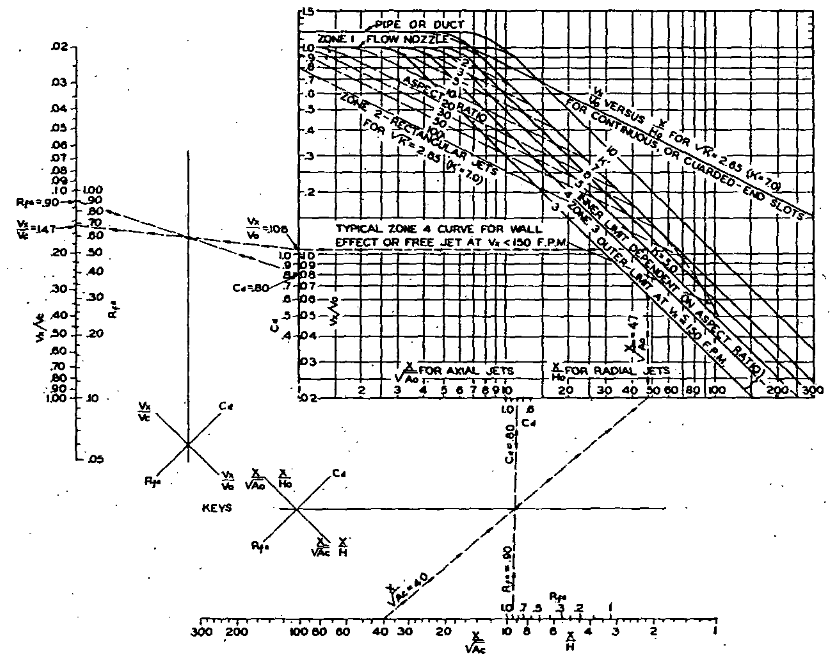

Fig. 2. . . . Chart for Determining Centerline Velocities of Axial and Radial Jets

be experimentally determined. Values of C_d and R_{fa} are required for determining V_0, D_0, and A_0 for orifice-type and multiple-opening outlets, and should, therefore, be included in catalog data of these outlets.

In the case of multiple-opening outlets and annular-ring outlets, the streams coalesce into a solid jet before actual jet expansion takes place. This coalescence affects the experimentally determined proportionality constants K or K' and accounts for some of the divergence in reported values for similar outlets.

Centerline Velocities in Zones 1 and 2

Experimental evidence indicates that in Zone 2

$$\frac{V_x}{V_0} = \sqrt{\frac{K'H_0}{X}} \tag{3}$$

where

H_0 = width of jet at outlet or at vena contracta.

Approximately the same values of K' apply as for Zone 3 expansion from axial outlets.

In Zone 1, the ratio V_x/V_0 is constant and equal to the ratio of the center velocity of the jet at start of expansion to the average velocity, ranging from approximately 1.0 for rounded-entrance nozzles to about 1.2 for straight pipe discharge, but with much higher values for diverging-discharge outlets.

Determining Centerline Velocities

To permit correlation of data from all four zones, centerline velocity ratios are plotted against distance from outlet in Fig. 2 in accordance with the basic relation of Equation 2, and a nomogram for calculating the parameters

$$\frac{X}{A_0} \quad \text{and} \quad \frac{V_x}{V_c} \quad \text{from} \quad \frac{X}{\sqrt{A_c}} \quad \text{and} \quad \frac{V_x}{V_0},$$

through R_{fa} and C_d is given in the same illustration.

The variation of the centerline velocity ratio with distance from outlet, or more properly, from start of jet expansion, is also shown on Fig. 2 for Zones 1 and 2. V_x/V_0 is plotted against X/H_0 and, for a range of aspect ratios, against $X/\sqrt{A}$ for the single value of K' = 7.0. Values of V_x/V_0 for other values of K' may be obtained by direct proportioning of $\sqrt{K'}$ to $\sqrt{7.0}$.

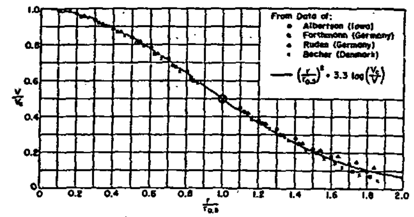

Fig. 3. . . . Cross-Sectional Velocity Profiles for Straightflow Turbulent Jets

The following *Example 1* which is solved on Fig. 2 will illustrate the use of the chart.

Example 1: A grille has a core area 12 in. x 18.75 in., R_{fa} = 0.90, C_d = 0.80, and K' = 5.0. Find V_c (velocity through core area) when V_x is 50 fpm for throw of 50 feet (X = 50).

Solution:

$$A_c = \frac{12 \times 18.75}{144} = 1.56 \text{ sq ft}$$

$$\frac{X}{\sqrt{A_c}} = \frac{50}{1.25} = 40$$

$$A_0 = 1.56 \times 0.80 \times 0.90 = 1.123$$

$$\frac{X}{\sqrt{A_0}} = \frac{50}{1.06} = 47.2$$

$$\frac{V_x}{V_0} = \frac{K'\sqrt{A_0}}{X} = \frac{5\sqrt{1.123}}{50} = 0.106$$

$$\frac{V_x}{V_c} = \frac{V_x}{V_0(C_dR_{fa})} = \frac{0.106}{0.80 \times 0.90} = 0.147$$

For V_x = 50,

$$V_c = \frac{50}{0.147} = 340 \text{ fpm.}$$

The quantity of air discharged is then,

$$Q = V_cA_c = 340 \times 1.56 = 530 \text{ cfm.}$$

Throw

Equation 2a can be used to determine the *throw* X of an outlet, if the discharge volume and the center velocity are known.

$$X = \frac{K'}{V_x} \cdot \frac{Q}{\sqrt{A_c \times C_d \times R_{fa}}} \tag{4}$$

or, if

$$Z = \sqrt{C_d \times R_{fa}}$$

$$X = \frac{K'}{V_x} \cdot \frac{Q}{Z\sqrt{A_c}} \tag{4a}$$

The maximum throw L is usually defined as the distance from the outlet face where the centerline velocity is 50 fpm. Therefore, for V_x = 50 fpm,

$$L = X = \frac{K'}{50} \cdot \frac{Q}{Z\sqrt{A_c}} \tag{4b}$$

Velocity Profiles of Jets

In Zone 3 of both axial and radial jets, the velocity distribution may be expressed by a single curve (Fig. 3) in terms of dimensionless coordinates, and this same curve can be used as a good approximation for adjacent portions of Zones 2 and 4. Experiments have shown that temperature and density differences have but a small effect on cross-sectional velocity profiles.

Velocity distribution in Zone 3 can be expressed by the Gauss error-function or probability curve which is approximated by a simple equation using common logarithms

$$\left(\frac{r}{r_{0.5}}\right)^2 = 3.3 \log \frac{V_x}{V} \tag{5}$$

where

r = the radial distance of the point under consideration from the centerline of the jet.

$r_{0.5}$ = the radial distance in the same cross-sectional plane from the axis to the point where the velocity is half the centerline velocity. (V = 0.5 V_x.)

V_x = the centerline velocity in the same cross-sectional plane, feet per minute.

V = the actual velocity at the point being considered, feet per minute.

Experiments show that the conical angle for 0.5 V_x and $r_{0.5}$ is approximately one-half of the total angle of divergence of a jet. The velocity profile curve for one-half of a straightflow turbulent jet (the other half being a symmetrical duplicate) is shown in Fig. 3. For multiple-opening outlets, such as grilles, or perforated panels, the velocity profiles are similar, but the angles of divergence are smaller.

Radial Jets

In the radial jet the cross-sectional area at any distance from the outlet varies as the square of this distance, the same as for an axial jet. Experiments have shown that the centerline velocity gradients and the cross-sectional velocity profiles are similar to those of Zone 3 of axial jets and that the angles of divergence are about the same. In using Fig. 2, X/H should be used as abscissa instead of $X/\sqrt{A}$.

Jets from ceiling plaques have the same form as one-half of a free radial jet. The jet is wider and longer than a free jet, with the maximum velocity close to the wall. This is demonstrated in Fig. 4 which also indicates that under the conditions shown the width of the slot between ceiling and plaque has

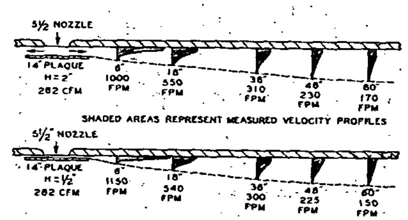

Fig. 4. . . . Air Jets from a 14-in. Ceiling Plaque for Two Slot Widths with Same Rate of Flow