Part 1
Aerodynamic Theory

1 Preliminaries

Before studying the chapters dealing with the aerodynamics of each phase of flight, it is essential to understand various definitions and the theory of engine performance.

1.1 Air Density

There are three factors that directly influence the density of the air. They are: altitude, ambient temperature and water vapour content.

- *Altitude*: Any increase of altitude will decrease the air density and vice versa. In a normal atmosphere an increase from mean sea level to 1000 feet above the surface will on average reduce the air density by 3 %.
- *Air temperature*: The density of the atmosphere increases with a decrease of temperature and vice versa. In a standard atmosphere the temperature decreases by approximately 2 °C per 1000 feet increase of altitude up to the tropopause, above which there is an isothermal layer. The change to the air density caused by the change of temperature from mean sea level to 1000 feet above mean sea level is + 0.66 % in a standard atmosphere.
- *Water vapour content*: High water vapour content in the atmosphere causes low air density. It is not possible to measure the water vapour content by any instrument in a normal aeroplane. However, the aircraft manufacturers make allowance for it in the aeroplane performance graphs by using an average content for the altitude concerned. High humidity decreases the air density.
- *Overall effect*: The overall effect of the influencing factors is that the change of altitude causes, by far, the greatest change to the air density. This is so throughout the whole atmosphere up to the tropopause, at which altitude the compensating effect of the associated temperature reduction, in a normal atmosphere, ceases. Therefore on average an increase of 1000 ft from mean sea level decreases the air density by 2.34 %.

1.1.1 The Effect of Air Density

The density of the air affects lift, thrust, fuel flow and speed conversions.

1.1.1.1 Lift

The amount of lift generated by the wings is dependent on the density of the air. In a dense atmosphere a large amount of lift is generated and vice-versa.

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1.1.1.2 Thrust

For a given throttle/thrust lever setting the amount of thrust developed by a jet engine or piston/propeller engine is directly proportional to the air density. A low air density decreases the thrust available when compared with that for a normal atmosphere. This fact is particularly important for take-off from a high elevation aerodrome, especially if the surface ambient air temperature is high, because the reduced thrust available decreases the rate of acceleration. This increases the length of the ground roll to attain the lift-off speed (VLOF), even at the maximum take-off thrust/power setting.

As altitude increases the thrust reduction caused by reduced air density becomes more significant. At 40 000 ft a jet engine only develops 31 % of the thrust it would at mean sea level for the same thrust lever setting at the same gross mass (see Figure 1.2).

1.1.1.3 Fuel Flow

The efficient operation of any aero-engine is dependent on the correct mixture of fuel and air, by mass, being delivered to the combustion chamber. The ratio of the amount of fuel to the amount of air is crucial for both the piston and jet engines. For a given throttle setting the fuel flow must be altered to maintain the correct ratio. Hence in a low-density atmosphere the fuel flow required is less than it is in a dense atmosphere. The fuel flow is, therefore, directly proportional to the air density. Thus at high altitude the fuel flow for a jet engine is less than it is at low altitude for the same gross mass and aircraft configuration.

1.1.1.4 Speed Conversion

Generally the speeds used for aeroplane take-off and landing performance are calibrated airspeeds (CAS). Indicated airspeeds (IAS) are used for climbs and descents below approximately 20 000 ft. Above this altitude indicated Mach numbers are used for climbs and descents. Pressure altitude and ambient air temperature, together, directly affect the conversion of indicated airspeed (IAS) or calibrated airspeed (CAS) to true airspeed (TAS), whereas the conversion of indicated Mach number to TAS is only affected by air temperature. For a given CAS, low air density produces a higher TAS than it would in a normal atmosphere.

1.1.1.5 Combined Effects

When the effects of all of the influencing factors are taken together, a low-density atmosphere produces poor aeroplane performance. This is particularly significant during take-off because the throttles/thrust levers are most likely to be positioned at the maximum setting permissible for this phase of flight. Low air density will cause the engines to develop less thrust than in a dense atmosphere. This will decrease the rate of acceleration and require a longer ground run and take-off distance to reach the requisite speeds.

However, in a low-density atmosphere these speeds will convert to higher true airspeeds and groundspeeds. This results in the tyres being in contact with the surface of the runway for a longer period of time at a higher speed, which generates high tyre temperatures that may exceed the maximum permissible. Furthermore, should it be necessary to abandon the take-off, it is likely to be more difficult to bring the aeroplane to a halt within the available distance because of the extremely high brake temperatures generated when stopping from a high groundspeed. Consequently, it may be necessary to restrict the take-off mass to meet the requirements imposed by the ambient conditions.

1.1.1.6 Power/Thrust Augmentation

The performance of a turbo-propeller or jet engined aeroplane can be improved for a short period of time (i.e. during take-off and the initial climb) by the injection of a refrigerant, such as water/methanol, into the engine intake. This decreases the intake air temperature and increases the air density.

1.2 Speeds

Before the four forces can be examined, it is important to understand the relationship of the speeds used in aeroplane performance. The following definitions are those contained in AMC Definitions. They are: airspeed indicator reading (ASIR), indicated airspeed (IAS), calibrated airspeed (CAS), equivalent airspeed (EAS) and true airspeed (TAS).

1. *Airspeed indicator reading (ASIR)*: The reading on the airspeed indicator without correction is the ASIR. The correction made to allow for inaccuracies in the construction of the instrument, which are permissible within the normal working accuracy, are referred to as instrument error. The ASIR becomes the indicated airspeed (IAS) when corrected for instrument error.
2. *Indicated airspeed (IAS)*: This is the speed of the aeroplane as shown by the pitot/static airspeed indicator calibrated to reflect standard atmosphere adiabatic compressible flow at mean sea level uncorrected for airspeed system errors, but corrected for instrument error. In the lower levels of the atmosphere the speed for climbing and descending, for any particular aeroplane type is usually specified as a constant IAS.
3. *Calibrated airspeed (CAS)*: The airspeed value when the IAS is corrected for pressure (system) error is calibrated airspeed, which is equal to equivalent airspeed and true airspeed in a standard atmosphere at mean sea level. The speeds quoted for take-off and landing are normally quoted in terms of calibrated airspeed.
4. *Equivalent airspeed (EAS)*: The CAS when corrected for adiabatic compressible flow at a particular altitude becomes equivalent airspeed. This means that in a standard atmosphere at mean sea level the values of CAS and EAS are the same.
5. *True airspeed (TAS)*: This is the speed of aeroplane relative to the undisturbed air. *True airspeed is equal to the EAS divided by the square root of the relative density. i.e.* $TAS = EAS/\sqrt{\text{Relative Density}}$.
6. *Mach number*: A Mach number is a figure of two decimal places that for a specified altitude and ambient temperature is the result of the actual TAS of an aeroplane when divided by the TAS of the speed of sound. It is of particular significance to jet aeroplanes at high altitude because it is likely to limit the maximum operating speed. Mach number is directly proportional to the static air temperature expressed in degrees Kelvin.

1.2.1 The Effect of Altitude on Speeds

The effect that increasing altitude at a constant speed has on other speeds is shown in Figure 1.1 for climbs below the tropopause and above the tropopause. The tropopause in a standard atmosphere occurs at 36 090 ft. The effects differ because of the isothermal layer above the tropopause.

1.2.1.1 Below the Tropopause

1. A constant IAS/CAS climb will result in an increasing TAS and Mach number as the climb progresses as shown in the first diagram.
2. A constant TAS climb will cause the Mach number to increase as the climb progresses but the IAS/CAS will decrease as illustrated in the second diagram.
3. Climbing at a constant Mach number will result in both the IAS/CAS and the TAS decreasing as the climb progresses, as shown in the third diagram.

1.2.1.2 Above the Tropopause

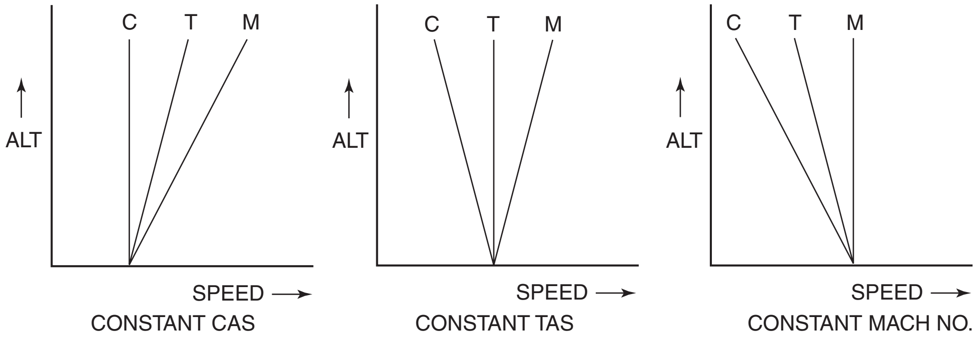
1. A constant IAS/CAS climb will cause both the TAS and Mach number to increase with increasing altitude.
2. Climbing at either a constant TAS or Mach number will result in the IAS/CAS decreasing as the climb progresses.

Pilots use the airspeed indicator to determine the forward speed of the aeroplane in the lower atmosphere; because of this the aircraft manufacturers provide the recommended speeds for various phases of flight in terms of IAS. Modern instruments are manufactured and installed with no instrument error therefore the airspeed indicator reading (ASIR) is the indicated airspeed (IAS).

The pressure error correction on modern aeroplanes is extremely small therefore it may be assumed that IAS is equal to calibrated airspeed (CAS) and this is equal to equivalent airspeed (EAS) at mean sea level in a standard atmosphere. If compressibility is ignored the IAS can be assumed to be equal to EAS at all altitudes. EAS is the speed used for the aerodynamic theoretical diagrams in Part 1 of this Manual.

Although the assumption that IAS is equal to EAS is technically incorrect, for the purposes of Part 1 of this Manual IAS and EAS are interchangeable.

(a) Below 36,090 ft



(a) Above 36,090 ft

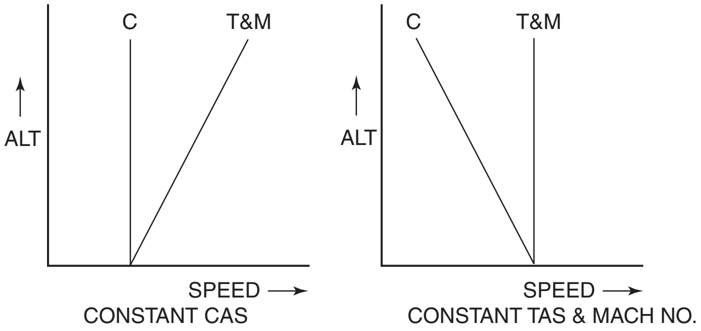


Figure 1.1 The effect of altitude on speeds.

1.3 Engine Performance

The essential forward thrust required by all aeroplanes is provided by one of three types of engine fitted to those aircraft. They are either a piston/propeller type, sometimes referred to as a reciprocating engine, a turbo-propeller engine or a jet engine. (Ramjet engines and Scramjet engines are not considered in this manual.) No matter what type of engine is considered the thrust produced by each of them is directly affected by air density.

1.3.1 Piston-Engine Performance

The propeller of a piston-engined aeroplane provides the forward thrust necessary to balance drag. The amount of power provided by the engine is dependent on the fuel/air ratio. Attached to the output shaft of a piston-engine is a load or brake device that measures the power developed by the engine. Hence the term ‘brake horse power’ which is a direct function of engine torque and rotative speed. The efficiency of a piston-engine is measured by its brake specific fuel consumption (BSFC). This is equal to the fuel flow divided by the brake horsepower (BHP). The fuel flow and speed are directly proportional to the percentage power set.

For a piston engine to operate efficiently it must have perfect internal combustion, which requires the ratio of air to fuel fed to the cylinders to be 15:1. The carburettor provides specific air/fuel ratios to the cylinders for the complete range of airflows. With modern engines this function is performed by an automatic mixture control. If other factors remain constant the power output can be directly related to the airflow and is therefore a function of the RPM of the engine. To ensure adequate cooling of a piston engine the airspeed of the aeroplane should be kept relatively high.

1.3.1.1 Altitude

If an aeroplane’s pressure altitude is increased the engine airflow is reduced because of the decreased air density, which results in a reduced power output. To increase the power output at high altitude a supercharger must be used. It achieves its purpose by compressing the inlet air of the carburettor thus increasing the density of the air before delivery to the engine. To do this it utilizes power derived from the engine itself which depletes the output. Without it, however, at a full throttle setting and a fixed RPM, the airflow and BHP would both diminish with increased altitude.

‘Full throttle height’ is defined as that altitude above which the supercharger is unable to compensate for the reduced air density and both the BHP and airflow decrease in direct proportion to any further increased altitude. The precise altitude at which this occurs varies according to the combination of manifold absolute pressure (MAP) and RPM. The full throttle height will be quoted in the Aeroplane Flight Manual (AFM) for the maximum rated and maximum cruise power conditions.

1.3.1.2 Critical Power Unit

The critical power unit is that which, when failed, has the most adverse effect on the aircraft performance. For propeller driven aeroplanes, viewed from behind, if both propellers rotate anti-clockwise the starboard engine is critical and vice versa. An inoperative engine increases the thrust required, power required and the total drag.

1.3.2 Turbo-Propeller-Engine Performance

A turbo-propeller engine is one on which the propeller is driven by a gas turbine engine. There are three types of engine, the direct drive turbine, the free power turbine and the compound.

1. *Direct drive turbine*: The power to the propeller is driven through a reduction gear by a turbine mounted on a common shaft with the compressor.
2. *Free power turbine*: The propeller on this type of engine is driven via a reduction gear by a free power turbine that is independent of the high-pressure turbine and the compressor.
3. *Compound engine*: An engine that has two spools on which the propeller is driven by the low-pressure spool is known as a compound engine. Of the energy produced by the burning of the fuel in the engine 90 % is used to drive the compressor(s) and the propeller and 10 % is jet exhaust thrust.

1.3.2.1 RPM

For all practical purposes the power output varies in direct proportion to the RPM. However, in the cruise, the RPM of a direct drive turbine is maintained at the maximum continuous setting whereas the free power turbine may require the high-pressure side to be restricted, which reduces its efficiency and increases the specific fuel consumption.

1.3.2.2 Altitude

The power output decreases with increasing altitude, at a constant TAS, because of the decreased density. This decrease is partially compensated by the decreased temperature up to the tropopause, above which the rate of decrease is markedly greater. The maximum pressure altitude that a turbo-prop aeroplane can attain is usually 30 000 ft.

1.3.3 Jet-Engine Performance

1.3.3.1 Thrust

Thrust is defined as the force developed by the engines to give an aeroplane its forward impetus. In a jet engine the gas loads resulting from the pressure and momentum changes of the gas stream reacting on the engine structure and its rotating parts are the thrust forces. Some of these are forward and exceed those that are rearward. The excess forward force produced by the rearward thrust is referred to as the rated thrust of the engine. It is measured by comparing the turbine discharge or the jet pipe pressure to the compressor inlet or intake pressure and is known as the engine pressure ratio (EPR) and is displayed on a gauge in the cockpit. The pilot can make a particular EPR setting by adjusting the thrust levers. The target EPR is that which it is aimed to achieve between 40 kt and 80 kt during take-off. At constant RPM the thrust is directly proportional to the airspeed.

1.3.3.2 Definitions

The following definitions apply to jet engines:

1. *Gross or static thrust*: This is the total thrust produced when an engine is stationary and is the product of the mass of air passing through the engine and the jet velocity at the propelling nozzle.
2. *Momentum drag*: The drag caused by the momentum of the air passing through the engine relative to the velocity of the aeroplane is known as momentum drag.
3. *Net thrust*: The product of the mass of air passing through an engine in flight and the change of velocity given to it is the net thrust.

Jet engine thrust = the mass flow of air x (jet pipe speed − intake speed).

1.3.3.3 Thrust Rating

For a jet-engined aeroplane to obtain a certificate of airworthiness it must have the following thrust ratings certificated:

- maximum take-off thrust
- maximum continuous thrust
- maximum go-around thrust.

Note: Maximum cruise thrust is not a certificated thrust rating.

1.3.3.4 Factors Affecting Jet-Engine Performance

The factors that affect jet-engine performance are thrust rating, aeroplane mass, airspeed, RPM and fuel flow.

1.3.3.5 Mass

A high aeroplane mass requires a large amount of lift to be generated by the wings. To increase the lift, in the cruise at a constant speed, the angle of attack would have to be increased which would cause increased drag. To overcome this disadvantage the thrust must be increased with the consequent increase of fuel flow. Alternatively, the aeroplane can be flown faster at a constant angle of attack to increase the lift generated but the thrust would still have to be increased.

1.3.3.6 RPM

Most jet aeroplanes cruise at between 85 % and 90 % of the maximum RPM. The mass flow of air through a jet engine and the thrust output are directly proportional to the RPM. High RPM increases the mass airflow, which consequently requires an increased fuel flow and results in an increased thrust output. A 1 % RPM change causes approximately a 3 % change to the thrust at high RPM. *Above 300 kts TAS, at constant RPM, the thrust output is also directly proportional to the airspeed*. If, however, the air density is low, the thrust output for a given RPM will decrease. To restore the thrust lost during take-off in low air density conditions it is necessary to inject water or water-methanol into the engine intake.

During the approach to land it is important to keep the RPM at a high value in case it is necessary to go around. If this is done and such is the case the time taken to ‘spool up’ a jet engine after the initiation of the go-around procedure is minimized.

1.3.3.7 Airspeed

For a given IAS, the equivalent TAS increases with increased altitude. Thus the speed of the air passing into the jet engine intake increases with increasing altitude. The maximum permitted jet pipe temperature requires the speed of airflow through the engine to be limited; consequently the benefit obtained from the rapid forward movement of the aeroplane is restricted by this limitation.

However, as a jet aeroplane accelerates to high speed, the effect of the compressor is enhanced by ‘ram effect’, which effectively increases the air density. At approximately 300 knots TAS, the increased density of the mass airflow fully compensates for the loss of thrust experienced due to its forward movement. Thus, the restricted airflow benefits from increased air density. Therefore, one effect decreases the thrust output while the other increases it.

Initially in the low-speed range, at a constant RPM, the thrust decreases, but above 300 kts TAS, when ‘ram effect’ becomes appreciable and thereafter the thrust increases in proportion to the airspeed. The net result of the two factors is that although the thrust of a jet engine changes with airspeed it is of no great significance.

1.3.4 Specific Fuel Consumption (SFC)

The amount of fuel used to generate the thrust output of an engine is the Specific Fuel Consumption. It is the fuel flow per hour divided by the thrust output. It is usually expressed as an amount of fuel used per hour per unit of thrust. The units used to specify SFC are:

- lb/BHP/hr for piston-engined aircraft.
- lb/Equivalent BHP/hr for turbo-prop aeroplanes.
- lb/lb. thrust/hr or kg/lb thrust/hr for jet-engined aircraft.

The main factors that affect the efficiency and SFC of a turbojet engine are:

(a) *RPM*: Turbojet engines are designed to operate at a low SFC in an optimum band, which is between 80 % and 95 % of the maximum RPM. It is most efficient at the optimum RPM which is approximately 90 % of the maximum RPM.
(b) *Temperature*: A measure of the thermal efficiency of a jet engine is the rise of temperature imparted to the intake air temperature. The thermal efficiency of any jet engine is improved if the intake air temperature is decreased; this will also reduce the SFC. This can be achieved by flying the aeroplane at a high altitude in a standard atmosphere where the ambient air temperature is extremely low. *The SFC is directly proportional to the ambient temperature in degrees Kelvin.*
(c) *Altitude*: The required thrust for a turbojet aeroplane to maintain level flight is attained at a relatively low RPM at low altitude. At higher altitudes the RPM has to be increased until eventually at a particular altitude the RPM enters the optimum band. At very high altitude the rarefied atmosphere may cause inefficient combustion. If such is the case the engine RPM must be increased beyond the optimum range to produce enough thrust to maintain level flight.
(d) *Speed*: The speed of a jet aeroplane has an insignificant effect on the magnitude of the SFC compared with the increase of RPM required to achieve it.

At a constant Mach number, the *fuel flow* decreases with increased altitude and/or increased ambient temperature, due to the decreased air density. However, for the same reason the *thrust* also decreases but not in exactly the same proportion. The overall effect, below the tropopause, is that at a constant Mach number the SFC remains virtually unchanged with changing altitude and /or temperature in a standard atmosphere, if all other factors remain constant.

At constant thrust, altitude and mass, the magnitude of SFC slightly increases with increased airspeed. The position of the CG will not affect the value of the SFC provided the RPM remains in the optimum range. If the CG moves forward it will cause the trim drag to increase, consequently the RPM would have to be increased beyond the optimum range, which would result in an increase to the SFC.

Overall, the SFC reduces with decreased ambient temperature and increased RPM (up to the optimum value). Speed in the cruise does not affect the SFC significantly.

1.3.5 Fuel Flow

Fuel flow is the quantity of fuel used per unit of time, measured in lbs per hour or kg per hour. The fuel flow of a jet engine varies with the air density, the RPM and the airspeed. The factors affecting the magnitude of the fuel flow of a jet engine are:

(a) *Air density*: The quantity of the fuel flow is dependent on the density of the air entering the engine intake. The greater the air density the greater is the fuel flow and consequently the thrust produced and vice versa. Air density is determined by a combination of altitude and air temperature. In a normal atmosphere, the air pressure decreases with increased altitude and, up to the tropopause, is accompanied by a decrease in ambient temperature. The fall in air pressure with increased altitude results in decreased air density and causes the fuel flow to decrease but the fall in temperature associated with the increased altitude causes it to increase. *The fuel flow will decrease in proportion to the ambient pressure at a constant temperature*. Overall the decreased atmospheric pressure has the greater effect, thus the *fuel flow for a constant thrust setting and indicated airspeed will reduce with increased altitude up to the tropopause.*
(b) *Airspeed and RPM:* If the indicated airspeed and/or RPM are increased the fuel flow will increase. At high-indicated airspeeds ‘ram effect’ will increase the air density at the engine intake; which will cause both the fuel flow and the thrust generated to increase.
(c) *Mass:* The thrust required varies in direct proportion to the aeroplane mass. A heavy aeroplane requires a large amount of lift to maintain level flight. To attain this, the aeroplane engines must produce enough thrust to enable the aeroplane to travel at a high enough speed to develop sufficient lift. Thus the fuel flow necessary to produce the required thrust is directly proportional to the mass

of the aeroplane. If the SFC (fuel used per hour per unit of thrust) remains constant, the change to the fuel flow is directly proportional to the aeroplane mass change when it is flying at VIMD, i.e. the percentage fuel flow change is the same as the percentage aeroplane mass change. This is because at a constant IAS, Thrust = Total Drag, which is directly proportional to aeroplane mass.

The formula to calculate the fuel flow at an increased mass when flying at VIMD, the maximum endurance speed for a jet aeroplane, is:

$$\mathbf{FF2 = FF1 \times (W2 \div W1).}$$

Where FF1 = original fuel flow; FF2 = revised fuel flow; W1 = aeroplane original mass; W2 = aeroplane revised mass. Thus the percentage fuel flow change is equal to the percentage mass change.

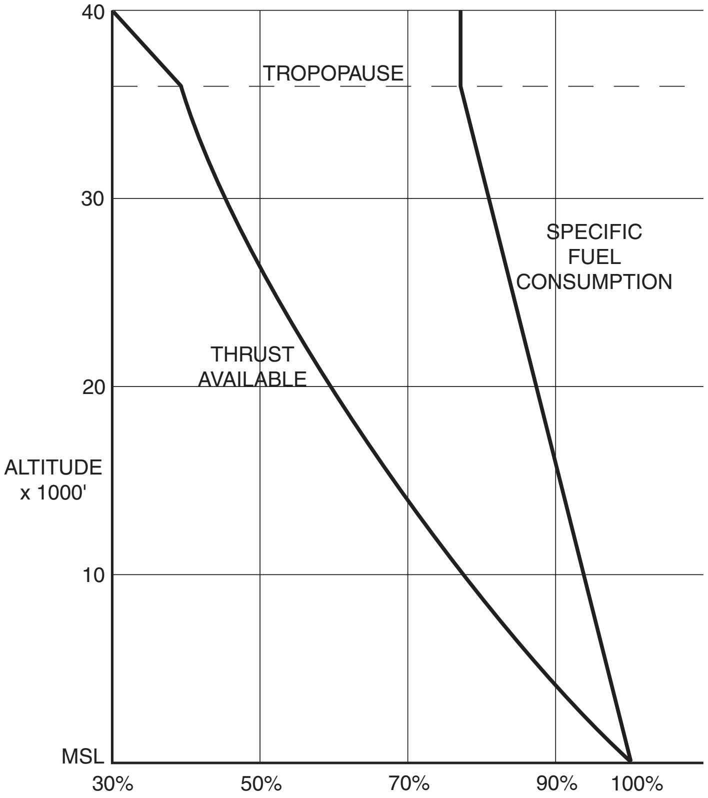


Figure 1.2 Jet thrust available as a percentage of MSL thrust available.

Example 1.1

Given: A jet aeroplane at an original mass of 100 000 kg and fuel flow 6000 kg/hr has a revised mass of 90 000 kg.

Calculate the revised fuel flow (i) for holding or maximum endurance.

Solution 1.1

Mass change = 10 000 ÷ 100 000 × 100 = 10 %

(i) new FF = old FF × (new mass ÷ old mass) = 6000 × (90 000 ÷ 100 000) = 5400 kg/hr = 10 % change.

(d) *High altitude flight*: Above the tropopause, any increase of altitude is not accompanied by a decrease in temperature, because there is an isothermal layer present. In the ISA, this layer is considered to extend to 66 000 ft. This causes the thrust to decrease at a greater rate with increased altitude, for the same throttle setting, because there is no temperature compensation; thus the fuel flow also decreases at greater rate, whereas the SFC remains constant (see Figure 1.2). Therefore, at high altitude above the tropopause, to maintain level flight the power setting has to be increased, resulting in increased in fuel flow.

1.3.6 Flat Rating

The rating of a jet engine is the thrust that is guaranteed by the manufacturer for particular phases of flight, e.g. take-off, maximum continuous climb. Some engines are rated to a constant compressor speed (RPM) and others to a constant exhaust gas temperature (EGT).

Full authority electronic control (EEC) systems automatically adjust the engine speed to maintain the guaranteed thrust which is displayed on an engine pressure ratio (EPR) gauge by a ‘reference bug’ set by the power management computer (PMC).

1.3.6.1 Take-off

For take-off the pilot adjusts the throttle lever angle until the ‘command needle’ on the EPR gauge is aligned with the ‘reference bug’ that is set by the Electronic Engine Control (EEC) system, which is part of the Power Management Computer (PMC). The fuel flow on take-off, and hence the engine RPM, is automatically adjusted by the EEC to account for changes of altitude, airspeed and ambient temperature to maintain the set engine pressure ratio (EPR). This is the ‘flat rated system’.

The EEC therefore maintains the thrust at a constant value, that is at a ‘flat rated’ value. Thus for take-off in a dense atmosphere, the fuel flow is automatically decreased. However, this automatic adjustment is limited in conditions of low air density; the fuel flow cannot be increased above a particular limit to maintain the thrust developed, because the engine temperature would exceed its maximum safe limit. If such is the case, the EPR set for take-off has to be restricted to prevent damage being caused to the engine. This is referred to as the ‘flat rating cut-off’ and is shown by a kink or line across the FLL TOM graph and the Climb Limited TOM graph in the Aeroplane Flight Manual (AFM). In CAP 698 Section 4, p. 11, Figure 4.5 this occurs at ISA + 15 °C.

Self-Assessment Exercise 1

Q1.1 A jet aeroplane flying for maximum endurance has a mass decrease, because of the fuel used, by 5 % from its original mass, the change to the fuel consumption per hour from that at the original mass is:
(a) Increase by 5 %.
(b) Decrease by 5 %.
(c) Increase by 10 %.
(d) Decrease by 10 %.

Q1.2 Two identical turbo-jet aeroplanes are flying at the same altitude at VIMD. Aircraft A weighs 130 000 kg and has a fuel flow of 4300 kg/hr. If aircraft B weighs 115 000 kg its fuel flow will be:
(a) 3804 kg/hr
(b) 4044 kg/hr
(c) 3364 kg/hr
(d) 3530 kg/hr

Q1.3 A jet aeroplane weighing 95 000 kg flying at VIMD has a fuel flow of 4000 kg/hr. What is the fuel flow at a mass of 105 000 kg when flying at VIMD?
(a) 3619 kg/hr
(b) 3942 kg/hr
(c) 4287 kg/hr
(d) 4421 kg/hr

Q1.4 Given: fuel consumption 0.06 kg per Newton of thrust per hour; fuel mileage 14 kg/nm. If all other conditions remain constant, with an SFC of 0.035 kg per Newton of thrust per hour the fuel mileage will be:
(a) 10.7 kg/nm
(b) 8.17 kg/nm
(c) 14.0 kg/nm
(d) 11.7 kg/nm

Q1.5 Given: fuel flow 3100 kg/hr; aeroplane mass 95 000 kg: speed VIMD. What is the fuel flow for the same aeroplane at a mass of 105 000 kg flying at VIMD?
(a) 3787 kg/hr
(b) 3426 kg/hr
(c) 3259 kg/hr
(d) 3602 kg/hr

Q1.6 At a constant thrust setting and altitude the fuel flow of a jet engine:
(a) decreases with decreasing OAT
(b) increases slightly with increasing speed
(c) is independent of speed
(d) decreases slightly with increasing airspeed.

Q1.7 At a constant Mach number, the thrust and fuel flow of a jet engine:
(a) increase with increasing altitude
(b) are independent of OAT
(c) increase in proportion to the airspeed
(d) decrease in proportion to the ambient pressure at constant temperature.

Q1.8 The thrust of a jet engine at constant RPM:
(a) is inversely proportional to the airspeed
(b) increases in proportion to the airspeed
(c) does not change with changing altitude
(d) is independent of airspeed.

Q1.9 Which of the jet engine ratings below is not a certificated rating?
(a) Go-around Thrust
(b) Maximum Take-off Thrust
(c) Maximum Cruise Thrust
(d) Maximum Continuous Thrust.

Q1.10 How does TAS vary in a constant Mach climb in the troposphere?
(a) TAS increases.
(b) TAS is constant.
(c) TAS is not related to Mach number.
(d) TAS decreases.

Q1.11 With all other things remaining constant and with T the outside static air temperature expressed in degrees Kelvin, the specific fuel consumption of a turbojet-powered aeroplane in a constant Mach number cruise in still-air, is proportional to:
(a) T
(b) $1/T^2$
(c) $1/T$
(d) $\sqrt{T}$.

Q1.12 Climbing at a constant TAS below the tropopause, the effect on (i) the CAS and (ii) the Mach number is:
(a) (i) decreases (ii) decreases
(b) (i) decreases (ii) increases
(c) (i) increases (ii) increases
(d) (i) increases (ii) decreases.

Q1.13 Descending at a constant Mach number above the tropopause, the effect on (i) the CAS and (ii) the TAS is:
(a) (i) constant (ii) increases
(b) (i) decreases (ii) increases
(c) (i) increases (ii) constant
(d) (i) decreases (ii) increases.

Q1.14 TAS is equal to:
(a) $\sqrt{\text{Relative Density}}/\text{EAS}$
(b) $\text{EAS}/\text{Relative Density}^2$
(c) $\text{EAS}/\sqrt{\text{Relative Density}}$
(d) $\text{Relative Density}^2/\text{EAS}$.