V_c = nominal velocity of discharge based on the core area, feet per minute.
C_d = coefficient of discharge (usually between 0.65 and 0.90).
R_{fa} = ratio of free area to gross (core) area.
X = distance from face of outlet, feet.
K and K' = proportionality constants, with $K' = 1.13\ K$
D_0 = effective or equivalent diameter of stream at discharge from open-end duct or at a contracted section, feet.
$A_0 = A_c \times C_d \times R_{fa}$ = effective area of stream at discharge from an open-end duct or at a contracted section, square feet.
A_c = measured gross (core) area of outlet, square feet.
Q = discharge from outlet, cubic feet per minute.

Equation 1 is nondimensional and requires only that consistent units be used, as in the above nomenclature. Values of K and K' are listed in Table 1.[2, 4]

TABLE 1. RECOMMENDED VALUES OF THE CENTERLINE VELOCITY CONSTANT K OR K' (*See Equation 1*)

TYPE OF OUTLET	K		K'	
	V_0 = 500 to 1000	V_0 = 2000 to 10,000	V_0 = 500 to 1000	V_0 = 2000 to 10,000
Free Openings				
Round or Square	5.0	6.2	5.7	7.0
Rectangular, large aspect ratio (<40)	4.3	5.3	4.9	6.0
Annular slots axial or radial[a]	—	—	3.9	4.8
Grilles and Grids				
Free area 40% or more	4.1	5.0	4.7	5.7
Perforated Panels				
Free area 3 to 5%	2.7	3.3	3.0	3.7
Free area 10 to 20%	3.5	4.3	4.0	4.9

[a] For radial slots use X/H instead of $X/(A)^{1/2}$. H is the height or width of the slot.
Note: K and K' are indexes of loss in axial kinetic energy. Interpolate as required. Departures from maximum value indicate losses in first and second zones when compared with the jet from a rounded-entrance, circular nozzle.

Low velocity test results, in the range $V_x < 150$ fpm, indicate that the normal values of K and K' should be reduced about 20 percent for $V_x = 50$ fpm, as used in later Equation 4b for throw. Fig. 2 gives the effective diameter D_0 in inches for single openings and includes the coefficient of discharge.[5] Similar values for grilles are available in the literature or can 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 (see diagram A of Fig. 1), 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

$$\frac{V_x}{V_0} = \sqrt{\frac{K'H_0}{X}} \qquad (3)$$

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.

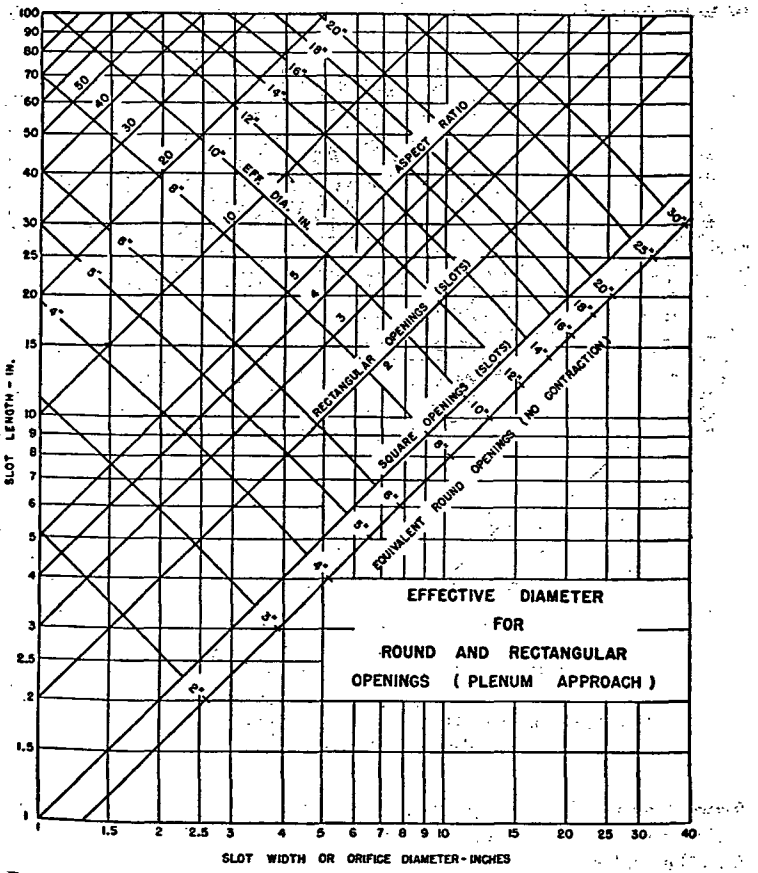

FIG. 2. EFFECTIVE DIAMETERS FOR ROUND AND RECTANGULAR OPENINGS (PLENUM APPROACH)

Determining Centerline Velocities

To permit correlation of data from all four zones, centerline velocity ratios are plotted against distance from outlet in Fig. 3 in accordance with