TABLE 5. RATIO OF PRESSURE LOSS TO BRANCH VELOCITY PRESSURE

TAKE-OFF ANGLE	RATIO OF VELOCITY IN BRANCH TO VELOCITY IN MAIN DUCT						
	0.4	0.6	0.8	1.0	1.5	2.0	3.0
90-deg	6.5	3.1	2.0	1.5	0.95	0.74	0.62
60-deg	5.0	2.2	1.3	0.77	0.47	0.47	0.58
45-deg	3.5	1.3	0.64	0.43	0.40	0.45	0.54

LOSSES DUE TO AREA CHANGES

Area changes in ducts, generally unavoidable, are necessitated frequently by the building construction or changes in the volume of air carried. Experimental investigations[12, 13, 14, 15] of pressure changes, and pressure losses at changes of the area of duct cross sections, indicate that the excess pressure loss over the normal friction loss is a dynamic loss due to a faster stream expanding into a slower stream, as determined by the actual areas occupied by the flow rather than the areas of the duct. No perceptible dynamic loss is due to the converging of the air stream itself where the flow is contracted, but the air stream continues to converge beyond the edge of the contraction and reaches a minimum at the *vena contracta*. For contraction, therefore, the dynamic loss is caused by expansion from the vena contracta to the full area following the contraction. Abrupt contraction in area may therefore be considered as a special condition of abrupt enlargement. Fig. 11 illustrates (a) abrupt enlargement and (b) abrupt contraction.

For a sudden symmetrical enlargement, a theoretical expression for the loss is

$$H_e = \left(\frac{V_1 - V_2}{4005}\right)^2 = \left(1 - \frac{A_1}{A_2}\right)^2 \left(\frac{V_1}{4005}\right)^2 = C_1\left(\frac{V_1}{4005}\right)^2 = C_2\left(\frac{V_2}{4005}\right)^2 \quad (8)$$

where

H_e = pressure loss due to sudden enlargement, based on standard air, inches of water.

V_1 = velocity of standard air in the inlet duct, feet per minute.

V_2 = velocity of standard air in the outlet duct, feet per minute.

A_1 = area of the inlet duct, square feet.

A_2 = area of the outlet duct, square feet.

C_1 = loss coefficient based on area A_1.

C_2 = loss coefficient based on area A_2.

For a gradual symmetrical enlargement, Equation 8 changes to

$$H_{ge} = C_r\left(\frac{V_1 - V_2}{4005}\right)^2 = C_r C_1\left(\frac{V_1}{4005}\right)^2 = C_r C_2\left(\frac{V_2}{4005}\right)^2 \quad (9)$$

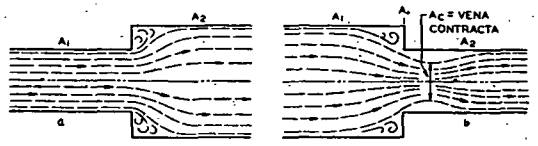


FIG. 11. AIR FLOW AT ABRUPT ENLARGEMENT OR CONTRACTION OF AIR STREAM

where

H_{ge} = pressure loss due to gradual enlargement, inches of water.

C_r = coefficient of loss, as ratio of loss to loss for abrupt expansion, dependent upon the total angle included between the sides of the duct.

The loss for a sudden symmetrical contraction can be expressed as

$$H_c = C_2\left(\frac{V_2}{4005}\right)^2 = C_1\left(\frac{V_1}{4005}\right)^2 = C_0\left(\frac{V_0}{4005}\right)^2 \quad (10)$$

where

H_c = pressure loss due to sudden contraction (Fig. 10b).

C_0 = loss coefficient based on orifice area A_0.

V_0 = velocity of air through orifice, feet per minute.

The loss for a gradual symmetrical contraction can be similarly expressed as

$$H_{gc} = C_2\left(\frac{V_2}{4005}\right)^2 \quad (11)$$

where the coefficient of loss, C_2, depends on the included angle of the sides of the duct and the sharpness of the edges at the junction of taper to following duct section.

DUCT DESIGN

The following discussion refers to ducts for commercial and industrial heating, ventilating, and air conditioning systems of the central station type. The design procedures given yield the static pressure required to overcome the resistance of the ductwork, including the supply outlets and return intakes. The fan selected for the duct system must not only produce this pressure but also the additional pressure required by the central equipment such as washers or spray chambers, heating or cooling coils, and filters. Pressure losses of these components should be obtained from the manufacturers' catalogs.

Special duct design procedures for heating ducts used in residences can be found in Chapter 19, Warm Air Heating Systems. The design of ducts in industrial exhaust systems is discussed in Chapter 45.

General rules which should be followed in the design are:

1. The air should be conveyed as directly as possible at the permissible velocities to obtain the desired results with minimum noise and greatest economy of power, material and space.

2. Sudden changes in the direction or velocity of the air should be avoided. When sudden changes are necessary at bends, turning vanes should be used to minimize the pressure loss.

3. Diverging transition pieces should be made as gradual as practicable. As shown in the section on area changes, losses in abrupt enlargements are high and therefore such transitions should be avoided. The included angle of divergence for enlargement should not exceed 20 deg. Losses in contractions are low but the included angle of convergence should not be greater than 60 deg.

4. Where the greatest air carrying capacity per square foot of sheet metal is desired, rectangular ducts should be made as nearly square as possible. Aspect ratios (ratio