obtrusive means of distribution is desired, and where it is desirable to submerge the outlets into the room decoration and to minimize the effect of obstructions in the line of discharge. They are adaptable to narrow rooms having low ceilings. In this case the slots should extend the full length of the room. In all applications air quantity and distribution must be carefully planned, as correction after installation is difficult.

5. *Ejector Nozzles*. These are outlets operating at high static pressure. They give a high conversion from static in the duct to velocity pressure in the outlet, and have a high induction effect due to their high outlet velocity. They are chiefly used for long throw and industrial process installations, such as drying, freezing, cooking, etc. Another type of ejector is sometimes referred to as a *louver nozzle* and has a 45 to 90 deg elbow, which can be rotated similarly to a universal joint about an axis perpendicular to the surface to which it is fastened. These outlets give a considerable degree of adjustability and are, therefore, desirable for use in confined spaces where spot cooling is employed. The use of very high velocities is gradually disappearing due to noise difficulties.

6. *Wall Diffusers*. These outlets incorporate design features originally developed for ceiling outlets, and use, therefore, semi-conical or semi-pyramidal guide vanes instead of the straight vanes of the conventional side wall outlet.

Ceiling Outlets

Generally used ceiling outlets are: (1) plaques, (2) ceiling diffusers, and (3) perforated ceilings and panels. A discussion of each follows.

1. *Plaques*. Plaques are of simple design. The air from the supply opening impinges on a plate, which permits the air to be deflected horizontally in all directions. Plaques, although inexpensive, are difficult to control and are not generally satisfactory. In certain applications, a properly designed plaque yields satisfactory results.

2. *Ceiling Diffusers*. Ceiling diffusers are round or rectangular outlets installed on, or parallel to, the ceiling, and discharge supply air in a variety of directions and planes. Performance of the different designs varies according to principle employed. Some have no internal induction, but hasten external induction by supplying air in multiple layers. Others have internal induction and distribute air over an entire half sphere. 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 blow is both desired and permissible.

3. *Perforated Ceilings and Perforated Panels*. These devices obtain air diffusion by discharging air through perforations in the ceiling, or part of the ceiling or walls. Some perforated panels feature 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. The advantages are unobtrusive appearance and the ready application of sound absorbing material to the design. Also, if designed properly, this system provides a low rate of room air motion and consequently, lends itself to applications having high load or high ventilating requirements. The perforations should be kept free of accumulations of dirt, as clogging will cause uneven distribution, and result in smudging of the ceiling. Best results are obtained in systems having efficient cleaning devices.

In present practice relatively low velocities are used because the perforated material offers only small resistance to the air flow. Therefore, great care must be taken to distribute the primary air at uniform velocities over the perforated panels to avoid uneven air distribution and primary air streams of undesirable velocities and direction.

OUTLET LOCATION AND SELECTION

In selecting the location of outlets, consideration must be given to the factors of (1) physical construction, (2) physical appearance, (3) location of heating or cooling loads, and (4) outlet performance.

1. The *physical construction* of a building, particularly of old buildings, immediately places limitations on the type of distribution system which can be employed. The first factor in the selection of outlet locations, therefore, is a consideration of the possible location of the supply duct, that is, whether it is above the ceiling, within the walls, through furred spaces above corridors, or in the conditioned space, etc. A particular method of distribution may be highly desirable, but its execution, due to the location of beams and masonry walls, may be impossible.

2. The *physical appearance* of the outlets should conform to the esthetic appearance of the room. In factories, warehouses, etc., the esthetic demand may not be high; however, in department stores, clubs, theaters, etc., the location of the grilles may be dictated largely by such demands.

3. The *location of heating or cooling loads* in a room dictates to a great extent the general location of the outlets. The outlets should be located to neutralize any undesirable cold drafts or radiation effects set up by a concentration of the heating or cooling load. The problem can be divided into *natural loads* due to outside weather and *internal heat loads*.

In winter the natural or primary heating load is caused by exposed walls, windows and skylights. Heat is lost primarily through convection to these exposed surfaces. The convection currents or cold drafts drop down the exposed surfaces and seriously impair the comfort conditions in the room, particularly at the floor level near the exposed surfaces. The outlets should be located to counteract these down drafts. Methods which may be employed are:

a. Direct counteraction of convection currents from cold surfaces can be obtained by locating the outlets to blow upward from beneath windows or exposed walls, or to blow across the exposed wall. This method is desirable in small offices or bedrooms, or any location where people are seated or working near exposed surfaces. In northern climates, where the outside temperature may be constantly below 40 F, and the construction consists of uninsulated walls and single glass, this method of distribution is particularly useful for the maintenance of comfort requirements.

b. High induction by ceiling or wall outlets may be employed to nullify the convection currents from exposed surfaces. If outside temperatures are consistently below 40 F, and the exposed surfaces are not well insulated, the induction effort required for neutralization of the downdrafts is so great that the air motion in the room may exceed comfort limits, unless care is taken in selection and location of the outlet. Where comfort conditions are not critical as in factories for heavy manufacturing, warehouses, etc., satisfactory results can be obtained even in cold climates. For uninsulated walls and glass areas some supplementary heating is often valuable. Wall diffusers, direct radiation or warm panels will satisfy these requirements for supplementary heating.

c. The location of exhaust or recirculated air openings at the base of large areas of glass is sometimes effective in reducing cold downdraft into the occupied space.

If a *concentrated source of heat* creating an *internal heat load* 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 latter method will prove more economical, as heat will be withdrawn at its source rather than be dissipated into the conditioned space. Where a lighting load is particularly heavy (five watts per square foot) and located high in a conditioned space, it may be economically desirable to locate the outlets below the lighting load. Warm air from the lights will stratify near the ceiling and can be removed by an exhaust or return fan, the former being advisable if the wet-bulb temperature of the air is above the outside temperature, and the latter being preferable if the wet-bulb temperature is below that of the outside air. Either method reduces the requirements for supply air. If the lamps are exposed, less saving can be realized than if enclosed, as a considerable portion of the total energy is radiant.

4. *Outlet Performance*. The laws of air distribution, previously discussed, will be found to exercise an important influence upon the design of an acceptable distribution system. This applies particularly to such features as throw, drop, capacity and room air motion.

Procedure for Outlet Location and Selection

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