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.

Vertical Drop and Rise

The distance that the lower edge of the air stream drops below the bottom of the outlet is important, since the air stream should not reach the occupied zone until the velocity has fallen to about 50 fpm. The drop (H, ft) is influenced by two forces; the natural vertical spread of the stream and the gravitational force due to the difference in density between supply air and

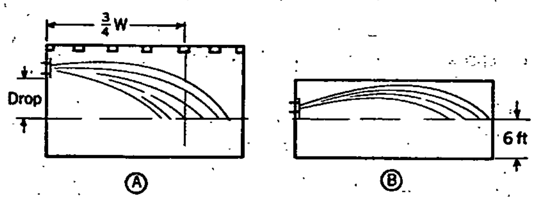

FIG. 5. THROW OF WALL OUTLETS

room air. For air emerging at room temperature, the drop will be a function of the spread only and will be equal to:

$$H_1 = L \times \tan\left(\frac{\text{Spread Angle}}{2}\right) \qquad (11)$$

where

H_1 = drop due to spread (when emerging air and room temperature are the same), feet.

L = throw, feet.

When there is a temperature difference between the air stream and the room, there is an *additional* drop which is approximately[4]:

$$H_2 = \frac{n_1(t_r - t_{sa})L^{n_2}}{V_1} \qquad (12)$$

where

H_2 = additional drop due to temperature difference, feet.

n_1 and n_2 = constants (tentative suggested values $n_1 = 5$, $n_2 = 1.2$).

t_r = room temperature, degrees Fahrenheit.

t_{sa} = supply air temperature, degrees Fahrenheit.

V_1 = jet velocity, feet per minute.

It should be remembered, that the total drop $H = H_1 + H_2$. H_1 is positive for either heating or cooling; H_2 is positive for cooling, negative for heating. In consequence, there will always be vertical drop in cooling, and a vertical rise in heating only if $H_2 > H_1$.

Another empirical equation for the *total drop* is[2]:

$$H = \frac{m(t_r - t_{sa})L}{V_1} \qquad (13)$$

where

m = constant (tentatively suggested value of $m = 16$).

In other words, for a given throw L the drop or rise increases as the temperature difference increases and the outlet velocity decreases. This equation is only valid, if a temperature difference exists between room air and supply air.

Room Air Motion (Wall Outlet)

One of the most important problems in air distribution is to achieve air motion in the occupied zone within acceptable velocity limits. Therefore, outlet performance and characteristics of the space have to be related to this air motion.

The air moving in the occupied zone is (for a side wall outlet) equal in quantity to the total air contained in the outlet stream at the end of the throw and it is generally moving in a direction opposite to the stream. Assuming that the maximum volume of air is in circulation when the air stream velocity V_3 drops to 200 fpm, that the free area for return flow is 0.6 of the area of the wall in which the outlets are located, then, according to the momentum theory[2,4]:

$$V = \frac{Q_3}{0.6 \times A_w} \qquad (14)$$

where

V = average room velocity, fpm.

Q_3 = volume of room air in motion, cfm.

A_w = area of wall in which outlet is located, square feet.

Since $Q_3 = Q_1 \times r$, (by definition); and $r = \dfrac{V_1}{V_3}$ according to Equation 3; the average room velocity is:

$$V = \frac{Q_1 r}{0.6A_w} = \frac{Q_1}{0.6A_w}\left(\frac{V_1}{V_3}\right)$$

or, with $V_3 = 200$ fpm

$$V = \frac{Q_1 V_1}{120A_w} \qquad (15)$$

When Q_1, the volume of primary air, V_1, the velocity of primary air and A_w, the wall area are known, the average room velocity may be calculated from Equation 15 in order to determine the acceptability of the air distribution system.

OUTLET PERFORMANCE

The factors of outlet performance, throw, drop, room air motion, capacity, temperature differential, dirt and noise place considerable limitations on the design of a satisfactory distribution system.