The direction of flow, distribution and velocity (measured 12 in. from outlet) of the air, based on tests [3], are shown in Fig. 4 for various types of stack heads expanding from a 14 in. x 6 in. stack to 14 in. x 9 in. outlets, without grilles. The air velocity for each was 500 fpm in the stack below the elbow, but the direction of flow and the distribution patterns are generally indicative of performance obtainable with non-expanding elbows of similar shapes for a range of velocities 200 to 1400 fpm. Some of the conclusions drawn from the tests were:

1. Experiments with various elbow outlets on the 14 in. x 6 in. vertical stack [3] with stack air velocities of 200 to 1400 fpm indicated that enlargement of the outlet area, whether used in connection with square or rounded elbows, would not reduce either the angle of discharge (which was 20 to 30 deg above the horizontal) or the outlet velocity. The effect of the enlargement of the outlet was mainly to increase the reverse flow area in the lower part of the outlet, but in each case enlargement of the outlet reduced the static pressure in the duct below the elbow.

2. Splitters in the elbows had the effect of dividing the air stream into a number of streams flowing through rounded elbows and therefore lowered the angle of discharge, reduced or eliminated the reverse flow area, and made the outlet velocity quite uniform.

3. Turning vanes having 2 in. inner and 1 in. outer radii located in the center of the elbow were found most effective in improving performance in regard to angle of discharge, outlet velocity, and elimination of reverse flow area.

4. Pressure loss through stack heads may be reduced by use of splitters or turning vanes or by increasing the inner radius of an elbow. Considering the sum of the velocity and static pressure as a measure of the energy required to change the direction of the air stream and to deliver the air into the atmosphere, and considering the energy required for a plain fitting as 100 per cent, it was found that *turning vanes* dropped the energy requirement of square type stack heads to 45 per cent. Splitters reduced the energy requirement to 90 per cent in long radius elbows and to 74 per cent in short radius turns. In expanding heads splitters reduced the energy requirement to 58 per cent.

Side Outlets in Air Ducts

When air is supplied to a room from side outlets in horizontal ducts it is necessary to use directive devices within the duct at each outlet in order to obtain a uniform velocity of delivered air and to obtain a direction of flow perpendicular to the face of the outlet. In tests[4] conducted with 3 in. x 10 in., 4 in. x 9 in., and 6 in. x 6 in. outlets in a 6 in. x 20 in. horizontal duct at duct velocities of 200 to 1400 fpm (in the 6 in. 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. Figs. 5 and 6 show the flow patterns and outlet velocities for two 3 in. x 10 in. and two 6 in. x 6 in. outlets respectively, at 500 and 1100 fpm duct velocities with outlets equipped with 1 in. and 13 in. extensions. The superiority of the multiple curved deflectors and the beneficial effect of the 13 in. extensions is evident.

Throttling Dampers

In the case where multiple louvers or single blade dampers are used for throttling, considerable deflection of the stream may result. This is particularly true when the fins of the grille core are perpendicular to the damper blades. If the core has sufficient depth and the fins are parallel to the blades, there is a marked tendency to straighten the air stream, although some deflection may still result.

Dampers of special construction, as illustrated in Fig. 7, may be used to maintain a constant direction of blow, approximate distance of blow, and constant outlet velocity regardless of the damper's position. The

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	500–700
Undercutting of doors (through undercut area)	600

capacity of dampers diagrammed as A and B will be roughly in proportion to the position of the operating lever. They are particularly effective for cooling work with oversized grilles. The single leaf damper shown as C in Fig. 7 is objectionable in that it frequently results in a condition whereby two high velocity jets are created along the sides of the duct, or the air spills immediately downward on the occupants below the outlet.

Another important consideration is the increased noise produced by high localized velocities. Obviously, uneven velocities over the outlet will cause the noise level to exceed the values obtained when face velocities are equalized. Also, excessive throttling of dampers to balance systems that are poorly designed will increase the noise level.

RETURN AND EXHAUST INTAKES

The factors that control the selection of return and exhaust intakes are: (1) velocity in occupied zone adjacent to intake, (2) permissible pressure drop through intake, (3) noise, and (4) location.

1. Air handled by an exhaust or return intake is drawn from all directions, the velocity dropping off rapidly in every direction. The only locality where drafts may prove objectionable is adjacent to the intake. To prevent excessive air motion in the occupied space due to the return system, it is advisable to compute the total air motion toward the exhaust opening as outlined in Equation 10 where A is the exhaust wall area in square feet. Recommended return intake face velocities are given in Table 2.

The withdrawal of air from a space through a return intake is a minor factor in control of the room air motion. The control of the room air motion for the maintenance of comfort conditions depends on the proper selection of the supply outlets. Thus the location of the return intake is not critical, nor the use of an elaborate return system necessary, provided the air motion in the occupied zone adjacent to the intake does not exceed comfort limits. A single return intake or a few large intakes will prove satisfactory provided no local high velocity zones are created.

TABLE 3. APPROXIMATE PRESSURE DROPS FOR LATTICE RETURN INTAKES

Inches Water Gage—Standard Air

PER CENT 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