

18.1 The Effect of Altitude on Power

- As an aircraft climbs, the air density decreases. For a
- normally aspirated engine (one that breathes air at ambient atmospheric pressure), this
- means less weight of air and fuel enters the cylinders on each intake stroke, causing power to
- decrease with altitude¹⁰⁷.
- ☐ Density Altitude: This is the pressure altitude corrected for non-standard temperature. It is
- the altitude in the standard atmosphere at which the prevailing density would occur¹⁰⁸. Higher
- density altitude (due to high elevation, high temperature, or high humidity) reduces engine
- performance¹⁰⁹.

18.2 Power Augmentation

- To counteract the loss of power with altitude, an engine can be fitted with a supercharger or
- a turbocharger. These are air compressors that force air into the induction manifold at a
- pressure higher than ambient, increasing the weight of the charge and thus increasing or
- restoring engine power¹¹⁰.
- ☐ Rated Altitude: The maximum altitude at which an engine can maintain its rated sea-level
- power¹¹¹.

18.3 Superchargers vs. Turbochargers

- ☐ Supercharger: An internally-driven compressor, powered mechanically by gearing from the
- engine's crankshaft¹¹².
- ☐ Turbocharger (or Turbo-supercharger): An externally-driven compressor. It consists of a
- turbine and a compressor on a common shaft. The turbine is placed in the engine's exhaust
- stream and is spun at high speed by the hot exhaust gases. This rotation drives the
- compressor, which boosts the intake air pressure¹¹³. Turbocharging is more efficient as it uses
- waste energy from the exhaust.

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18.4 Turbocharger Operation and Control

- ☐ Waste Gate: Not all exhaust gas is needed to drive the turbine, especially at lower altitudes.
- A waste gate is a valve that can bypass some of the exhaust gas around the turbine, sending it directly overboard¹¹⁴. Controlling the position of the waste gate controls the speed of the turbine, and therefore the output pressure of the compressor¹¹⁵.
- ☐ Automatic Control: The waste gate is typically controlled automatically by an Absolute Pressure Controller (APC), which senses the compressor outlet pressure (upper deck pressure)¹¹⁶. The APC modulates the waste gate to maintain the manifold pressure selected by the pilot's throttle.
- ☐ Operation during Climb: At sea level on takeoff, the waste gate is nearly fully open, bypassing most of the exhaust. As the aircraft climbs and the air becomes less dense, the APC will progressively close the waste gate to direct more exhaust gas through the turbine, spinning it faster to maintain the desired manifold pressure¹¹⁷.
- ☐ Critical Altitude: The altitude at which the waste gate becomes fully closed. Above this altitude, the turbocharger can no longer maintain its rated sea-level manifold pressure, and power will begin to decrease as the aircraft climbs further¹¹⁸.