effect on takeoff distance and is approximated by the following relationship:

$$\frac{S_2}{S_1}=\left[1-\frac{V_w}{V_1}\right]^2$$

where

S_1 = zero wind landing distance
S_2 = landing distance into a headwind
V_w = headwind velocity
V_1 = landing ground velocity with zero wind or, simply, the landing airspeed

As a result of this relationship, a headwind which is 10 percent of the landing airspeed will reduce the landing distance 19 percent but a tailwind (or negative headwind) which is 10 percent of the landing speed will increase the landing distance 21 percent. Figure 2.33 illustrates this general effect.

The *effect of runway slope* on landing distance is due to the component of weight along the inclined path of the airplane. The relationship is identical to the case of takeoff performance but the magnitude of the effect is not as great. While account must be made for the effect, the ordinary values of runway slope do not contribute a large effect on landing distance. For this reason, the selection of the landing runway will ordinarily favor the direction with a downslope and headwind rather than an upslope and tailwind.

The *effect of pressure altitude and ambient temperature* is to define *density altitude* and its effect on landing performance. An increase in density altitude will increase the landing velocity but will not alter the net retarding force. If a given weight and configuration of airplane is taken to altitude above standard sea level, the airplane will still require the same q to provide lift equal to weight at the landing C_L. Thus, the airplane at altitude will land at the same equivalent airspeed (EAS) as at sea level but, because of the reduced density, the true airspeed (TAS) will be greater. The relationship between true airspeed and equivalent airspeed is as follows:

$$\frac{TAS}{EAS}=\frac{1}{\sqrt{\sigma}}$$

where

TAS = true airspeed
EAS = equivalent airspeed
σ = *altitude density ratio*

Since the airplane lands at altitude with the same weight and dynamic pressure, the drag and braking friction throughout the landing roll have the same values as at sea level. As long as the condition is within the capability of the brakes, the net retarding force is unchanged and the acceleration is the same as with the landing at sea level.

To evaluate the effect of density altitude on landing distance, the following relationships are used:

since an increase in altitude does not alter acceleration, the effect would be due to the greater TAS

$$\frac{S_2}{S_1}=\left(\frac{V_2}{V_1}\right)^2\times\left(\frac{a_1}{a_2}\right)$$

$$\frac{S_2}{S_1}=\frac{1}{\sigma}$$

where

S_1 = standard sea level landing distance
S_2 = landing distance at altitude
σ = altitude density ratio

From this relationship, the minimum landing distance at 5,000 ft. (σ=0.8617) would be 16 percent greater than the minimum landing distance at sea level. The approximate increase in landing distance with altitude is approximately 3½ percent for each 1,000 ft. of altitude. Proper accounting of density altitude is necessary to accurately predict landing distance.

The effect of *proper landing velocity* is important when runway lengths and landing distances are critical. The landing speeds specified in the flight handbook are generally the minimum safe speeds at which the airplane can be landed. Any attempt to land at below the