

TABLE 1. VALUES OF ROUGHNESS ϵ FOR DIFFERENT PIPES*

PIPE	DEGREE OF ROUGHNESS	ROUGHNESS IN FEET
Drawn Tubing	Very smooth	0.000015
New Steel or Wrought Iron Pipe	Medium smooth	0.00015
Galvanized Iron	Average	0.0005
Average Concrete	Medium rough	0.003
Average Riveted Steel	Very rough	0.01

* Used in computing values for Fig. 5.

CIRCULAR EQUIVALENTS OF RECTANGULAR DUCTS

An air-handling system is usually sized first for round ducts. Then, if rectangular ducts are desired, their sizes are selected to provide flow rates equivalent to those of the round ducts originally selected.

A comprehensive study at the ASHAE Research Laboratory proved that for most practical purposes rectangular ducts of aspect ratios not exceeding 8:1 will have the same friction pressure loss for equal lengths and mean velocities of flow as a circular duct of the same hydraulic diameter. When duct sizes are expressed in terms of hydraulic diameter, and when equations for friction loss in round and rectangular ducts are equated for equal flow rate and equal length, Equation 6 giving the circular equivalent of a rectangular duct is obtained.⁵

$$d_c = 1.30 \frac{(ab)^{0.625}}{(a+b)^{0.250}} = 1.30 \sqrt[4]{\frac{(ab)^5}{(a+b)^2}} \quad (6)$$

where

a = length of one side of rectangular duct, inches.

b = length of adjacent side of rectangular duct, inches.

d_c = circular equivalent of a rectangular duct for equal friction and capacity, inches.

Table 2 gives the circular equivalents of rectangular ducts for equal friction and flow rate for aspect ratios not greater than 11.7:1 based on Equation 6.⁵ Note that the mean velocity in a rectangular duct will be less than in its circular equivalent.

Multiplying or dividing the length of each side of a duct by a constant is the same as multiplying or dividing the equivalent round size by the same constant. Thus, if the circular equivalent of an 80- x 24-in. duct is required, it will be twice that of a 40- x 12-in. duct, or $2 \times 23.0 = 46.0$ in.

DYNAMIC LOSSES

Wherever eddy flow is present, brought about by sudden changes in the direction or magnitude of the velocity of the air flowing, a greater loss in pressure takes place than would occur in a steady flow through a similar length of straight duct having a uniform cross section. The amount of this loss, in excess of straight duct friction, is termed *dynamic loss*. Although dynamic losses may be assumed to be caused by changes in area actually occupied by the air flow, for convenience they are divided into two

general classes: (1) those caused by *changes in direction* of the duct and (2) those caused by *changes in cross-sectional area* of the duct.

Dynamic losses vary substantially as the square of the mean velocity of the air, and are therefore conveniently expressed as a fraction of the velocity head:

$$H_d = C \left(\frac{V}{4005} \right)^2 \quad (7)$$

where

H_d = dynamic pressure loss, inches of water.

V = mean velocity of air flow, feet per minute.

C = an experimentally determined constant (dynamic loss coefficient).

Where different areas are involved, subscripts are used to denote the area to which the coefficient applies, as C_1 for inlet area, C_2 for outlet area, and C_o for orifice area.

The dynamic loss coefficient C is dimensionless and represents the number of velocity heads lost at the conduit transition or bend. Values of the dynamic loss coefficient for elbows and other duct elements have been determined experimentally and are given in Tables 3 and 4. It should be noted, however, that absolutely reliable dynamic loss coefficients are not yet available for all duct elements and that the information available for pressure losses due to area changes is generally restricted to symmetrical area changes.

Fig. 7, which shows the relation of velocity pressure to velocity for standard air ($V = 4005 \sqrt{H_v}$), can be conveniently used to find the total dynamic pressure loss for any duct element with known *dynamic loss coefficient* C .

PRESSURE LOSSES IN ELBOWS

Dynamic-loss coefficients are nearly independent of the air velocity and are affected by the roughness of the duct walls only in the case of bends, for which the dynamic losses are often grouped with the friction losses to facilitate design calculations. An ASHAE survey⁶ of available data has indicated that the method of expressing the combined dynamic and friction losses due to an elbow as equivalent to the loss in a length L of similar straight duct is justified for design purposes, owing to the relation of the loss to the corresponding friction factor, f .

Fig. 8 gives the *additional equivalent length* of duct in terms of widths W

TABLE 2. CIRCULAR EQUIVALENTS OF RECTANGULAR DUCTS FOR EQUAL FRICTION AND CAPACITY
Dimensions in Inches

SIDE RECTANGULAR DUCT	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
3.0	3.8	4.0	4.2	4.4	4.6	4.8	4.9	5.1	5.2	5.4	5.5	5.6	5.7
3.5	4.1	4.3	4.6	4.8	5.0	5.2	5.3	5.5	5.7	5.8	6.0	6.1	6.3
4.0	4.4	4.6	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.4	6.6	6.8
4.5	4.6	4.9	5.2	5.4	5.6	5.9	6.1	6.3	6.5	6.7	6.9	7.0	7.2
5.0	4.9	5.2	5.5	5.7	6.0	6.2	6.4	6.7	6.9	7.1	7.3	7.4	7.6
5.5	5.1	5.4	5.7	6.0	6.3	6.5	6.8	7.0	7.2	7.4	7.6	7.8	8.0