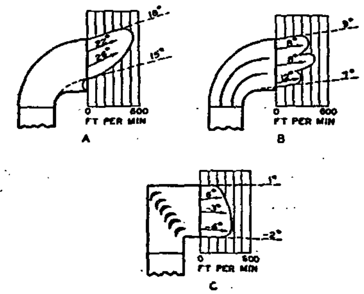
the duct, and perpendicular to the outlet face. No air outlet can compensate for improper duct approach.

A wall grille installed at the end of a horizontal duct and a ceiling outlet at the end of a vertical duct receive the air perpendicularly and at (for practical purposes) uniform velocity over the entire duct cross-section, provided the system is carefully designed. However, very few outlets are installed in this manner. Most side wall outlets are installed either at the end of vertical ducts or in the side of horizontal ducts, and most ceiling outlets are attached either directly to the bottom of horizontal ducts or to special vertical take-off ducts which connect the outlet with the horizontal duct. In all these cases, special devices for directing and equalizing the air flow are necessary to obtain proper direction and distribution of the air.

The influence of the duct approach on outlet performance has been investigated for vertical stack heads with plain



Stack 14 in. x 6 in. Outlets 14 in. x 9 in. Stack Velocity 500 fpm
A. Rounded Throat and Rounded Back
B. Rounded Throat and Back and 2 Splitters.
C. Square Throat and Back and 6 Guide Vanes.

Fig. 10. . . . Outlet Velocity and Air Direction Diagrams for Stack Heads with Expanding Outlets

openings[13] or equipped with grilles[14] and for side outlets on horizontal ducts.[15] In the tests conducted with the stack heads it was found that it is necessary to provide splitters or guide vanes in the elbows at the top of the vertical stacks regardless of the shape of the elbows, whether of rounded, square, or expanding types. Cushion chambers at the top of the stack heads have no beneficial effect. Fig. 10 shows the direction of flow, distribution and velocity (measured 12 in. from opening) of the air for various types of stack heads tested, expanding from a 14 x 6 in. stack to a 14 x 9 in. opening, without grille. The air velocity for each was 500 fpm in the stack below the elbow, but the direction of flow and the distribution pattern are generally indicative of performance obtainable with nonexpanding elbows of similar shapes for a range of velocities 200 to 1400 fpm.

In tests conducted with 3 x 10 in., 4 x 9 in., and 6 x 6 in. side outlets in a 6 x 20 in. horizontal duct at duct velocities of 200 to 1400 fpm (in the 6 x 20 in. section) it was found that multiple curved deflectors produced the best flow characteristics. Vertical guide strips in the outlet were not so effective as curved deflectors. A single scoop type deflector at the outlet did not improve the flow pattern obtained from a plain outlet, and was therefore not found to be desirable.

Directional Adjustment

Many devices for directing and equalizing air flow in side wall and ceiling outlets are now commercially available, and should be used whenever necessary. They are indispensable for all side outlets in horizontal ducts and for most ceiling outlets.

Ceiling outlets are usually installed below horizontal supply ducts so that the supply air has to make a 90-deg turn before entering the outlet itself. The shorter the connection between bottom of duct and outlet, the greater is the need for directive devices to obtain uniformity of flow. Generally speaking, conditions and remedy in such cases strongly resemble those for side outlets in horizontal air ducts. Ceiling ducts often have a rectangular cross-section, while the connections to the ceiling outlets are circular. It will then be quite difficult to install turning vanes successfully, particularly if the ducts are shallow and the connection areas are comparatively large. This will be the case when more than one outlet is installed on one duct run, and restrictions of duct areas must be avoided. In such cases good results have been obtained by using a series of vertical guide strips, installed at right angles to the direction of air approach in the outlet connection where it leaves the horizontal air duct.

Volume Adjustment

Various methods are used to regulate volume of supply and return (exhaust) air. Some of these accomplish only minor changes in volume; most of them, however, permit a range of adjustment from maximum air supply to complete shut-off.

When selecting type and location of such dampers, the following points must be considered, especially when the volume adjustment feature is to be located near the air outlet itself: (1) deflection of air stream by the damper; (2) need and feasibility of directional adjustment; (3) increase of noise level due to irregular and localized high air velocities caused by damper operation.

The following types of volume adjustment are most frequently encountered:

1. *Slide Damper.* A single plate which can be pushed across the duct. Since its operation changes the free area of air passage in a one-sided manner, it should not be located near any air outlet, and its use is practicable only where no intermediate setting between full open and closed is required.

2. *Hit-and-Miss Damper.* Two slotted plates or discs, closely adjacent; by moving one of the two plates the respective slots may be opened or closed. This type of volume adjustment may be installed close to an air outlet and it is easy to operate, but its main disadvantage is that even in the open position the air passage area is blocked by at least 50 percent. This requires oversizing of the air outlet in order to avoid excessive increase of noise level.

3. *Splitter Damper.* A single blade sheet metal plate hinged at one edge, usually located at the branch connection of a duct or outlet. It is easy to operate, but often causes irregular air flow in the duct. When used in connection with, and near an outlet, additional directional adjustment is required.

4. *Butterfly Damper.* A single blade sheet metal plate hinged in the middle, usually located in a straight duct run.

Table 2. . . . Recommended Return Intake Face Velocities

Intake Location	*Velocity Over Gross Area Fpm*
Above occupied zone	800 up
Within occupied zone, not near seats	600–800
Within occupied zone, near seats	400–600
Door or wall louvers	200–300
Undercutting of doors (through undercut area)	200–300

It is easier to handle than a splitter damper, since only half the motion is necessary to change its setting. However, if located too close to an air outlet, it is objectionable because its operation frequently results in a condition whereby two high velocity jets are created along the sides of the duct, or the air spills immediately downward into the occupied zone.

5. *Louver Dampers.* Numerous designs have been developed incorporating a series of splitter or butterfly dampers across the duct or air outlet. Their main advantage consists in retaining greater uniformity of air flow, and in requiring less depth for installation. Some designs provide for louver blades moving in opposite directions, and while decreasing free air passage area, retain a constant air flow direction along the axis of the duct air outlet connection.

RETURN AND EXHAUST INTAKES

The *selection of return and exhaust intakes* depends on: (1) velocity in occupied zone near intake; (2) permissible pressure drop through intake; and (3) noise.

1. *Velocity.* The control of the room air motion for the maintenance of comfort conditions depends on the proper selection of the *supply* outlets. The effect of air flow through return intakes upon air movement in the room is slight. Air handled by the intake approaches the opening from all directions and its velocity decreases rapidly as the distance from the opening increases. Therefore, drafty conditions will rarely be encountered near return intakes. Recommended return intake face velocities are given in Table 2.

2. *Permissible Pressure Drop.* The permissible pressure drop will depend on the choice of the designer. Table 3 gives pressure drop through plain lattice intakes as a function of free area and face velocity.

Proper pressure drop allowance should be made for control or directive devices.

3. *Noise.* The problem of *noise* generated by return intakes is the same as that for supply outlets. In computing resultant room noise levels from the operation of an air-conditioning system, the return intake must be included as a part of the total grille area. The major difference between the supply outlets and return intakes is the frequent installation of the latter at ear level. When so located, it is recommended that the return intake velocity be not in excess of 75 percent of the maximum permissible outlet velocity.

The *location of return and exhaust intakes* does not critically affect air motion, unless room air velocities in the occupied zone near the intake exceed comfort limits. The locations of return or exhaust intakes are, however, important for obtaining the desired room temperature equalization.

Ceiling locations for exhaust outlets are recommended for

Table 3. . . . Approximate Pressure Drops for Lattice Return Intakes

Inches Water Gage—Standard Air

Percent Free Area	*Face Velocity, Fpm*						
	400	500	600	700	800	900	1000
50	0.06	0.09	0.13	0.17	0.22	0.28	0.35
60	0.04	0.06	0.09	0.12	0.16	0.20	0.24
70	0.03	0.05	0.07	0.09	0.12	0.15	0.18
80	0.02	0.03	0.05	0.07	0.09	0.11	0.14

bars, kitchens, lavatories, dining rooms, club rooms, etc. where warm air will rise to the ceiling level. In heating installations, location of the return grilles in the ceiling or high on the wall is not recommended, as it may result in stratification of the conditioned air, and—depending on the relative location of supply and return outlets—in short-circuiting. (Refer to previous section Outlet Location and Selection.)

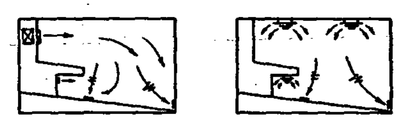
Some ceiling outlets combine the supply and return openings in a single unit. This method is used for heating as well as for cooling applications. However, the application for heating is more critical and requires consideration of ceiling height, amount of outside wall area, and number of air changes required. In some cases, stratification of warm air may cause short-circuiting. (Refer to previous section Outlet Location and Selection.)

Floor locations of returns are used in heating installations for ceiling or side-wall supply. When located so that air is drawn across exposed walls, the performance of the system may be somewhat improved. In general, floor locations tend to collect dirt and refuse.

Wall and door locations of exhaust outlets depending on their elevation, have the characteristics of either floor or ceiling returns. In large buildings with many small rooms, the return air may be brought through door grilles or door undercuts into the corridors, and then to a common return or exhaust. The pressure drop through door returns should not be excessive; otherwise the air distribution to the room may be seriously unbalanced with the opening or closing of the doors. Outward leakage through doors or windows cannot be counted upon for dependable results.

SPECIFIC APPLICATIONS

For *theaters and auditoriums* the air distribution methods used are the downward distribution system with ceiling diffusers, and the horizontal distribution system with ejector nozzles or wall diffusers. Fig. 11 shows both methods. Ceiling distribution is accomplished by ceiling outlets under main ceiling and balcony. It is indicated when main ceiling or



Rear wall distribution   Ceiling distribution

Fig. 11. . . . Air Distribution Methods for Theaters, Churches, and Auditoriums