have no internal induction, but hasten external induction by supplying air in multiple layers. Others have internal induction and distribute air over an entire hemisphere. The induction effect is greatest in the direction of the axis of the outlet, and least in the plane perpendicular to the axis and located at the ceiling level. Thus the induction is greatest in the vertical direction where the least throw can be tolerated, and least in the horizontal plane at the ceiling where the greatest throw is desired. (Refer to section *Slotted Outlets* under Wall Outlets.)

3. *High-pressure or High-velocity Outlets.* Refer to text in section Wall Outlets.

4. *Perforated Ceilings and Perforated Panels.* These devices discharge air through perforations in the ceiling or part of the ceiling, and share with slotted outlets the advantage of unobtrusive appearance. In addition, sound-absorbing materials may be used for the panels, or the panels may provide a luminous ceiling.

Outlet air velocities may be kept low by using large outlet areas, particularly in spaces with high room loads, high ventilating requirements, or low ceilings. Some perforated panels have a control plate frame which is inserted in the conventional ceiling duct. Supply air enters the plenum above the distribution plates through an adjustable air valve which can be set for varying air quantities and velocities. (Refer to Perforated Panels in section Ventilating Jets in Air Distribution.)

OUTLET LOCATION AND SELECTION

The design of the air-conditioning plant for a building depends on the use to which the building is put, on its size, and its construction type. The design of the air transmission and air distribution system is influenced by the same factors. Therefore, these factors must be considered in designing the air transmission system, and in selecting the type and location of the supply outlets. The location and selection of the supply outlets is further influenced by the interior design of the building, local sources of heat gain or loss, and outlet performance and design.

Use, Size, Construction of Building

The use, size, and construction of a building are three factors which may influence or even govern the selection of a particular type of air distribution system, as is shown by the development of special high-pressure or high-velocity transmission and distribution systems for multi-room and other buildings. Generally, the physical details of the individual rooms of a building, such as height and shape, and the location of beams and other obstructions, influence the possible location of the supply ducts which in turn influences the outlet locations. The location of the supply ducts—above the ceiling or within the walls, in a furred space above corridors, or in the conditioned room itself—has an important bearing, therefore, upon the design of the air distribution system. A particular method of air distribution may be highly desirable but it may be impossible to use it, due to the location of beams and masonry walls.

Refer to later section Specific Applications for a discussion of air distribution methods in various buildings.

Heat Gain or Loss

Local sources of heat gain or loss promote convection currents or cause stratification, and may, therefore, determine both the type and location of the supply outlets.

Generally, the outlets should be located to neutralize any undesirable convection currents set up by a concentrated heating load. If a concentrated source of heat is located at the occupancy level of the room, the heating effect may be counteracted by blowing the supply air toward the heat source, or by locating an exhaust or return grille adjacent to the heat source. The second method is more economical, as heat will be withdrawn at its source rather than be dissipated into the conditioned space. Where lighting loads are heavy and ceilings relatively high (five watts per sq ft and above 15 ft), the outlets should be located below the lighting load, and the stratified warm air removed by an exhaust or return fan. An exhaust fan is recommended if the wet-bulb temperature of the air is above that of the outdoors, a return fan, if it is below this temperature. Either method reduces the requirements for supply air. If the lights are exposed, less saving can be realized than if they are enclosed, as a considerable portion of the energy is radiant.

An important function of any supply outlet during *winter heating* is to maintain the temperature difference between the floor and ceiling at the lowest possible value. Since the air within a room is never so perfectly mixed that all of it is at exactly the same temperature, a certain amount of stratification is inevitable. Unless the supply outlets are properly selected and located, the temperature difference will be large enough to result in discomfort to the occupants.

The proper selection and location of outlets is particularly difficult for rooms with large windows and exposed wall areas. Heat is lost primarily through these areas, and room air in contact with these surfaces is chilled and flows downward, causing drafts near the exposed surfaces and floor.

This condition can best be prevented by locating the air outlets under the windows, by discharging warm air across the exposed surfaces, or by providing supplementary radiation under the windows, in addition to the wall or ceiling air distribution outlets. This solution must be used for comfort installations in northern latitudes (outdoor temperatures below 40 F), when the building walls are uninsulated or single-glass windows are used.

In buildings located in regions where winter heating is a minor problem, high induction by ceiling or wall outlets may be employed to mix properly the entire room air with the supply air and to prevent downdrafts along the exposed surfaces. In northern latitudes, this solution can only be used if the buildings have double-glass windows and insulated walls, as otherwise the induction effort required for neutralization of the downdrafts is so great that the air motion in the room exceeds comfort limits. Where comfort conditions are not critical as in factories for heavy maunfacturing, warehouses, etc., satisfactory results with high induction outlets can be obtained even in cold climates. For uninsulated walls and glass areas in these buildings some supplementary heating is often valuable. Wall diffusers, direct radiation, or warm panels will satisfy these requirements for supplementary heating.

The location of exhaust or recirculating air openings at the base of large areas of glass is sometimes effective in reducing downdrafts into the occupied space.

Great care should be exercised in the use of supply-exhaust air outlets for heating in northern latitudes when considerable exposed wall and window surfaces are involved. In such cases additional radiation is usually required. When the system is used for ventilating only during the heating season, direct radiation should be regulated to provide heat until room and outside temperature are balanced. To avoid

stratification, it is advisable to operate the fan continuously and to limit the temperature differential by supplying air at a high rate of change per hour.

Outlet Performance and Design

Outlets should perform efficiently and conform to the esthetic appearance of the room. The physical appearance of air outlets has been highly influenced by modern interior design, and to meet the demands of architects and engineers. Outlets to be installed flush with the ceiling and outlets with built-in lighting as well as square and linear-type outlets have been developed in the past years. Linear-type outlets and perforated ceilings or panels have the advantage of unobtrusive appearance.

Procedure for Outlet Location and Selection

In determining outlet location and selecting the type of outlets, it is customary to proceed as follows:

1. Study the plan of the building and note the amount of air to be supplied to each room. (For computation of the *required air quantity* for heating and cooling refer to the formulas given in Chapters 12, Heating Load, and 13, Cooling Load. The amount of outdoor air introduced into the room must be checked against the ventilation requirements of state or local codes.)

2. Select number of outlets for each room, considering air quantity required and distance available for throw or as radius of diffusion. The same factors, as well as distance from floor level available as mounting height, structural characteristics of the space, and consideration of appearance, will determine the type of outlet used.

3. Arrange location of outlets in the room. Generally, the outlets must be evenly spaced to distribute the air uniformly throughout the room. More air, however, must be supplied and directed towards areas with exceptional heat gain or loss. An important point to consider is the combination of proper outlet location and efficient duct design (see Chapter 21). Consult manufacturers' tables for recommended location and spacing of outlets.

Refer to Chapter 19 for a discussion of zone control.

4. Select size of outlets according to air quantities handled, permissible throat or discharge velocities, or effective throw, taking into consideration other factors, such as permissible noise level, etc. In order to determine whether the selection made will satisfy the requirements of the job, the type, size, and location of the outlet must be checked against manufacturers' ratings. The most important questions to be considered are:

   a. Will drafts be created because of divergence between rated throw (radius of diffusion) and distance between outlet and nearest obstacle (wall, beam, column, etc.) in the air stream.
   b. Will drafts be created because of excessive cooling temperature differential or too low mounting height of the outlet?
   c. Will drafts created because of too low velocity energy of the air stream cause excessive downward air flow in cooling installations?
   d. Will the air pass through the outlet at too high a velocity and thereby cause an excessive increase in noise level?

Balancing the System

In designing a system, the engineer aims to size ducts and outlets in such a manner that the supply of air is properly distributed. He may, however, feel it necessary to oversize certain trunks, branches, or outlets to allow flexibility or to permit future redistribution, so that the system as designed may not be self-balancing. Even if ducts are designed for self-balancing and outlets are properly selected, all air systems must be balanced, that is, the amount of air through supply ducts, supply outlets, outdoor air intakes, exhausts, return outlets, and ducts must be properly adjusted so that the air quantities correspond closely with the design quantities. Balancing, therefore, is part of the field test procedure to which each air-conditioning system should be subjected in order to determine whether the capacity and performance of the equipment correspond with the design.

For balancing, air systems may be equipped with dampers in supply, return, and outdoor air ducts, splitter dampers, or dampers in outlets. In selecting the desired type of damper or balancing method, the following points should be kept in mind:

1. Unfavorable effect on air stream and noise level should be avoided. This will often rule out blank-offs or dampers in outlets, unless such dampers are of special design.

2. It should be possible to alter outlet volume without altering the direction of discharged air, and to measure the amount of air handled without difficulty. Blanking off part of the area of supply outlets makes this difficult.

Generally speaking, it is most satisfactory to install dampers at some distance back of outlets so as to avoid disturbing the air flow. Dampers in both supply and return ducts form the most flexible means of controlling supply of air to the room and static pressure within the room. (Refer to following section Directional and Volume Control for discussion of various air distribution control devices.)

Instruments for balancing include instruments for measuring air quantities, static pressure, temperature and humidity. Commonly used instruments are the rotating vane anemometer, deflecting vane anemometer, thermal anemometer, smoke gun, clamp type ammeter-voltmeter, sling psychrometer and thermometers. Pressure, humidity and temperature recorders are sometimes useful. The Pitot tube and a manometer may be used on higher velocities, but only with the technique prescribed for its use by the manufacturer for the tube used. (See Air Flow Measurement in Chapter 44.)

The following balancing procedure is recommended for air systems:

1. Open all duct and outlet dampers.
2. Measure fan capacity. This can most often be done with a rotating vane anemometer inside the fan inlet plenum. For exhaust fans the discharge outlet will often serve.
3. Measure fan motor input.
4. Determine approximate flow at each outlet.
5. Adjust outlets or branches so that outlet deviation (from design quantity) is approximately the same (percentagewise) as fan capacity deviation (from total design quantity).
6. Recheck fan capacity.
7. Adjust fan speed or main trunk damper to make fan capacity equal to design. (The fan laws apply when changing speeds; quantity varies directly with speed,—power input as the cube of speed.) Use power input readings to check possibility of overloading the motor.

The procedure outlined may be shortened depending on the type of installation. For instance, where many outlets serve one room, exact balancing of each outlet may not be required, so long as drafts, noise and temperature differences are checked. Experience and judgment are valuable in determining how carefully or thoroughly a system must be tested and adjusted.

DIRECTIONAL AND VOLUME CONTROL

Duct Approaches to Outlets

The importance of the manner in which the air stream is introduced into the outlet cannot be overestimated. To obtain correct air distribution, the velocity of the air stream must be as uniform as possible over the entire connection to