The loss for a sudden symmetrical contraction, h_c can similarly be expressed as

$$h_c = \left(1 - \frac{A_1'}{A_2}\right)^2 \left(\frac{v_1'^2}{2g}\right) \quad (8)$$

where

v_1' = the velocity at the vena contracta, feet per minute
A_1' = the area of the vena contracta

Introduction of the *contraction coefficient* $\alpha = \frac{A_1'}{A_2}$ and the *loss coefficient* $c = \left(\frac{1}{\alpha} - 1\right)^2$ in Equation (8) gives (with $A_1' \times v_1' = A_2 \times v_2$):

$$h_c = c\,\frac{v_2^2}{2g} \quad (9)$$

or for standard air:

$$H_c = C\left(\frac{V_2}{4005}\right)^2 \quad (10)$$

where

V_2 = velocity in the smaller duct, in feet per min.

Values for C and α are given in following table:

Duct Element	α	C
Sharp corner	0.61 to 0.64	0.41 to 0.314
Broken corner	0.68 to 0.8	0.221 to 0.0625
Corner with small radius	0.9	0.0125
Corner with large radius	0.99	0.0001

Values of α for sharp corners for increasing ratios of A_2/A_1 are given in the following table:

A_2/A_1	0.01	0.1	0.2	0.4	0.6	0.8	1.00
α	0.6	0.61	0.62	0.65	0.7	0.77	1.00

For discharge to atmosphere from a pipe, C = 1.0 in Equation 10, whereas for discharge to atmosphere from an opening in a pipe or wall surface, it is approximately 2.5;

$$C = \left(\frac{1}{\alpha}\right)^2 = \left(\frac{1}{0.63}\right)^2 = 2.5$$

Conditions of expansion and contraction, in addition to abrupt expansion and abrupt contraction, include abrupt contraction followed by either abrupt or gradual expansion, and gradual contraction followed by either abrupt or gradual expansion. Pressure losses for various duct conditions have been determined experimentally, although the available information is generally restricted to symmetrical area changes.[12,13,14]

PRESSURE CHANGES

The fundamental energy equation for standard air flow in a horizontal duct can be written[15]

$$h_1 + \left(\frac{V_1}{4005}\right)^2 = h_2 + \left(\frac{V_2}{4005}\right)^2 + \text{Loss of Pressure (head)} \quad (11)$$

where

h_1 and h_2 = the static pressure (head) at two given points (1) and (2), inches of water.

$\left(\frac{V_1}{4005}\right)^2$ and $\left(\frac{V_2}{4005}\right)^2$ = the velocity pressure (head) at the same points, inches of water.

Equation 11 states that the mechanical energy at a given point (1) must be equal to the mechanical energy at another point (2), plus any dissipation of mechanical energy to internal energy (loss of pressure). Equation 11 is only valid, if no work is done by or upon the air between the sections (1) and (2) and if there is no heat transfer to or from the air.

In Equation 11, h is a measure of the potential energy and $\left(\frac{V}{4005}\right)^2$ a measure of the kinetic energy or energy of motion. The sum of static pressure and velocity pressure is called total (dynamic, impact) pressure and is a measure of the total energy.

Static pressure and velocity pressure are mutually convertible, that is to say, static pressure may be transformed into velocity pressure, and vice versa. Every change in the cross-sectional area of a duct results in such a conversion of energy which is always accompanied by some loss in efficiency, or loss in total pressure.

In the final analysis of pressure losses in ducts, shock losses are therefore due to accelerations and decelerations of the air stream as a whole. In a *converging* duct, the air velocity will be accelerated; some pressure head will be converted into velocity pressure. This conversion is generally a stable and efficient process; the energy losses are small, and there is no eddy formation.

In an *expanding* duct section on the other hand, the air will be decelerated and an opposing pressure gradient is required to reduce the velocity. If the angle of divergence is appreciable, the flow becomes unstable, there is danger of separation of the flow from the duct wall and large energy losses and eddy formation are possible.[16]

In order to keep losses in an expanding duct section to a minimum and to convert the velocity pressure efficiently into static pressure, the angle of divergence should be kept small.[17] Theoretically, it might seem possible to increase the duct area so gradually that the reduction in velocity and accompanying loss of velocity pressure would occur reversibly and thus permit 100 per cent conversion to static pressure. Such an ideal application of the principle of *static regain* in duct design is, of course, impossible for various reasons[18] such as: the necessity of using sections of uniform diameter because of cost, the need for using ducts of dimensions varying in full inches, the changing of duct sizes mainly at branch connections, and the inevitable loss due to turbulence. The principle of static pressure regain is, however, of importance in the economical design of duct systems.

Fig. 6 shows the application of static pressure regain to a simple fan and