The governing of the engine-propeller combination will allow operation throughout a wide range of power and speed while maintaining efficient operation.

If the envelope of maximum propeller efficiency is available, the propulsive horsepower available will appear as shown in the second chart of figure 2.19. The propulsive power available, Pa, is the product of the propeller efficiency and applied shaft horsepower.

$$Pa=\frac{TV}{325}$$

$$Pa=(\eta_p)\ (BHP)$$

The propellers used on most large reciprocating engines derive peak propeller efficiencies on the order of $\eta_p=0.85$ to 0.88. Of course, the peak values are designed to occur at some specific design condition. For example, the selection of a propeller for a long range transport would require matching of the engine-propeller combination for peak efficiency at cruise condition. On the other hand, selection of a propeller for a utility or liaison type airplane would require matching of the engine-propeller combination to achieve high propulsive power at low speed and high power for good takeoff and climb performance.

Several special considerations must be made for the application of aircraft propellers. In the event of a powerplant malfunction or failure, provision must be made to streamline the propeller blades and reduce drag so that flight may be continued on the remaining operating engines. This is accomplished by feathering the propeller blades which stops rotation and incurs a minimum of drag for the inoperative engine. The necessity for feathering is illustrated in figure 2.19 by the change in equivalent parasite area, Δf, with propeller blade angle, β, of a typical installation. When the propeller blade angle is in the feathered position, the change in parasite drag is at a minimum and, in the case of a typical multi-engine aircraft, the added parasite drag from a single feathered propeller is a relatively small contribution to the airplane total drag.

At smaller blade angles near the flat pitch position, the drag added by the propeller is very large. At these small blade angles, the propeller windmilling at high RPM can create such a tremendous amount of drag that the airplane may be uncontrollable. The propeller windmilling at high speed in the low range of blade angles can produce an increase in parasite drag which may be as great as the parasite drag of the basic airplane. An indication of this powerful drag is seen by the helicopter in autorotation. The windmilling rotor is capable of producing autorotation rates of descent which approach that of a parachute canopy with the identical disc area loading. Thus, the propeller windmilling at high speed and small blade angle can produce an effective drag coefficient of the disc area which compares with that of a parachute canopy. The drag and yawing moment caused by loss of power at high engine-propeller speed is considerable and the transient yawing displacement of the aircraft may produce critical loads for the vertical tail. For this reason, automatic feathering may be a necessity rather than a luxury.

The large drag which can be produced by the rotating propeller can be utilized to improve the stopping performance of the airplane. Rotation of the propeller blade to small positive values or negative values with applied power can produce large drag or reverse thrust. Since the thrust capability of the propeller is quite high at low speeds, very high deceleration can be provided by reverse thrust alone.

The *operating limitations* of the propeller are closely associated with those of the powerplant. Overspeed conditions are critical because of the large centrifugal loads and blade twisting moments produced by an excessive rotative speed. In addition, the propeller blades will have various vibratory modes and certain operating limitations may be necessary to prevent exciting resonant conditions.