destabilizing and the greatest contribution will occur at high power and low dynamic pressure as during a waveoff.

As in the case of longitudinal static stability, freeing the controls will reduce the effectiveness of the tail and alter the stability. While the rudder must be balanced to reduce control pedal forces, the rudder will tend to float or streamline and reduce the contribution of the vertical tail to static directional stability. The floating tendency is greatest at large angles of sideslip where large angles of attack for the vertical tail tend to decrease aerodynamic balance. Figure 4.24 illustrates the difference between rudder-fixed and rudder-free static directional stability.

CRITICAL CONDITIONS. The most critical conditions of static directional stability are usually the combination of several separate effects. The combination which produces the most critical condition is much dependent upon the type and mission of the airplane. In addition, there exists a coupling of lateral and directional effects such that the required degree of static directional stability may be determined by some of these coupled conditions.

Center of gravity position has a relatively negligible effect on static directional stability. The usual range of c.g. position on any airplane is set by the linits of *longitudinal* stability and control. Within this limiting range of c.g. position, no significant changes take place in the contribution of the vertical tail, fuselage, nacelles, etc. Hence, the static directional stability is essentially unaffected by the variation of c.g. position within the longitudinal limits.

When the airplane is at a *high angle of attack* a decrease in static directional stability can be anticipated. As shown by the second chart of figure 4.24, a high angle of attack reduces the stable slope of the curve of C_n versus β. The decrease in static directional stability is due in great part to the reduction in the contribution of the vertical tail. At high angles of attack, the effectiveness of the vertical tail is reduced because of increase in the fuselage boundary layer at the vertical tail location. The decay of directional stability with angle of attack is most significant for the low aspect ratio airplane with sweepback since this configuration requires such high angles of attack to achieve high lift coefficients. Such decay in directional stability can have a profound effect on the response of the airplane to adverse yaw and spin characteristics.

High Mach numbers of supersonic flight reduce the contribution of the vertical tail to directional stability because of the reduction of lift curve slope with Mach number. The third chart of figure 4.24 illustrates the typical decay of directional stability with Mach number. To produce the required directional stability at high Mach numbers, a very large vertical tail area may be necessary. Ventral fins may be added as an additional contribution to directional stability but landing clearance requirements may limit their size or require the fins to be retractable.

Hence, the most critical demands of static directional stability will occur from some combination of the following effects:

(1) high angle of sideslip
(2) high power at low airspeed
(3) high angle of attack
(4) high Mach number

The propeller powered airplane may have such considerable power effects that the critical conditions may occur at low speed while the effect of high Mach numbers may produce the critical conditions for the typical supersonic airplane. In addition, the coupling of lateral and directional effects may require prescribed degrees of directional stability.

DIRECTIONAL CONTROL

In addition to directional stability, the airplane must have adequate directional control to coordinate turns, balance power effects, create sideslip, balance unsymmetrical power, etc. The principal source of directional control is the rudder and the rudder must be