the inevitable loss due to turbulence. The principle of static pressure regain is, however, of importance in the economical design of duct systems.

Fig. 9 shows the application of static pressure regain to a simple fan and discharge duct.[22] The fan in the upper part of the figure has a free inlet and discharges air through a straight duct, the diameter of which is equal to the fan outlet. The total pressure which must be provided by the fan is therefore the sum of the pressure that is necessary to overcome the friction in the duct (no dynamic pressure loss), plus the velocity pressure which, in this case, is the same at any location along the length of the duct.

In arrangement B in the lower part of Fig. 9, a diverging section, with after section, has been added to the straight duct. The velocity in the diverging section is therefore decreased, and velocity pressure converted

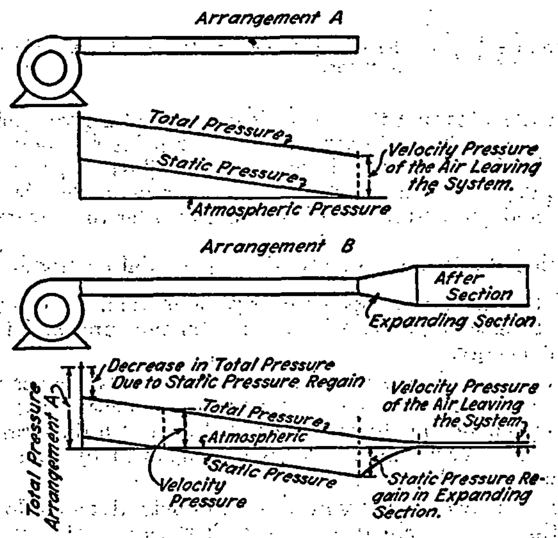

FIG. 9. APPLICATION OF STATIC PRESSURE REGAIN TO A SIMPLE FAN AND DISCHARGE DUCT

into static pressure before the air is released to the atmosphere. It can be seen that in case B, the total pressure at the fan outlet is less than in case A, and thus a saving in horsepower can be effected.

The regain in static pressure h_r in an abruptly expanded section is the difference in the velocity pressures of the small and the large duct, minus the dynamic pressure loss (Equation 6):

$$h_r = \left[\frac{v_1^2}{2g} - \frac{v_2^2}{2g}\right] - \left[\frac{(v_1 - v_2)^2}{2g}\right] \tag{13}$$

or simplified

$$h_r = \frac{v_1 v_2 - v_2^2}{g} = \frac{v_2(v_1 - v_2)}{g} \tag{14}$$

where

h_r = regain in static pressure, feet of fluid flowing.

v_1 and v_2 = mean velocities in inlet and outlet duct sections, respectively, feet per second.

The static pressure regain in a gradually expanding transition, followed by an after section, may be expressed as

$$h_r = \left[\frac{v_1^2}{2g} - \frac{v_2^2}{2g}\right] - \left[\frac{c_1(v_1 - v_2)^2}{2g}\right] \tag{15}$$

or

$$h_r = \frac{v_1^2 - v_2^2 - c_1(v_1 - v_2)^2}{2g} \tag{16}$$

where

c_1 = an experimentally determined regain constant depending on nature of construction.

Curves have been developed showing the static pressure regain and the *theoretical* efficiency of conversion in abrupt expansion, and in diverging sections in smooth circular ducts.[15,16]

DUCT DESIGN

The discussion of duct design in this chapter refers to ducts in fan systems for central heating, ventilating and air conditioning. Additional data for heating ducts used in residences are to be found in Chapter 18 (Gravity Warm Air Systems) and Chapter 19 (Forced Warm Air Systems). The design of ducts in industrial exhaust systems is discussed in Chapter 45.

The following general rules should be followed in design:

1. The air should be conveyed as directly as possible at the permissible velocities to obtain the desired results with greatest economy of power, material, and space.
2. Sharp elbows and bends should be avoided. Splitters and turning vanes should be used to reduce the elbow or outlet pressure loss.
3. Diverging transformation pieces should be made as long as practicable. As shown in the section on area changes, losses in sudden enlargements are high, and abrupt enlargements should be avoided. The included angle of divergence for enlargements should not exceed 20 deg. Losses in contractions are low, but the included angle of convergence should not be larger than 60 deg.
4. Special care should be taken to avoid restriction of flow in elbows or transformation pieces.
5. 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 greater than 10 to 1 should be avoided.
6. Ducts should be constructed of smooth material, such as steel or aluminum sheet metal. For ducts made from other materials, for example masonry, proper allowance for the surface friction coefficient should be made.

Procedure for Duct Design

The general procedure for design is outlined as follows:

1. Study the plan of the building and draw in roughly the most convenient system of ducts, taking cognizance of the building construction, avoiding all obstructions in steel work and equipment, and at the same time maintaining a simple design.
2. Arrange the positions of duct outlets to insure the proper distribution of air.
3. Divide the building into zones and proportion the volume of air necessary for each zone.
4. Determine the size of each outlet, based on the volume as obtained in the preceding paragraph, for the proper outlet velocity and throw. In case of some ceiling diffusers, determine size of outlet for proper throat velocity and radius of diffusion.