storing cold water or with a commercially available ice storage container. In this system, a relatively small condensing unit operates continuously 24 to 48 hours prior to the peak load, to store up the necessary capacity. This system had the stated advantage of low operating costs when high demand rates are charged. However, the operating costs of a standard system, making use of precooling, will be approximately the same or lower, due to the shorter running time. The disadvantages are high first cost, due to the storage tank, extra piping and controls, large space requirements, long recuperation period and operational complications.

Ice Melting System

A system similar to the ice or water storage system is the ice melting system, where capacity is bought in the form of ice. The chilled water, formed from spraying water over the ice, is circulated to an air handling unit for cooling. Very few of these systems are still in operation, due to high operating costs and poor temperature and humidity control.

Heat Pump Systems

On new construction, particularly in the southern portions of the country, heat pump units are becoming increasingly more popular for these applications. (See Chapter 4, Heat Pump Systems for Air Conditioning.)

DESIGN

Load Calculations

The cooling load is calculated in the normal manner using the information contained in the section on Cooling Load Factors in this chapter and also Chapter 26 Air-Conditioning Cooling Load in the 1961 GUIDE AND DATA BOOK.

The cooling load of the sanctuary portion of *churches* will vary between 0.045 and 0.060 tons per person. The load on the other spaces: educational facilities, fellowship halls, offices, etc., will depend on the usage and other pertinent factors.

A simplified estimating method for *theaters* based on field tests has been presented.[1] It applies to the basic movie theater, the auditorium portion and any other section connected directly to it, but not the manager's office, lobby, restroom areas and projection booths which have their own special and distinct problems. Allowing the excess ventilation air to spill out from the lobby to the street is usually sufficient to cool the lobby and advertise air conditioning to passers-by. In order to use this method, the following information is required: theater location (thus the outdoor design conditions), the seating capacity, the ventilation air (cfm per person) and the desired inside design conditions.

Equipment Location

The equipment should be located close to existing utilities (water, power, drain and gas) and to the conditioned space, in order to minimize installation cost. However, vibration and noise isolation is also an important consideration in the equipment location and design. The inherent noise level of these applications will range from 35 to 40 decibels. Equipment located on structural members of the buildings should have vibration eliminators and isolation type pipe hangers should be used to prevent vibration transmission to the building. Special treatment is also required where piping or ductwork passes through partitions or floors. Where short ductwork runs are necessary between supply or return grilles and the air handling units, sound absorbing duct lining, cells or baffles should be used.

Air Distribution

The air distribution system should be designed to supply the required air quantity without objectionable noise or drafts. Good engineering design is more important than the type of system used. Depending on the space arrangements, ceiling or sidewall distribution, wall registers and windowsill outlets have been successfully used. Fig. 1 shows a typical theater air distribution system. In churches, special treatment is required to provide spot cooling at the altar and pulpit and sometimes in the choir loft. These locations are usually elevated above the congregational seating area, and thus are warmer due to stratification, whereas due to the heavy vestments or robes worn, a lower temperature is required.

Noise prevention should be paramount in the design. The following duct design recommendations are based on the usual engineering factors. Main duct velocities of 1500 feet per min and branch or runoff velocities of 1200 feet per min

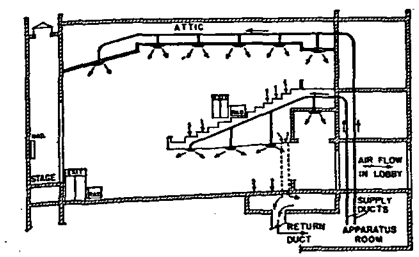

Fig. 1 .... Air Distribution of a Typical Theater Using Ceiling Diffusers

are recommended for conventional systems Take-off runs should be carefully designed and all square and short radius elbows should be equipped with properly designed turning vanes. Return air grille locations are not critical except that they should not be placed near seated people, nor permit direct transmission of sound from apparatus. Normal locations are at the rear of the auditorium, the back of rear pews or in the steps to the altar or stage. In theaters or auditoriums used for live shows with orchestral accompaniment, the proscenium (or pit) should not be used for return air. Return air grille free area velocity should not exceed 600 feet per min. Return air duct velocity of 1200 feet per min is satisfactory. To allow good balancing of the system, dampers and splitters should be installed. Outlet velocity should be selected to give good air quantity and distribution.

Control System

The control system for these applications should be designed for the operational and maintenance help available at the project. For instance, in the case of churches, a janitor will probably operate the system, whereas on some larger systems an operating engineer may be employed. The lower the quality of the operating personnel, the simpler and more automatic should be the system. A simple control system will also require less maintenance and service.

Church auditoriums can usually be adequately controlled by means of an on-off system, whereas Sunday school rooms or an educational building may require zoning or means of individual room control to take care of changes in population and solar effects. Small classrooms can usually be controlled by means of limited volume control. The normal control system employed for theaters and auditoriums is face and bypass control. This system will give better relative humidity control than on-off control. On larger jobs, it is usual to vary the compressor capacity with the coil load as it changes with outdoor air temperature. Operating cost can be saved by using outdoor air for cooling during the intermediate seasons.

Many churches have Sunday school rooms in the basement underneath the church sanctuary. If this space is not used simultaneously with the church sanctuary, a first cost saving can be made by sizing air handling equipment for each space, but sizing the refrigeration equipment for the larger of the two loads. The refrigeration equipment will operate only for the space requiring cooling. Note that in most cases, compressor capacity control is required to prevent coil frosting when only the small unit is running. When the Sunday school load is small, the refrigeration capacity may be enough to cool these quarters and also precool the sanctuary prior to the service, operating only on return air.

SYSTEM OPERATION

The operation of the system is dependent entirely on its design. Therefore, detailed instructions for the operating personnel are required. Many of the factors of the system operation have been discussed in the previous sections. Maintenance in many installations had been neglected due to the lack of knowledge and necessary skills on the part of the operating personnel.

ECONOMICS

The installation cost of the equipment and systems can be estimated in a normal manner. The problem is somewhat simplified by the load estimating methods described here.[1] As these methods reduce the load estimating time to a minimum and allow a general calculation of the tons per seat to be made for a specific geographical area and inside design condition, the next logical step is to calculate the dollars per seat based on the various types of systems used. These figures will prove useful for checking and budget estimating.

PART III—EATING AND AMUSEMENT PLACES

Air conditioning of restaurants, cafeterias, bars, and night clubs presents all of the usual problems encountered in comfort conditioning with the addition of several factors specifically applying to this type of application. Some of these are:

1. Extremely variable loads with high peaks occurring in many cases twice a day.
2. High sensible and latent heat gains due to gas, steam, and electric appliances.
3. High concentration of food, body, and tobacco-smoke odors necessitating adequate ventilation with proper exhaust facilities.
4. Localized high sensible and latent heat gains in night club and dinner club dancing areas.
5. Unbalanced conditions in restaurant area adjacent to kitchens which, although not a part of the conditioned area require attention.
6. Heavy infiltration of outdoor air through doors due to high usage factor during rush hours.

SURVEY

The first approach to any air conditioning problem is an accurate survey. It is especially important in restaurant applications to obtain all the data relating to time and duration of all peak loads caused by people, sunlight, and restaurant equipment. Amusement establishments are often divided into several areas such as a bar, a cocktail room, restaurant and night club; in which case, it is necessary to determine the peak loads in each area since they usually do not occur simultaneously.

During the survey, it is advisable in restaurant and cafeteria applications to advise the owner of any possible improvements that can be made to reduce existing heat gains. Due to the highly concentrated sensible and latent heat loads encountered reductions can frequently be made that more than pay for the initial outlay in reduced cost and operating expense of the air conditioning equipment. Items to be considered are as follows:

1. If any unhooded or improperly hooded equipment, such as coffee urns, steam tables, toasters, grills, etc., are within the conditioned area, they should, if at all possible, be removed to the kitchen, or efficiently designed hoods should be installed.
2. A study should be made of existing exhaust fans with the following possibilities in mind: