

# Q. What are the principles of supercharging?

**A.** The power of an aircraft engine depends on the pressure developed in its individual cylinders whilst on their working strokes. This pressure arises from the combustion of liquid fuel which has been introduced into the cylinder along with a charge of air during the induction stroke.

Since it is a chemical fact that good combustion is possible only over a comparatively narrow range of mixture strengths, it follows that the amount of fuel that can be burnt per power stroke is limited by the weight of air in the cylinder. More air means more power and so the current demand for increased engine outputs is met by larger cylinders, by more of them, or by running at higher speeds to deal with a greater weight of air in unit time.

With a normal (unsupercharged) engine, it is the pressure of the atmosphere which forces air through the carburettor and into the cylinders on the induction stroke. As atmospheric pressure falls with altitude, the weight of air available for combustion also falls off and power goes lower in sympathy (Fig. 1).

It was soon realised that this natural fall-off with altitude could be avoided if we could deceive the engine that it was still at sea level by blowing air into its induction system using some kind of pump. This process is "supercharging." Then why not have a slight pumping effect at sea level to boost up the air flow and so the take-off power? This is "ground-boosting."

These two effects are often combined and an engine will be "ground-boosted" for take-off whilst still having a margin in pumping capacity to maintain the induction pressure to some altitude. If this altitude is great, then we have a "high-altitude" supercharger; if it is fairly low, we have a "moderate altitude" supercharger. Obviously, the higher we go, the larger must be the pumping apparatus (usually a centrifugal blower) and the more power it will absorb from the crankshaft.

For reasons of safety we cannot use the full delivery of a high-altitude supercharger at sea level and the throttle must be partly closed to give "maximum permissible boost" until a safe altitude is reached. This means that at low altitude there is a wastage of engine power in driving an oversize supercharging pump and for this reason the net power of an engine supercharged to high altitudes is always less near the ground than one which is supercharged to moderate altitudes.

These effects are indicated in Fig. 2, which is comparative with Fig. 1. Calling the unsupercharged engine 100 per cent. power at sea level, the ground-boosted engine will show better powers at all altitudes but will start to fall off at once from sea level. If the output of the supercharger is increased, the altitude performance will be better than the ground-

boosted version but there will be some loss of take-off output as just explained. The high-altitude curve shows these effects to an increased degree.

For some time engines were available with alternative ratios for their supercharger gearing but the desire to have the best of two worlds in one unit led naturally to the development of the two-speed gear. With this mechanism, the blower will rotate at a moderate speed in low gear and give a good power at low altitudes by avoiding unnecessary pumping. At greater heights the gearing is arranged to drive the blower at a higher speed and deliver the permissible boost at a greater altitude. Thus, with this type of blower, there are two maximum powers at different heights (Fig. 3).

When air is compressed its temperature is raised and we know that high inlet temperatures and pressures promote detonation and knocking in the engine. Improvements in fuels have greatly assisted in this respect but where operation at high altitudes is required special steps are taken. Thus two blowers are used in series because two-stage compression is usually more efficient than single-stage compression. If charge temperatures still tend to run high, "intercooling" may be resorted to, which means passing the compressed air through a sort of radiator between blower outlet and induction manifold. Fig. 4 indicates this arrangement and shows the power output obtainable with a mechanically-driven, two-speed, two-stage supercharger with intercooler.

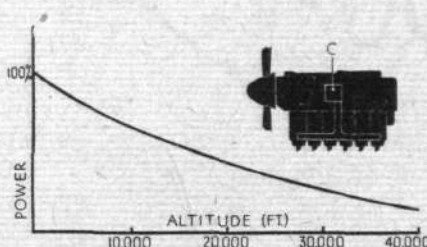
An ideal drive for a supercharger would be an infinitely variable gear which would avoid the "valley" in the altitude power curve which now occurs due to the low ratio being too low and the high ratio being too high at certain intermediate altitudes.

The general effect of an infinitely variable drive is obtained by using an exhaust turbine to drive the blower. With this device the speed of the blower can be regulated by admitting more or less exhaust gas to blow on the rotating blades of the turbine. This effect is approximately obtained automatically, since, for a certain pressure in the engine exhaust pipe, the falling atmospheric pressure produces a bigger pressure drop across the turbine and enables it to develop more power. The limit of altitude is reached when the speed and temperature of the turbine wheel approach the safe margin for the materials employed in its construction.

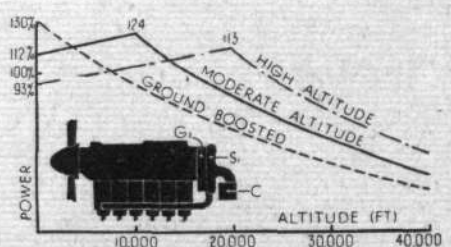
Quite often a combination of turbine and geared drives is used. In this case the mechanically-driven blower provides the ground boost for take-off and the turbo-driven blower looks after the altitude effects. Such a combination will give almost a straight-line power curve up to great heights as indicated in Fig. 5.

The supercharging arrangements for any particular installation will depend intimately on the engine characteristics and especially on the purposes for which the aircraft is intended.

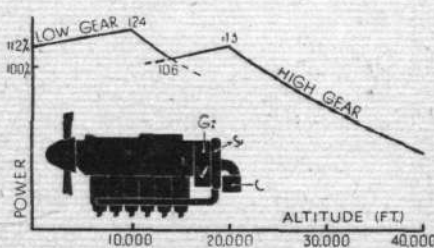
- C = Carburettor
- I = Intercooler
- G1 = Single-speed gear box
- G2 = Two-speed gear box
- S1 = Single-stage supercharger
- S2 = Two-stage supercharger
- T-5 = Turbo-supercharger



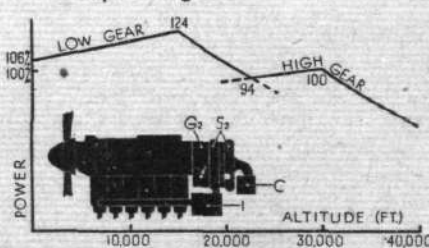
1. Unsupercharged



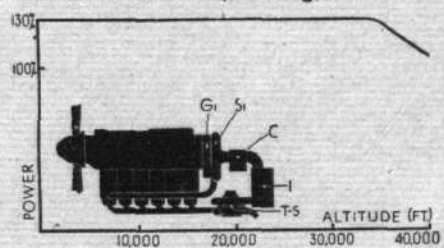
2. Gear-driven supercharger



3. Two-speed gear-driven supercharger



4. Two-speed, two-stage, gear-driven supercharger with intercooler



5. Gear-driven and exhaust turbine-driven supercharger with intercooler.

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