where

M_1 = mass of primary air.
M_2 = mass of secondary air.
V_1 = velocity of primary air.
V_2 = velocity of secondary air (normally = 0).
V_3 = velocity of the mixture.

Substituting zero for V_2 and the volume rate Q for the mass (M), and solving for the induction ratio (r):

$$r = \frac{V_1}{V_3} = \frac{Q_1 + Q_2}{Q_1} \qquad (2)$$

The total air entrained by an air stream is in direct proportion to the distance from the discharge of the outlet. For a given blow from a wall in which a number of outlets are located, the induction ratio may be increased by increasing the aspect ratio, diverging the vanes of the outlet, or by simultaneously increasing the number of outlets, reducing their size, and increasing the velocity but maintaining a constant blow. The aspect ratio must be increased considerably from that of a rectangle to a slot before marked changes in the entrainment ratio take place.

Spread

The induction effect results in the spreading of the air stream. Equation 3 derived from induction Equation 1 gives spread or cross-sectional area of the stream as a function of induction ratio, volume of primary air, and primary air velocity.

$$A = \frac{r^2 Q_1}{V_1} = \frac{V_1 Q_1}{(V_3)^2} \qquad (3)$$

where

Q_1 = primary air quantity, cubic feet per minute.
V_1 = primary air velocity, feet per minute.
V_3 = air velocity of mixture, feet per minute.
r = induction ratio.

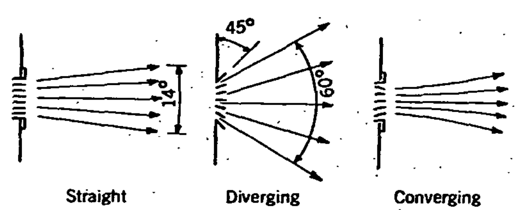

FIG. 1. SPREAD OF AIR STREAM WITH VARIOUS VANES

The average jet angle (included angle in both planes, see Fig. 1) for an air stream as it emerges from a rectangular outlet of any shape without spreading vanes is about 19 deg, plus or minus 5 deg, depending on the type of approach, type of outlet and velocity. The spread increases slightly with velocity. A vaned outlet discharging air uniformly forward will result in a spread of about 14 deg. This is equivalent to a spread in any direction of about one foot in every 8 ft of blow.

Throw

The distance air will carry measured along the axis of an air stream from the supply opening to the position in the stream at which the average frontal air velocity reduces to 50 fpm is termed the *throw*. The throw distance is based on an assumed terminal velocity, which can be assigned any arbitrary value. Since air striking a wall at too high a velocity may bring the air stream down within the occupied zone, the terminal velocity should be limited to 50 fpm. The maximum transverse velocity of the air stream is usually from 2.5 to 3.5 times the average frontal velocity. Assuming no obstructions, the blow is affected by face velocity, core area, aspect ratio and included angle of effluent stream as determined by vanes. For low aspect ratios, the major variables of velocity, area and effluent angle are related[1] approximately as given in Equation 4 when the air stream is unaffected by obstructions of any kind.

$$X_a = \frac{kQ}{\sqrt{a_o b_o}} \qquad (4)$$

where

X_a = throw, feet.
Q = air volume flow rate, cubic feet per minute.
a_o and b_o = grille width and height, inches.
k = dimensionless constant with the following approximate empirical values:

Vanes set straight ahead		= 0.77
Vanes causing a spread on each horizontal side of	15 deg	= 0.66
	30 deg	= 0.45
	45 deg	= 0.34

Vanes

For vanes to be mechanically satisfactory, the depth of the vane should be between one and two times the spacing between the vanes. If the ratio of vane depth to spacing is less than one, effective turning by means of the vanes cannot be obtained. Little improvement is obtained by increasing the ratio beyond two.

Straight Vanes. As mentioned previously, the included angle between both planes will be in the neighborhood of 14 deg, for a straight setting of the vanes as shown in Fig. 1.

Diverging Vanes. Such vanes set for an angular spread will have a marked effect on the direction and distance of travel of an air stream. An outlet having vertical vanes set straight forward in the center, with uniformly increasing angular deflection to a maximum at each end of 45 deg, will produce an air stream with a horizontal included angle of approximately 60 deg as shown in Fig. 1. The throw will be reduced one-half for such a vane setting. Increasing the divergence of the vanes reduces the air quantity handled by an outlet for a given duct static pressure. The primary function of the vanes is to spread the air horizontally. Little is gained by spreading the air vertically.

Converging Vanes. The blow of an outlet may be somewhat increased by converging the vanes of an outlet as illustrated in Fig. 1. Even with converging vanes, the resultant angle of spread of an air stream will not be less than 14 deg. The air converges for a few feet in front of the outlet, and then diverges more than if the vanes had been set straight.

Both the horizontal and vertical vanes of an outlet are important. After an installation has been made, many conditions of draftiness or stuffiness can be alleviated by some vane adjustment, provided an independent means for regulation of static pressure behind the vanes is included.

Room Air Motion

The air motion in the occupied zone is usually such that the air travels across the room in reverse direction to the blow of the outlet. The cross-

[1]The Rationale of Air Distribution and Grille Performance, by C. O. Mackey (*Refrigerating Engineering*, Vol. 35, No. 6, June, 1938, p. 417).