3. Natural convection currents form a stagnant zone from the ceiling down during cooling and from the floor up during heating. It should be noted that this zone is formed above the terminal point of the total air during heating and below the terminal point during cooling. Since this zone is a result of the natural convection currents, the air velocities within the zone are usually low (15–20 fpm) and the air stratifies in layers of increasing temperatures from a low to a high level. The concept of a stagnant zone is an important tool in the proper application and selection of outlets as it permits due consideration of the natural convection currents from warm and cold surfaces and internal loads.

4. The return intake affects the room air motion only within its immediate vicinity. The intake should, in general, be located in the stagnant zone so as to return the warmest room air during cooling and the coolest room air during heating. The importance of the location depends on the relative size of the stagnant zone which results with the various types of outlets.

5. The general room air motion (shown by clear areas in Figs. 2 to 6) is a gentle drift toward the total air. Room conditions are maintained by the entrainment of the room air into the total air stream. The room air motion between the stagnant zone and the total air is relatively low and uniform. The highest air motion occurs in and near the total air streams.

Group A Outlets (Fig. 2). This group includes high sidewall grilles, sidewall diffusers, ceiling diffusers, linear ceiling diffusers and similar outlets. High sidewall grilles and ceiling diffusers are illustrated in Fig. 2.

The primary air envelopes (isovels) show a horizontal two-jet pattern for the high sidewall, and a 360 deg diffusion pattern for the ceiling outlet. Although variation of vane settings might cause a discharge in one, two or three jets in the case of the sidewall outlet, or obtain a smaller diffusion angle for the ceiling outlet, the general effect in both will be the same.

During cooling, the total air drops into the occupied zone at some distance from the outlet, which depends on air quantity, supply velocity, temperature differential between supply and room air, deflection setting, ceiling effect, and the type of loading within the space. Analytical methods of relating some of these factors are given in the section Isothermal Axial Flow Jets.

The cooling diagram for the high sidewall outlet shows a condition of *overthrow* which causes the total air to drop along the opposite wall and flow slowly some distance across the floor. This condition should be avoided, because in this case the total air region becomes a region of high velocity accompanied by temperature depressions. Velocities in the order of 100 to 150 fpm may be found near the wall, but will dissipate rapidly within a few inches from the wall.

The cooling diagram of the ceiling outlet shows that the total air movement is somewhat counteracted by the rising natural convection currents on the heated wall, and therefore drops before reaching the heated wall. On the other hand, the total air reaches the inside wall and descends some distance along the wall. With this type of outlet, temperature variations within the room are held to a minimum, and there is hardly a stagnant region. Since the maximum velocity as well as the maximum temperature variation occurs within and near the total air envelope, the drop region (Equation 1) becomes highly important. For this reason, it is imperative to know how far the air drops, before velocities and temperatures reach acceptable limits.

Since these outlets discharge horizontally near the ceiling, the warmest air in the room is mixed immediately with the cool primary and total air far above the occupied zone. Therefore, the outlets are capable of handling relatively large quantities of air at large temperature differentials.

During heating, the warm total air tends to rise, and then occupies the region near the ceiling. This results in a large stagnant zone between the floor and some distance above the floor. Temperature variations will be small in the region between the stagnant layer and the total air, that is to say, the air in this region is uniformly mixed.

There is a large temperature gradient between the floor and the stagnant layer, primarily as a result of the natural convection currents, due to the heat load and the construction of the space. This condition indicates that the outlets should have additional radiation to take care of the perimeter exposures. On the other hand, in an interior zone, where the loading is not severe, the stagnant layer is practically nonexistent, and conditions throughout the whole room are uniform with a minimum temperature gradient.

Flow rate and velocity for both heating and cooling are the same for both outlet types in Fig. 2. The heating diagram for the sidewall unit shows that under these conditions the total air does not descend along the wall. Consequently, a condition of overblow may not be objectionable during heating. In fact, such a condition might be beneficial in eliminating the stagnant zone, since overblow causes some of the warm air to reach the floor level and counteract the stratification of the stagnant region.

The heating diagram for the ceiling outlet again shows the effect of the natural convection currents. It results in a larger throw toward the cold exposed wall. It may be assumed that the velocity of the total air toward the exposed wall complements the natural convection currents. However, it will be noted that the warm total air loses its downward momentum at its terminal point, and that buoyancy forces cause it to rise toward the primary air. Although these forces are complementary, the heating effect of the total air replaces the cool natural convection currents with warm total air.

Group B Outlets (Fig. 3). This group includes floor registers, baseboard units, low sidewall units, linear type grilles in the floor or window sill and similar outlets. Fig. 3 illustrates a floor outlet adjacent to an inside wall.

These outlets have no deflecting vanes, and consequently the primary air is discharged in a single vertical jet. When the total air strikes the ceiling, it fans out in all directions from the point of contact, and during cooling follows the ceiling for some distance before dropping toward the occupied zone. During heating, the total air flow follows the ceiling across the room, and then decends the exterior wall for some length.

The cooling diagram shows that a stagnant zone is formed outside the total air region above the terminal point of the total air. Below the stagnant zone, the air temperature is uniform, and complete cooling is effected within this region. Also, the space below the terminal point of the total air will be satisfactorily cooled. For example, if the total air flow is projected upward for a distance of 8 ft, the region from this level down to the floor will be satisfactorily cooled. This, of course, does not apply to an extremely large space. Some judgment is needed to determine the acceptable size of the space outside of the total air. A distance of 15–20 ft between the drop region and the exposed wall has been found to be a conservative design value.

A comparison of Figs 2 and 3 for heating shows that the stagnant region is smaller for Group B than Group A outlets. This is due to the fact that the air entrained in the immediate vicinity of the outlet is mainly taken from the stagnant region, and thus it is the coolest air in the room. This results in greater temperature equalization and fewer buoyant effects in the total air than would occur with Group A outlets.

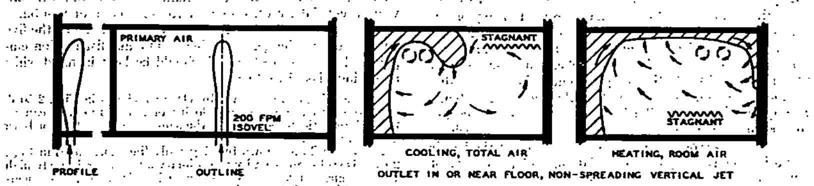

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Fig. 3 . . . . Air Motion Characteristics of Group B Outlets

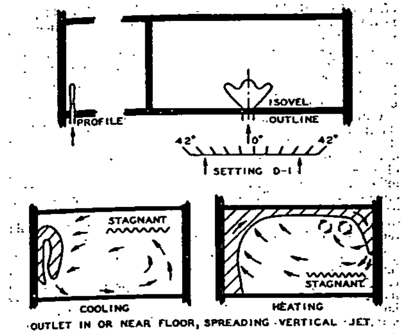

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Fig. 4 . . . . Air Motion Characteristics of Group C Outlets

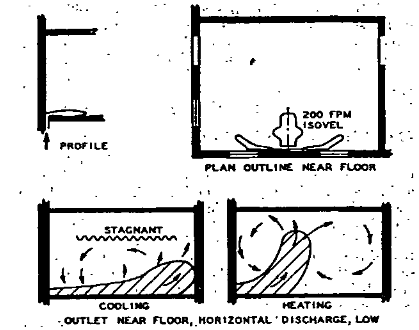

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Fig. 5 . . . . Air Motion Characteristics of Group D Outlets

The temperature gradients for both outlet groups are about the same, except that the stagnant layer for Group B is lower than for Group A outlets.

Group C Outlets (Fig. 4). This group includes floor diffusers, side wall diffusers, linear type diffusers and other outlets installed in the floor or window sill.

Although outlets of this group are related to Group B, they are characterized by wide spreading jets and diffusing action. Nevertheless, total air and room air characteristics are very similar to those of Group B, although the stagnant zone formed is larger during cooling, and smaller during heating. Diffusion of the primary air usually causes the total air to fold back on the primary air and total air during cooling, instead of following the ceiling. This diffusing action of the outlets makes it more difficult to project the cool air, but it also provides a greater area for induction of room air. This is especially beneficial during heating, since the induced air comes from the lower regions of the room.

Group D Outlets (Fig. 5). This group includes baseboard and low sidewall registers and similar outlets.

These outlets discharge the primary air in a single or in multiple jets. However, since the air is discharged horizontally across the floor, the total air, during cooling, remains near the floor, and a large stagnant zone is established in the entire upper region of the room.

During heating, the warm total air rises toward the ceiling, as a result of the buoyant effect of the warm air. Also, the temperature variations are uniform with the exception of the total air region.

Group E Outlets (Fig. 6). This group includes ceiling diffusers, linear type grilles, sidewall diffusers and grilles, and similar outlets. Fig. 6 shows the heating and cooling diagrams for a ceiling diffuser with vertical downward projection.

During cooling, the total air projects to the floor, and follows the floor, which results in a stagnant region near the ceiling. During heating, the total air flow, after reaching the floor, folds back toward the ceiling. If the projected air does not reach the floor, a stagnant zone will result near the floor.

General Factors Affecting Outlet Performance

Effect of Vanes. Vanes affect grille performance if their depth corresponds at least to the distance between the vanes. If the *vane ratio* is less than unity, effective control of the air stream discharged from the grille by means of the vanes is impossible. If it is higher than two, further improvement is slight.

A grille discharging air uniformly forward (vertical vanes in straight position), will have a *spread* of 14 to 24 degrees, depending on type of outlet, duct approach, and discharge velocity. Turning of the vanes will influence the direction and the throw of the discharged air stream.

A grille with *diverging vanes* (vertical vanes with uniformly increasing angular deflection to a maximum at each end of 45 deg) will have a spread of approximately 60 deg and the throw will be reduced considerably. With increasing divergence the quantity of air handled by the grille for a given duct static pressure will decrease.

A grille with *converging vanes* (vertical vanes with uniformly decreasing angular deflection) will have a slightly higher throw than a grille with straight vanes, but the spread will be the same for both settings. The air stream will converge slightly for a short distance in front of the outlet, and then spread somewhat more than the air discharged from a grille with straight vanes.

In addition to vertical vanes which normally spread the air horizontally, horizontal vanes may be used to spread the air vertically. However, spreading the air vertically entails the risk of hitting beams or other obstructions, or of blowing primary air at excessive velocities into the occupied zone. On the other hand, vertical deflection may increase the adherence to the ceiling and reduce the drop. (See Chapter 30).

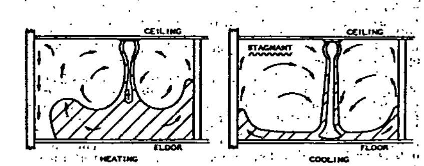

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Fig. 6 . . . . Air Motion Characteristics of Group E Outlets