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GSM-AUS-CPL.010

DOCUMENT TITLE

AIRCRAFT GENERAL KNOWLEDGE

CHAPTER 11 – SUPERCHARGING

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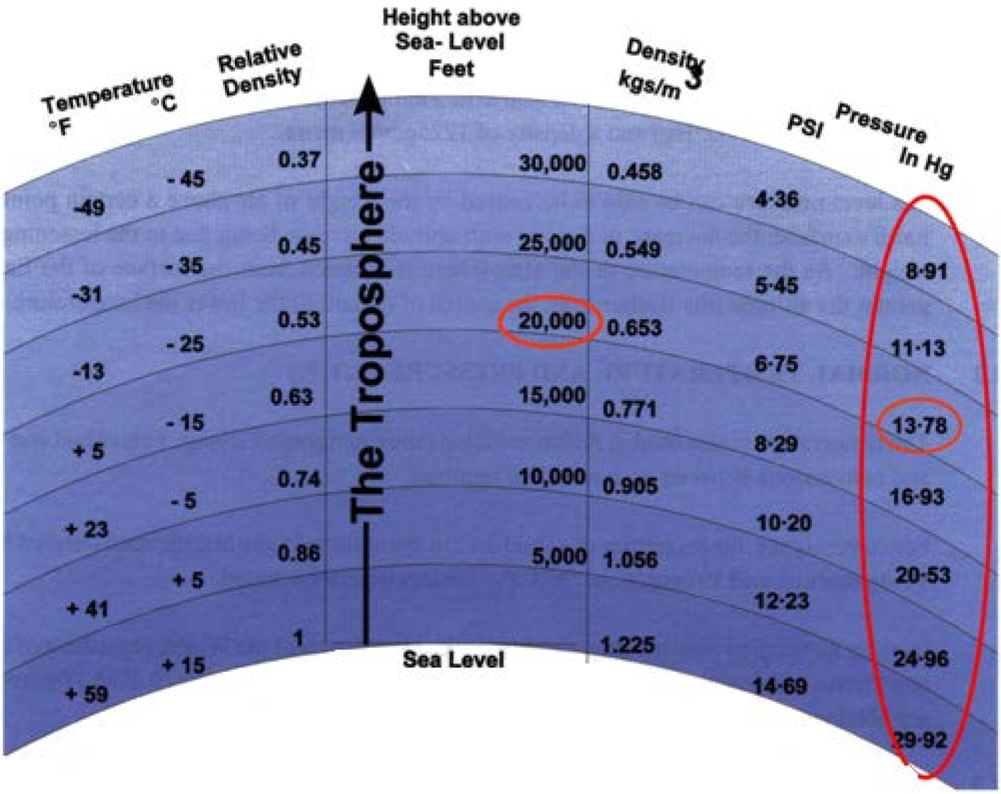
SUPERCHARGING

11.1 Introduction

In normally aspirated piston engines, the **THROTTLE** sets the **MANIFOLD PRESSURE (MAP)** for more power to be developed. The MAP will always be lower than ambient pressure because it is due to the suction caused by the pistons moving downward during the Induction stroke and also due to losses in the induction system.

The MAP and therefore the power will decrease as altitude increases because ambient pressure decreases with altitude (approximately 1"Hg per 1000').

A normally aspirated engine will lose 50% of its maximum available power by 20,000'.



Power may be increased if available MAP is increased since more air and therefore more fuel can be burned per unit time (i.e. volumetric efficiency increase).

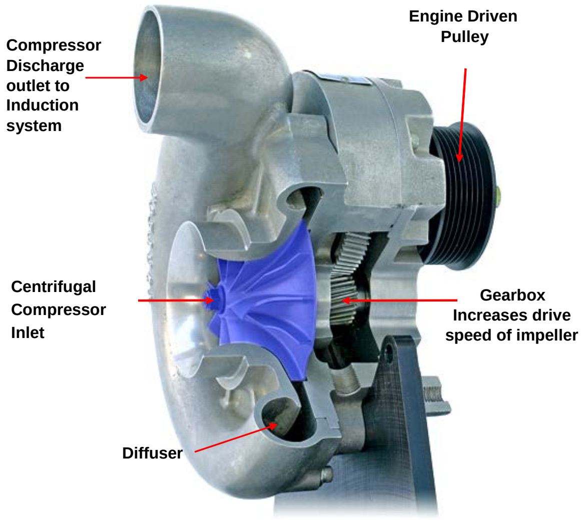
Increased MAP can be obtained by using a Supercharger or a Turbocharger. This increased MAP is often referred to as **BOOST**.

A **SUPERCHARGER** is a centrifugal compressor mechanically driven by the crankshaft. A **TURBOCHARGER** is an external centrifugal compressor driven by an exhaust turbine.

SUPERCHARGERS are COMPRESSORS that are driven by the CRANKSHAFT and may be fitted before or after the carburettor to provide compressed air to increase MAP.

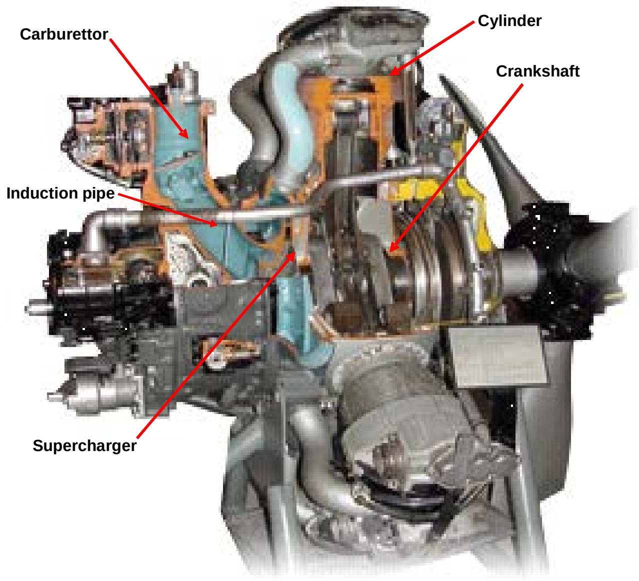
11.2 External Supercharger

External Superchargers compress only air and therefore have to be used in conjunction with fuel injection. Generally speaking External Superchargers are NOT fitted to aircraft.



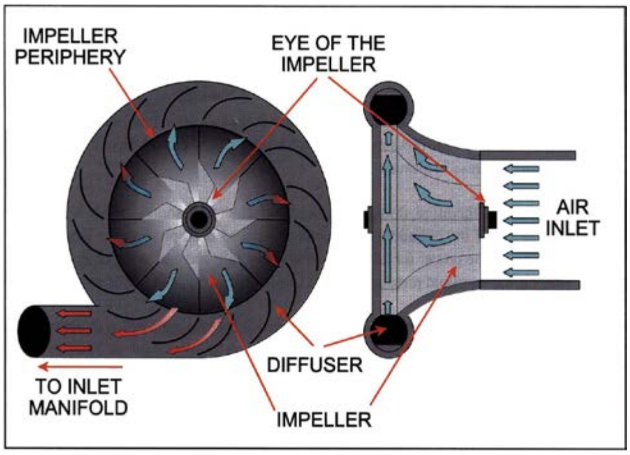
11.3 Internal Supercharger

An Internal Supercharger is driven directly by the Crankshaft and is fitted downstream of (i.e. after) the carburettor. This means that the compressor will compress the **MIXTURE** of fuel and air and then deliver this compressed mixture to the cylinders.



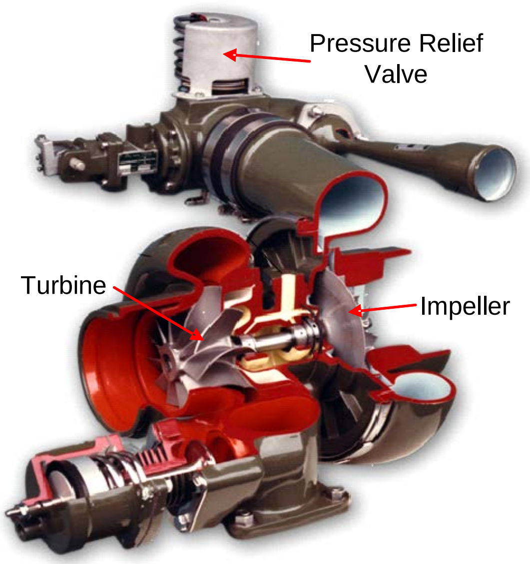
11.3.1 Centrifugal Compressor

The Centrifugal Compressor consists of two parts: a central rotating Impeller which accelerates the air radially into the stationary Diffuser where it is abruptly slowed down. This process causes the air to become compressed.



11.4 Pressure Relief Valve

The purpose of this spring loaded valve, located on the discharge side of the compressor, is to protect the engine from over boost if the throttle is mishandled by the pilot or a control system malfunction occurs.

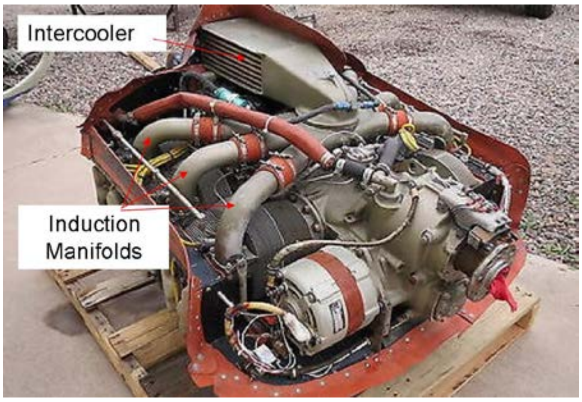


11.5 Terminology

- **RATED BOOST:** The highest MAP that the engine can withstand without the danger of DETONATION.
- **RATED POWER:** The maximum power at which the engine can be operated continuously, usually associated with RATED BOOST.
- **FULL THROTTLE HEIGHT**: (a normally aspirated term) is that height where, with the throttle fully open, any further climb above this height would result in a MAP decrease. So for a Normally Aspirated Engine FULL THROTTLE HEIGHT will be sea level.
- **RATED ALTITUDE:** is the FULL THROTTLE HEIGHT at RATED BOOST or the maximum altitude at which maximum continuous power can be maintained on a **Supercharged** engine (on a **Turbocharged** engine this is known as **CRITICAL ALTITUDE**).
- **ALTITUDE BOOSTING**: (also called **NORMALISING**) by use of a Supercharger or Turbocharger, sea level MAP and therefore horsepower is maintained at altitude. For example if an engine produces 300 BHP at sea level, this horsepower can be maintained to a higher altitude by the use of an **ALTITUDE BOOSTED** Supercharger or Turbocharger.
- **GROUND BOOSTING:** refers to the process of increasing the MAP to ***more*** than sea level MAP on the ground. This means that the actual horsepower is increased by increasing the MAP on the ground before take-off. Some engines may develop MAP as high as 48' Hg. This means that the engine will be subjected to high stress forces, so must be built from stronger materials. Generally engine compression ratios have to be reduced in Supercharged engines to prevent the onset of **DETONATION.**

11.6 Intercooling

As the inlet air is compressed its temperature rises sharply. Temperature rises of 150˚C are not uncommon. This greatly increases the risk of DETONATION, so an air to air heat exchanger called an **INTERCOOLER** is often fitted between the compressor and the inlet manifold to reduce inlet temperatures. This is a particular problem associated with Turbocharged engines. Engines fitted with Internal Superchargers are less susceptible to detonation because the fuel contained in the compressed mixture helps to keep the temperature of the charge being delivered to the engine low enough to prevent detonation.



The output of a Supercharger (or Turbocharger), i.e. the pressure within the INLET MANIFOLD, may be displayed to the pilot in 2 ways:

11.6.1 Boost Pressure

This is the pressure in the Induction System relative to standard sea level pressure.

The gauge is calibrated in pounds per square inch, PSI, *above* or *below* standard sea level atmospheric pressure, which is marked **ZERO**.

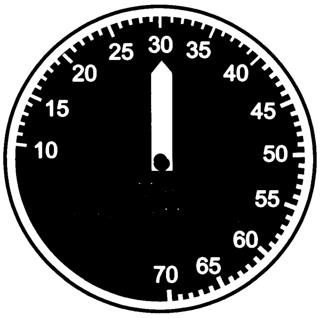
(Standard sea level atmospheric pressure = 14.7 PSI)

Boost Gauge

11.6.2 Manifold Pressure

(MAP) is the customary way of indicating MANIFOLD PRESSURE and the gauge is calibrated in INCHES OF MERCURY (“Hg).

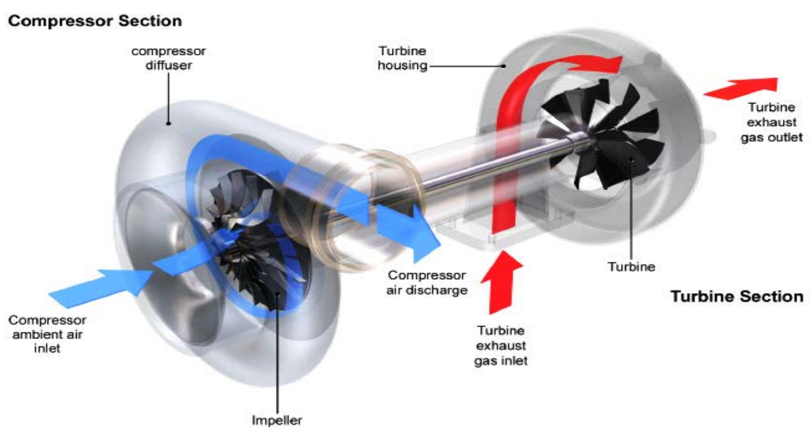
Standard atmospheric pressure at sea level is 14.7 PSI or 29.92 “Hg, which is equal to ZERO PSI of BOOST PRESSURE. Both the Gauges are indicating the same value.



Manifold Absolute Gauge

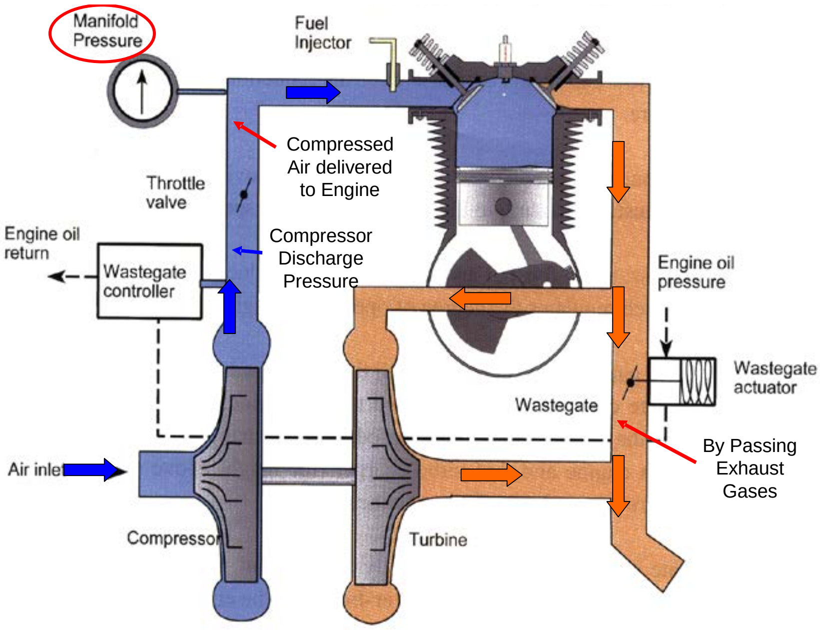
11.7 Turbochargers

EXTERNALLY mounted compressors that use an EXHAUST DRIVEN TURBINE to drive the Impeller. The Turbine is placed in the exhaust system and energy is extracted from the exiting exhaust gases to drive the Turbine. This in turn drives the Impeller. The Impeller then delivers the compressed air to the Induction Manifold, often via an Intercooler. Turbochargers compress only air and are used in conjunction with fuel injection, because of the close proximity to the exhaust it would be too dangerous to try to compress a mixture of fuel and air as in an Internal Supercharger.



11.8 Wastegate

The speed of the Turbocharger and therefore the compressor output is controlled by altering the amount of exhaust gases acting on the turbine. This is done by by-passing some of the exhaust gases overboard through a WASTEGATE, i.e. the more exhaust gases that are by-passed overboard through the WASTEGATE then the slower the Turbine and Impeller will turn and the less pressure will be produced.

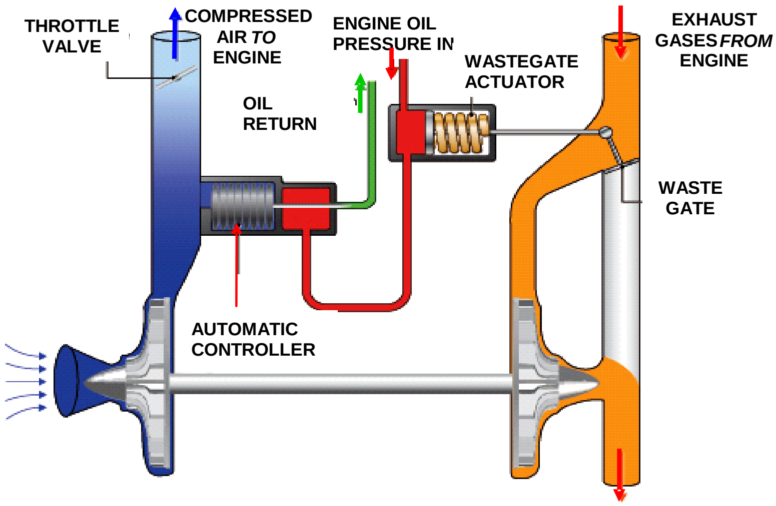


11.9 Wastegate Control

There are 3 ways in which the Wastegate (and therefore the speed of the IMPELLER) may be controlled:

- **COCKPIT ADUSTABLE (MANUAL):** A separate lever or control in the cockpit that directly adjusts the Wastegate in flight. The Wastegate is left fully OPEN during CLIMB until the required MAP can no longer be maintained, even with the throttle fully open (FULL THROTTLE HEIGHT). There after it may be manually closed to provide the required MAP.
- **THROTTLE OPERATED (MANUAL):** The first part of throttle movement just controls the throttle butterfly, leaving the Wastegate fully open. When the throttle butterfly reaches the fully open position, further movement of the throttle begins to close the Wastegate.
- **AUTOMATIC CONTROL:** Special **Density** and **Differential Pressure** Controllers automatically control the Wastegate to maintain the desired MAP. The Wastegate is operated by a Single Acting Actuator, which uses engine oil pressure as the hydraulic medium to close the Wastegate valve. Spring pressure and oil return allow the Wastegate valve to open.

When the Wastegate is automatically controlled, engine oil pressure will close the Wastegate after engine start. The Automatic Controller will control the oil return line during engine operation. If the Wastegate is required to OPEN then oil pressure is allowed to return to the sump, which relieves the hydraulic pressure on the Wastegate and the internal spring will open the Wastegate to allow exhaust pressure to bypass the TURBINE and reduce the manifold pressure.



11.10 Automatic Wastegate Controllers

11.10.1 Density Controller

This is used to prevent the compressor output from exceeding the limiting pressure at **FULL THROTTLE**. It contains a NITROGEN filled capsule which is sensitive to temperature and ambient pressure changes. It will react to changes in density as the aircraft climbs and will adjust the Wastegate to prevent OVERBOOSTING at *full throttle* regardless of altitude.

11.10.2 Differential Pressure Controller (DPC)

This operates at those throttle settings **OTHER** than full throttle. The turbocharger compressor is capable of producing pressures far in excess of what is required. The DPC senses the pressure differential across the throttle valve. This means that at full throttle where there is little differential across the valve it allows the Wastegate to be fully closed. However, as the throttle is retarded and the pressure differential across the throttle valve increases it will open the Wastegate to reduce compressor outlet pressure to suit the new throttle setting.

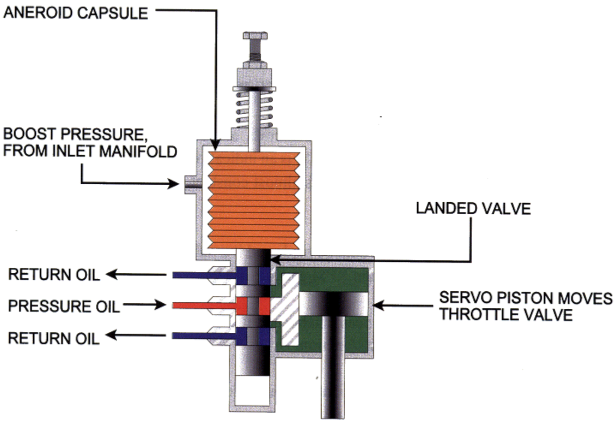
While these two controllers are separate devices they are often incorporated into one unit.

11.11 Automatic Boost Control

The compressors in a SUPERCHARGED engine are designed to turn at very high speeds to produce the pressure required at altitude. This means that they can potentially produce TOO MUCH pressure at lower altitudes. To prevent possible DETONATION caused by over boosting, an **AUTOMATIC BOOST CONTROL (ABC)** is fitted which mechanically varies the position of the THROTTLE valve. This can be especially helpful to the pilot because as the density of air decreases during a climb he would have to be constantly adjusting the throttle to maintain the required boost pressure. When an engine is fitted with **ABC**, the pilot will set climb power after take-off, and then the **ABC** would maintain his selected boost pressure as the aircraft climbs by gradually opening the throttle. During descent as the air density increases the **ABC** would prevent the boost pressure becoming excessive by gradually closing the throttle

Supercharging and Turbocharging increase both the pressure and the temperature of the air that is compressed and delivered to the engine.

This coupled with higher operating temperatures during for example the climb can easily lead to detonation. Therefore strict adherence to POH power settings is imperative.



11.12 Over Boosting

Over boosting with a Turbocharged Engine: When an engine and oil is cold, excessive and rapid throttle movements should be avoided as the high viscosity of the oil whilst cold could result in rapid closing of the Wastegate, causing Turbine (and compressor) RPM to be exceeded and OVERBOOSTING to occur.

OVERBOOSTING results in excessive pressures being developed within the cylinders and the possibility of catastrophic engine failure.

11.13 Oil Supply

Due to the extremely high rotational speeds developed in the TURBOCHARGER (80 000 RPM +), oil supply to the bearings is very important, so application of power before the oil has reached its normal operating temperature should be avoided.

On engine shut down, it takes a long time for the turbine to slow down from its operating RPM so 'quick' engine shutdowns should be avoided as oil pressure may be lost before the turbine assembly has stopped rotating. Additionally, if oil is allowed to be stationary in the hot turbocharger it will get overheated and form carbon deposits within the bearings, which may result in bearing failure at high RPM.

11.14 Summary

SUMMARY	
SUPERCHARGER	**TURBOCHARGER**
1. Internally driven	Externally driven
2. Rotational speed controlled by engine RPM.	Rotational speed controlled by the Waste Gate
3. Compresses mixture	Compresses air
4. Requires engine HP	Uses no HP
5. ABC senses MAP and controls the throttle	APC senses compressor discharge pressure and controls Waste Gate
6. Compressor discharge pressure same as MAP	Compressor discharge pressure greater than MAP
7. Throttle controls MAP	Throttle controls MAP
8. Decreased exhaust back pressure in climb	Increased back pressure in climb