equal area handling the same air quantity, and their throw is shorter. (Refer to Discharge From a Long Slot in section Ventilating Jets in Air Distribution.)

The perforated panel is an excellent device for producing a large diameter stream with a uniform velocity across its entire area. Although this type of outlet can handle the greatest amount of air in proportion to room size, jet velocities must be kept low. (Refer to Perforated Panels in section Ventilating Jets in Air Distribution.)

For all types of ceiling outlets the following considerations should be noted: (1) if the temperature of the supply air is below that of the room, it should be thoroughly mixed with the room air before it enters the occupied zone; (2) air slightly above room temperature will usually be properly distributed by outlets selected for cooling; and (3) if the temperature of the supply air is substantially higher than that of the room, it should be projected downward in a broad diverging pattern to avoid stratification and to obtain proper mixing and controlled air flow.

4. *Drop.* The air discharged from a wall outlet should not reach the occupied zone until the velocity has fallen to about 50 fpm. Therefore, the outlets should be located high enough

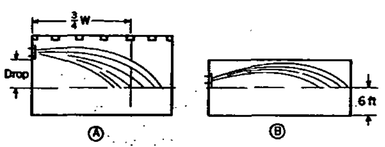

Fig. 9. . . . Throw of Wall Outlets

for the air stream at the termination of the throw to be not less than 5 or 6 ft above the floor level, or in other words, the drop should not be more than the difference between mounting height and zone of occupancy (see Diagram A of Fig. 9). As illustrated in Diagram B of Fig. 9 the maximum permissible throw for a given ceiling height may be obtained by locating the outlet low on the wall, arching the blow, and sweeping the air across the flat area. The air, as it traverses, will adhere to the ceiling. The objection to this method is the possible streaking of the ceiling with dirt.

Capacity

The quantity of air to be handled is determined by the heating, cooling, or ventilating requirements as given in Chapters 11 Infiltration and Ventilation, 12 Heating Load, and 13 Cooling Load. Manufacturers' rating sheets are usually consulted for selection of the proper number, size, and type of outlets for a given air quantity. The basis of rating should be carefully noted to make certain that resulting velocities are suitable for the application.

Temperature Differential

The temperature difference between supply and room air is highly important, because temperature control in the conditioned room is strongly affected by this difference. The greater the temperature differential, the greater the change in room temperature for a given change in the heating or cooling load. The use of outlets which cause a large amount of room air to be mixed with the supply air, permits the use of greater temperature differentials. (Refer to section Air Quantity and Temperature Differential, Chapter 19, Central Systems for Air Conditioning.)

Room Air Motion

To achieve a constant air motion in the occupied zone without exceeding acceptable velocity limits is one of the most important problems in air distribution. Some of the factors which may cause air motion to exceed these limits are: excessive air discharge velocities; high air volume per cubic foot of space (often referred to as number of air changes per hour); premature drop of cold air into the occupied zone; overblow causing spilling of high velocity air into the occupied zone; heating in severe climates by means of downward projection of hot air. These factors will not affect equally the various designs and types of air outlets, and their effect will also depend on the temperature differential, the mounting height of the outlet, and other circumstances. For instance, certain outlets will handle safely more air per cubic foot of space at higher discharge velocities than others, and downward projection of air may sometimes even be necessary if the supply air temperature is substantially higher than the room temperature. (Refer to section on Throw.)

Sometimes excessive air motion may be encountered in correctly designed air distribution systems due to drafts occurring, if stairways or exit doors are left open, or if windows are opened when design of system requires that they be closed. Discomfort is frequently attributed to drafts when it is actually due to too low room temperature. This may occur during the heating as well as the cooling season. Systems designed for heating and ventilation only may easily cause complaints of drafts when cooling is added.

The following papers give useful information with regard to room air motion: Room Air Distribution Research for Year 'Round Air Conditioning, Part I—Supply Outlets at One High Sidewall Location, by S. F. Gilman, H. E. Straub, A. E. Hershey, and R. B. Engdahl (ASHVE Transactions, Vol. 59, 1953, p. 151); Room Air Distribution Research For Year 'Round Air Conditioning, Part II—Supply Outlets at Three Floor Locations, by H. E. Straub and S. F. Gilman (ASHVE Transactions, Vol. 60, 1954, p. 249); Performance and Evaluation of Room Air Distribution Systems, by Alfred Koestel and G. L. Tuve (ASHAE Transactions, Vol. 61, 1955, p. 533); Air Velocities in Two Parallel Ventilating Jets, by Alfred Koestel and J. B. Austin, Jr. (ASHAE Transactions, Vol. 62, 1956, p. 425).

Permissible Noise Level

The increase of the noise level caused by an outlet is primarily a function of its discharge velocity and its size. The maximum acceptable noise level in a space may dictate completely the selection of the permissible outlet velocity. In addition, however, noise may be caused by excessive restriction of the free outlet area due to outlet design, by unnecessary turbulence due to one-sided air flow through the outlet, or by impingement of high velocity air on sharp edges.

The origin of excessive noise may be spotted by removing the outlet without stopping the air supply. If noise is still evident, other elements of the air-conditioning system or entirely different sources are at fault. High-pitched, rushing noise indicates that the duct system or excessive velocities in the duct are the cause, low-pitched rumbling noise points to the mechanical equipment of the air-conditioning plant.

When very high duct velocities are used, sound-absorbing lining or special acoustical filters (sound traps) must be

provided. High-pressure or high-velocity outlets for multiroom and other buildings are equipped with a special pressure reduction and sound attenuation box. (Refer to section Types of Air Outlets.)

For a general discussion of permissible room noise levels and air supply outlet noises, refer to Chapter 25, Sound Control.

Smudging

All air outlets have their particular *smudging* problems which have been studied by various investigators but cannot yet be considered solved. Smudging is due to dirt in the room air and in the air discharged by the outlets. Although the primary air may be carefully filtered, small particles of dirt and dust will not be captured by mechanical filters, and may finally be deposited on the walls or ceiling. With ceiling outlets, dirt streaking may be minimized by carefully controlling the discharge of the outlets, or by the use of special deflecting plates or anti-smudge rings. With wall outlets, dirt streaking may be minimized by preventing direct impingement of the air on any ceiling or room surface. Floor outlets may be objectionable as dirt collectors.

TYPES OF AIR OUTLETS

Air supply outlets for commercial, industrial, and residential applications are either side-wall- or ceiling-type outlets. In homes, baseboard and floor type outlets are also used. (Refer to Chapter 18, Warm Air Heating Systems.) As a great variety of outlets of various design are available in these four types, the final selection of a supply air outlet depends to a large degree upon the specific problems of the air distribution system to be used.

In addition to the comments which follow on use and application of outlets, reference should also be made to sections Outlet Location and Selection and Specific Applications.

Wall Outlets

Side wall outlets in general use are (1) perforated grilles, (2) fixed and adjustable bar and vane grilles, (3) registers, (4) wall diffusers, (5) slotted wall outlets, and (6) high-pressure or high-velocity wall outlets.

1. *Perforated Grilles.* These grilles have a small vane ratio and are not adjustable. They are useful primarily where directional air flow is unnecessary, and for applications where the grille size can be increased in order to provide the required free area.

2. *Fixed and Adjustable Bar and Vane Grilles.* Grilles with fixed bars or vanes are used for wall, floor, or baseboard applications when the performance is not critical or can be adequately predicted. Adjustable grilles are equipped with either vertical or horizontal adjustable bars or vanes or both, and are used where proper control of air motion is essential. Vanes should be designed for quiet operation.

3. *Registers.* Grilles equipped with dampers or adjustable valves for controlling volume distribution of the supply air are called registers.

4. *Wall Diffusers.* These outlets incorporate design features originally developed for ceiling outlets, and therefore make use of semi-conical or semi-pyramidal guide vanes instead of the straight vanes of the conventional side-wall outlet. In warm air perimeter systems they are used to blanket the outside wall with the warm supply air.

5. *Slotted Outlets.* These outlets are available in a great variety of designs, consisting either of elongated outlets with perforations, or flat outlets with a number of long narrow slots or a single narrow slot, or straight long outlets with one long slot or diffusing vanes. Due to their high aspect ratio, slotted outlets have higher entrainment than comparable round or square vaned outlets of equal area and consequently, the throw is reduced. (Refer to Discharge from a Long Slot in section Ventilating Jets in Air Distribution.)

Slotted outlets are particularly useful in connection with the linear design motif in architecture, for applications where it is desired to merge air outlets unobtrusively with the room decoration. They may be used for either ceiling or wall air distribution, including the so-called under-the-window application. In all applications, capacity limitations, proper duct approaches, and correct balancing of slotted outlets must be carefully considered, as correction after installation is difficult.

6. *High-Pressure or High-Velocity Outlets. Ejector nozzles* operate at high static pressure and convert this pressure into velocity pressure with resulting high induction of room air. They are mainly used for industrial process installations, particularly drying. Another type of ejector nozzle 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, useful for spotcooling in confined spaces.

High-pressure or high-velocity air-conditioning systems installed in multi-room and other buildings, use very high velocity and pressure so that the size of the ducts can be reduced. This in turn requires the use of *high-pressure or high-velocity air outlets* which reduce the velocity and pressure and attenuate the sound to predetermined values at the point where the air is discharged. It is also possible, of course, to use high velocity only in part of the system, for example in the main trunk ducts, and conventional velocities in the branch ducts. Special high-pressure control units are then installed at the end of the main duct, and the air is discharged through conventional air outlets in the various spaces of the building.

Various high-pressure or high-velocity outlets of different design, but usually consisting of a pressure reduction and sound attenuation box and a grille or diffuser, have been developed for high-velocity systems and are described in the literature of the manufacturers. These outlets may be used in the ceiling or in the wall of the air-conditioned space, including under-the-window installation, or in the ceilings of corridors. Refer to Unitary-Central Systems for multi-room buildings in Chapter 19, Central Systems for Air Conditioning, and to Design of High-Velocity Ducts in Chapter 21, Air Duct Design.

Ceiling Outlets

Ceiling outlets in general use are (1) ceiling plaques, (2) ceiling diffusers, (3) high-pressure or high-velocity ceiling outlets, and (4) perforated ceilings and panels.

1. *Ceiling Plaques.* Plaques are of simple design. The air from the supply opening impinges on a plate and is discharged horizontally. Plaques are inexpensive, but as the air is not always uniformly discharged in all directions, proper control is difficult.

2. *Ceiling Diffusers.* Ceiling diffusers are round, square, rectangular, or slotted outlets of various designs installed on, or parallel to, the ceiling. Performance of the different designs varies according to the principle employed. Some