Engine Performance

Note applicable to Chapters 4 and 5: The ATP Single-engine exam (ATS) focuses on the Cessna 208 and the ATP Multi-engine exam (ATM) focuses on the Bombardier CRJ200 and 0400.

There are four types of engines in use on modern airplanes: **reciprocating engine, turboprop engine, turbofan engine** and **turbojet engine**. The type of engine selected for a particular airplane design depends primarily on the speed range of the aircraft. The reciprocating engine is most efficient for aircraft with cruising speeds below 250 MPH, the turboprop works best in the 250 MPH to 450 MPH range and the turbofan and turbojet engines are most efficient above 450 MPH.

Manifold pressure (MAP) is a measurement of the power output of a reciprocating engine. It is basically the pressure in the engine's air inlet system. In a normally-aspirated (unsupercharged) engine, the MAP will drop as the aircraft climbs to altitude. This severely limits a piston-powered airplane's altitude capability.

Most piston-powered airplanes flown by air carriers are turbocharged. On this type of engine, exhaust gas from the engine is used as a power source for a compressor that in turn raises the MAP at any given altitude. The flow of exhaust gas to the turbocharger is controlled by a device called a **waste gate**.

Turbocharging allows an aircraft to fly at much higher altitudes than it would be able to with normally-aspirated engines. The term **critical altitude** is used to describe the effect of turbocharging on the aircraft's performance. The critical altitude of a turbocharged reciprocating engine is the highest altitude at which a desired manifold pressure can be maintained.

The pilots of reciprocating-engine-powered aircraft must be very careful to observe the published limits on manifold pressure and engine RPM. In particular, high RPM and low MAP can produce severe wear, fatigue and damage.

Turboprops, turbofans and turbojet engines are types of **gas turbine engines**. Turbine engines are classified by the type of compressors they use-centrifugal flow, axial flow, and centrifugal-axial flow. All gas turbine engines consist of an air inlet section, a compressor section, the combustion section, the turbine section and the exhaust. Air enters the inlet at roughly ambient temperature and pressure. As it passes through the compressor the pressure increases and so does the temperature due to the heat of compression. **Bleed air** is tapped off the compressor for such accessories as air conditioning and thermal anti-icing.

The section connecting the compressor and the combustion sections is called the diffuser. In the diffuser, the cross sectional area of the engine increases. This allows the air stream from the compressor to slow and its pressure to increase. In fact, the highest pressure in the engine is attained at this point.

Next, the air enters the combustion section where it is mixed with fuel and the mixture is ignited. Note that after the initial start of the engine there is no need for an ignition system that operates continuously (such as the spark plugs in a piston engine) because the uninterrupted flow of fuel and air will sustain combustion after the initial "light off." The combustion of the fuel-air mixture causes a great increase in volume and because there is higher pressure at the diffuser, the gas exits through the turbine section. The temperature of the gas rises rapidly as it passes from the front to the rear of the combustion section. It reaches its highest point in the engine at the turbine inlet. The maximum turbine inlet temperature is a major limitation on turbojet performance, and without cooling, it could easily reach up to 4,000°F, far beyond the limits of the materials used in the turbine section. To keep the temperature down to an acceptable 1,100° to 1,500°F, surplus cooling air from the compressor is mixed aft of the burners.

The purpose of the turbine(s) is to drive the compressor(s) and they are connected by a drive shaft. Since the turbines take energy from the gas, both the temperature and pressure drop.

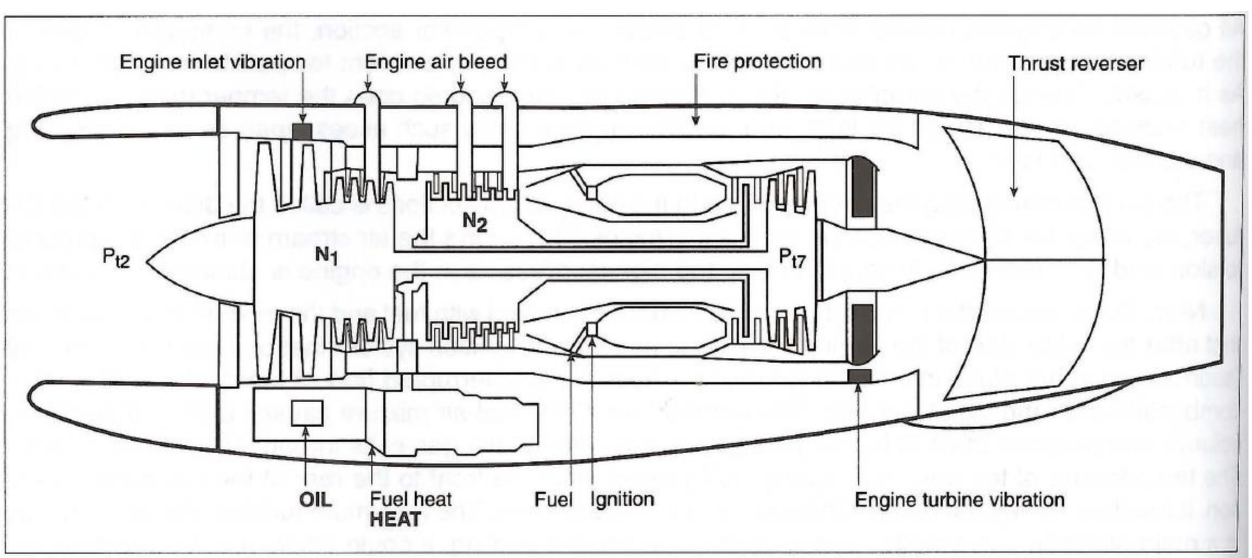
The gases exit the turbine section at very high velocity into the tailpipe. The tailpipe is shaped so that the gas is accelerated even more, reaching maximum velocity as it exits into the atmosphere. See Figure 4-1.

Combinations of slow airspeed and high engine RPM can cause a phenomenon in turbine engines called **compressor stall**. This occurs when the angle of attack of the engine's compressor blades becomes excessive and they stall. If a transient stall condition exists, the pilot will hear an intermittent "bang" as backfires and flow reversals in the compressor take place. If the transient condition develops into a steady state stall, the pilot will hear a loud roar and experience severe engine vibrations. The steady state compressor stall has the most potential for severe engine damage, which can occur literally within seconds of the onset of the stall.

If a compressor stall occurs in flight, the pilot should reduce fuel flow, reduce the aircraft's angle of attack and increase airspeed.

The turboprop is a turbine engine that drives a conventional propeller. It can develop much more power per pound than can a piston engine and is more fuel efficient than the turbojet engine. Compared to a turbojet engine, it is limited to slower speeds and lower altitudes (25,000 feet to the tropopause). The term **equivalent shaft horsepower (ESHP)** is used to describe the total engine output. This term combines its output in shaft horsepower (used to drive the propeller) and the jet thrust it develops.

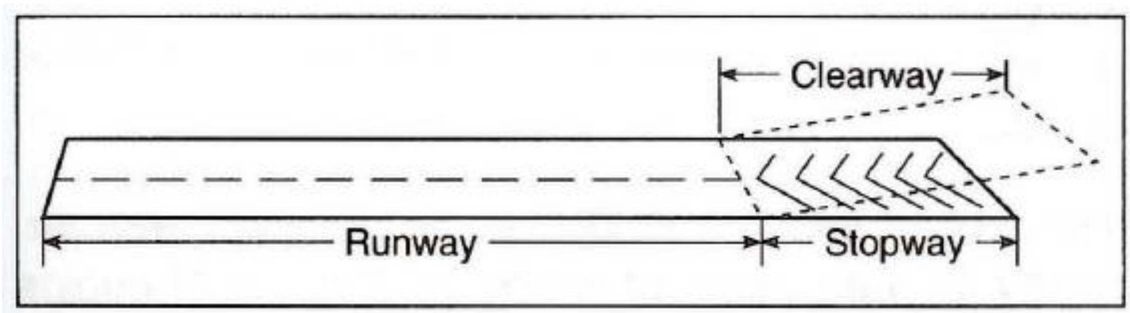
As the density altitude is increased, engine performance will decrease. When the air becomes less dense, there is not as much oxygen available for combustion and the potential thrust output is decreased accordingly. Density altitude is increased by increasing the pressure altitude or by increasing the ambient temperature. Relative humidity will also affect engine performance. Reciprocating engines in particular will experience a significant loss of BHP (Brake Horsepower). Turbine engines are not affected as much by high humidity and will experience very little loss of thrust.



Takeoff Performance Terminology

Clearway—a plane beyond the end of a runway which does not contain obstructions and can be considered when calculating takeoff performance of turbine-powered transport category airplanes. The first segment of the takeoff of a turbine-powered airplane is considered complete when it reaches a height of 35 feet above the runway and has achieved V2 speed. Clearway may be used for the climb to 35 feet.

Stopway—an area designated for use in decelerating an aborted takeoff. It cannot be used as a part of the takeoff distance but can be considered as part of the accelerate-stop distance. See Figure 4-2.



Regulation requires that a transport category airplane's takeoff weight be such that, if at any time during the takeoff run the critical engine fails, the airplane can either be stopped on the runway and stopway remaining, or that it can safely continue the takeoff. This means that a **maximum takeoff weight** must be computed for each takeoff. Factors which determine the maximum takeoff weight for an airplane include runway length, wind, flap position, runway braking action, pressure altitude and temperature.

In addition to the runway-limited takeoff weight, each takeoff requires a computation of a climb-limited takeoff weight that will guarantee acceptable climb performance after takeoff with an engine inoperative. The climb-limited takeoff weight is determined by flap position, pressure altitude and temperature.

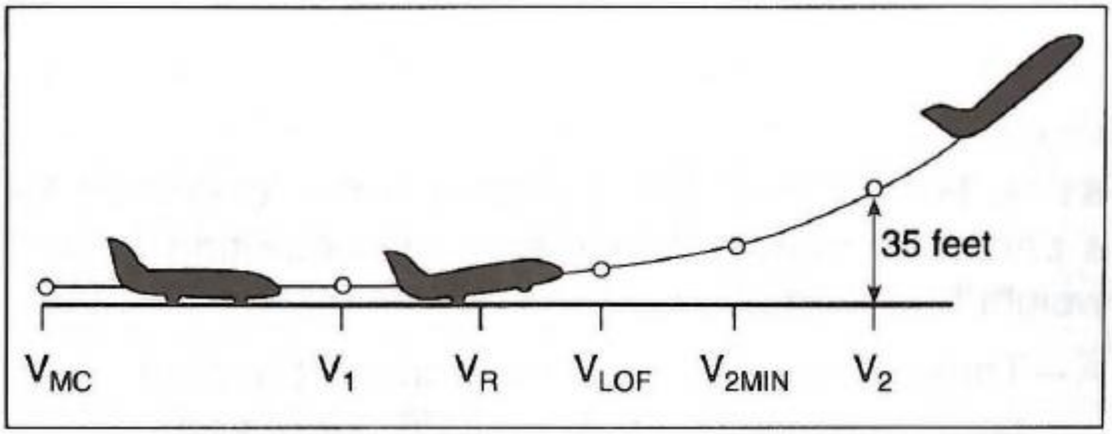
When the runway-limited and climb-limited takeoff weights are determined, they are compared to the maximum structural takeoff weight. The lowest of the three weights is the limit that must be observed for that takeoff. If the airplane's actual weight is at or below the lowest of the three limits, adequate takeoff performance is ensured. If the actual weight is above any of the limits a takeoff cannot be made until the weight is reduced or one or more limiting factors (runway, flap setting, etc.) is changed to raise the limiting weight.

After the maximum takeoff weight is computed and it is determined that the airplane's actual weight is within limits, then V_1, V_R and V_2 are computed. These takeoff speed limits are contained in performance charts and tables of the airplane flight manual, and are observed on the captain's airspeed indicator. By definition they are indicated airspeeds. See Figure 4-3.

V_1 (Takeoff Decision Speed) is the speed during the takeoff at which the airplane can experience a failure of the critical engine and the pilot can abort the takeoff and come to a full safe stop on the runway and stopway remaining, or the pilot can continue the takeoff safely. If an engine fails at a speed less than V_1, the pilot must abort; if the failure occurs at a speed above V_1 he/she must continue the takeoff.

V_R (Rotation Speed) is the IAS at which the aircraft is rotated to its takeoff attitude with or without an engine failure. V_R is at or just above V_1.

V_2 (Takeoff Safety Speed) ensures that the airplane can maintain an acceptable climb gradient with the critical engine inoperative.



V_{MU} (Minimum Unstick Speed) is the minimum speed at which the airplane may be flown off the runway without a tail strike. This speed is determined by manufacturer's tests and establishes minimum V_1 and V_R speeds. The flight crew does not normally compute the V_{MU} speed separately.

V_1 is computed using the actual airplane gross weight, flap setting, pressure altitude and temperature. Raising the pressure altitude, temperature or gross weight will all increase the computed V_1 speed. Lowering any of those variables will lower the V_1 speed.

A wind will change the takeoff distance. A headwind will decrease it and a tailwind will increase it. While a headwind or tailwind component does affect the runway limited takeoff weight, it usually has no direct effect on the computed V_1 speed. The performance tables for a few airplanes include a small correction to V_1 for very strong winds. For those airplanes, a headwind will increase V_1 and a tailwind will decrease it.

A runway slope has the same effect on takeoff performance as a wind. A runway which slopes uphill will increase the takeoff distance for an airplane and a downslope will decrease it. A significant slope may require an adjustment in the V_1 speed. An upslope will require an increase in V_1 and a downslope will require a decrease.

If there is slush on the runway or if the antiskid system is inoperative, the stopping performance of the airplane is degraded. This requires that any aborted takeoff be started at a lower speed and with more runway and stopway remaining. This means that both the runway-limited takeoff weight and the V_1 used for takeoff be lower than normal.

Calculating V-Speeds

The table in FAA Figure 82 is used in several problems to determine the pressure altitude from the indicated altitude and the local altimeter setting. The table uses the local altimeter setting to indicate the proper correction to field elevation. For example, assume the local altimeter setting is 29.36" Hg. Enter the table in the left-hand column labeled "QNH IN. HG." and then find the range of altimeter settings that contains 29.36" Hg. Read the correction to elevation in the center column. In this case, add 500 feet to the field elevation to determine the pressure altitude. If the altimeter setting is given in millibars, enter the table in the right-hand column.

CRJ200 V-Speeds

V_1, V_R, and V_2 are calculated by using the charts in FAA Figures 450, 452, and 454. In order to use these charts, you must first find a "Reference A" speed in FAA Figure 451. Once you have the Reference A speed, enter the chart in either Figure 452 or 454 at that speed and then move across directly right to determine the minimum V_{1MCA}.

From there, continuing to the right, intersect the aircraft weight line and proceed directly down, correcting for runway slope (if present), to note the V_R speed. If V_R is greater than 1.05 x V_{1MCA}, proceed to the right until entering the Chart B region; otherwise, use Chart A. Once intersecting the aircraft weight line in Chart A or B, move directly down and read the V_2 speed.

Q400 V-Speeds

V_1, V_R, and V_2 for the 0400 are calculated from the charts contained in FAA Figures 470, 471, and 472. Using operating conditions given either through airport diagrams or as part of the question, you must be able to calculate these important speeds.

Figure 470 is the chart used to determine V_1 and V_R. Start on this chart at the lower left with the OAT and move up to the field elevation. Move across to the right until intersecting the reference line. Then proceed diagonally until intersecting the aircraft weight line. From there, move across to the right and note the V_R speed. Continue to the right and intersect the reference line, then move down and to the left in parallel with the diagonal lines until intersecting the correct V_1/V_R ratio. Move directly right and find your V_1 speed. Note that V_1 cannot be less than V_R.

B-737 V-Speeds

Using Operating Conditions R-1 (FAA Figure 53), follow the steps for determining the V-speeds (See FAA Figure 55). Enter the table at the top left in the row appropriate for the pressure altitude and go across until in a column containing a temperature range which includes the given value. In this case, enter in the row labeled -1 to 1 (pressure altitude= 500 feet, refer to FAA Figure 54) and go to the first column which contains the temperature of +50°F (be sure to use the Fahrenheit or Celsius ranges as appropriate). Go down the first column until in the row appropriate for a flap setting of 15° and a gross weight of 90,000 pounds. The V_1 speed is 120 knots, the V_R speed is 121 knots and the V_2 speed is 128 knots. There are two possible adjustments to make to the V_1 speed only. They are noted at the bottom of the table.

DC-9 V-Speeds

The first step for calculating V_1 and V_R is to find the basic speeds in the table at the top of FAA Figure 47. Using the conditions from Operating Conditions A-1 from FAA Figure 45, the V-speeds for a weight of 75,000 pounds are: V_1 = 120.5, and V_R = 123.5 knots. Next, a series of corrections must be applied for pressure altitude, ambient temperature, runway slope, wind component, and engine and wing ice protection. There are table values for all these corrections at the bottom of FAA Figure 47 except for pressure altitude and ambient temperature.

The first step in the altitude correction is to use the table in FAA Figure 46 to determine the pressure altitude. Using the altimeter setting from Operating Conditions A-1 (29.40" Hg), the table shows a correction of +500 feet. The pressure altitude then is 3,000 feet (2,500 + 500).

Next, enter the graphs as shown in FAA Figure 47. Draw two vertical lines representing the pressure altitude of 3,000 feet. Next, draw a horizontal line through the ambient temperature (+10°F) to intersect each of the vertical lines. In this case, the lines meet in the "zero" correction area for both V_1 and V_R. Notice that the correction is marked by bands. For example, if the lines crossed anywhere in the highest shaded band, the correction would be +1 knot.

Next, set up a table similar to the one below to apply any necessary corrections:

	V_1	**V_R**
Table Value	120.5	123.5
Pressure Alt & Temp	0.0	0.0
Slope (+1%)	+ 1.5	+ 0.9
10HW	+ 0.3	0.0
Ice Protection	+ 0.8	+ 0.8
Corrected Speeds	123.1	125.2

Calculating Takeoff Power

CRJ200 Takeoff Thrust Settings

Calculating the appropriate thrust settings for the CAJ200 is accomplished by using FAA Figures 428 through 431. Pay special attention to the "Notes" at the bottom of each of these figures, as this tells how to determine the correct chart to use. For example, Figure 428 depicts thrust settings based on all engines operating with the bleed valves closed, which is a typical takeoff for the CAJ200. Enter the chart at the left at the correct temperature and move to the right until intersecting the correct pressure altitude. This will yield the correct N_1 power thrust setting to be used during takeoff.

Q400 Takeoff Power

The Q400 takeoff power settings are determined by the charts in FAA Figures 467 and 468. Figure 467 depicts the appropriate power settings while on the ground and Figure 468 is used in flight (during the climb). To determine the correct takeoff torque setting, use Figure 467. Start at the bottom of the chart at the OAT, then move directly up until intersecting the airport elevation. Move directly to the right to find the torque setting.

B-737 Takeoff EPR

The Takeoff EPR table at the top of FAA Figure 55 is similar to the B-727 takeoff EPR. In the table of FAA Figure 55, two EPR values are found: one for temperature and one for altitude (be sure to use the table in FAA Figure 54 to determine the pressure altitude). The lower of the two is the takeoff EPR. For example if the temperature is 50°F at a pressure altitude of 500 feet, the temperature-limited EPR is 2.04 and the altitude-limited EPA is 2.035. (The altitude-limited EPA is 2.01 from sea level up to 1,000 feet.) The only possible correction would be for if the air conditioning bleeds are off.

Climb Performance

The **best rate-of-climb** speed for any airplane is the speed at which there is the greatest difference between the power required for level flight and the power available from the engines. The L/D_{MAX} speed for any airplane is the one that requires the least power for level flight since it is the lowest drag speed. Because the power output of prop-driven airplanes is relatively constant at all speeds, L/D_{MAX} is the best rate-of-climb speed for them.

Turbojet engines produce more power as the aircraft speed increases. Even though drag increases at speeds above L/D_{MAX}, the engine's power output increases even more so that the maximum difference between power required and power available is achieved at a higher airspeed. For a turbojet, the best rate-of-climb speed is faster than L/D_{MAX}.

CRJ200 Performance Tables

FAA Figures 432 through 454 contain the information needed to correctly calculate takeoff performance data, including V-speeds, takeoff weights, and climb performance. It is very important to note that these tables are divided into two categories based upon flap setting used on takeoff. Note the boxed "Flaps 8" or "Flaps 20" usually found in the lower right-hand side of the figure in order to choose the correct chart.

Q400 Performance Tables

FAA Figures 475 and 476 contain the data needed to calculate first- and second-segment climb performance. This is done with one engine operating and is part of the performance pre-planning conducted prior to each flight. Note that you will start with the OAT on the bottom of the chart and move up. Most of the time you do not need to worry about the ISA lines—simply intersect the appropriate pressure altitude. Move right to the "Reference Line," follow the diagonal lines to the aircraft weight, and then move across to the right to find your climb gradient.

Q400 Climb and Cruise Power Tables

The 0400 figures include FAA Figures 481 (radius of turn), and Figure 482 (maximum-climb ceiling chart). The radius of turn depicts the radius in feet that will be flown given a 15-degree steady-state turn. This can be helpful when calculating distance needed to maneuver during single-engine operations. The enroute climb ceiling chart (Figure 482) uses two parameters—aircraft weight and temperature—to determine the maximum ceiling during single-engine operations.

B-737 Climb Performance Tables

The tables in FAA Figures 57 and 58 allow you to determine the time and fuel required for a climb to cruising altitude after takeoff. The table in FAA Figure 57 is for ISA temperatures, and the table in FAA Figure 58 is for ISA +10°C. Each intersection of Brake Release Weight and Cruise Altitude has a box with four numbers. These are the time, the fuel, the distance and the TAS required to climb from a sea level airport to cruise altitude in calm wind conditions. For example, with a brake release weight of 110,000 pounds, a climb to 33,000 feet in ISA + 10°C conditions will require 26 minutes, 4,100 pounds of fuel and cover a distance of 154 NM.

A headwind or tailwind component in the climb will change the distance flown. Assume that there is an average 20-knot headwind in the climb described above. The first step is to compute the average "no wind" GS. A distance of 154 NM flown in 26 minutes works out to a GS of 355.4 knots.

A headwind component of 20 knots will reduce this GS to 335.4 knots. The distance flown in 26 minutes at 335.4 knots is 145.3 NM.

Note: Using a CX-2 computer, select "Dist Flown" from the menu and enter TIME and GS. Do not use the TAS from the table as that will result in an inaccurate answer.

Departure from an airport that is significantly above sea level will reduce the fuel required for the climb. Notice that departure from a 2,000-foot airport will reduce the climb fuel by 100 pounds, however the effect on time and distance flown is negligible.

B-737 Climb and Cruise Power Tables

The Max Climb & Max Continuous EPR Table at the top of FAA Figure 60 is similar to the one discussed in Takeoff EPR. In this table two EPR values are found-one for temperature and one for altitude. The lower of the two is the maximum climb/continuous EPR. For example, if the temperature is +10°C at a pressure altitude of 10,000 feet, the temperature-limited EPR is 2.04 and the altitude-limited EPR is 2.30. (The altitude-limited EPR is 2.30 from 5,660 feet and up.) The max EPR is 2.04.

The Max Cruise EPR Table supplies one EPR value for a given TAT (Total Air Temperature) in one of two altitude ranges. The correction tables are similar to ones used previously and apply to both tables.

Cruise Performance

The maximum range speed for an aircraft is determined by its L/D curve. Propeller-driven airplanes will achieve best range performance if they are flown at the speed that yields L/D_{MAX}. In turbojet aircraft, a somewhat more complex relationship between lift and drag determines best range. Turbojets always have a best range speed higher than L/D_{MAX}.

A headwind or tailwind will affect the miles per unit of fuel burned. If an airplane is operating at its best-range airspeed and encounters a headwind, it should speed up to minimize the time in the adverse wind. By the same token, an airplane with a tailwind can slow down and let the wind maintain its ground speed with a lower fuel flow. The exact amount of airspeed change that is useful varies with airplane type.

Turbojet engines have a strong preference for operations at high altitudes and airspeeds. Both lower temperatures and higher altitudes increase engine efficiency by requiring a lower fuel flow for a given thrust. Besides increased engine efficiency, lift and drag both decrease at higher altitudes, so less thrust is required.

Turbine engines are much more efficient when operated at the upper end of their RPM range. Generally, the optimum cruise altitude for a turbojet airplane is the highest at which it is possible to maintain the optimum aerodynamic conditions (best angle of attack) at maximum continuous power. The optimum altitude is determined mainly by the aircraft's gross weight at the beginning of cruise.

As an aircraft burns fuel and becomes lighter, the optimum cruise altitude slowly increases and the speed that yields the optimum cruise performance slowly decreases. Since it is seldom practical to change speed and altitude constantly, it is common procedure to maintain a constant Mach cruise at a flight level close to optimum. As fuel is burned, thrust is reduced to maintain the constant Mach number.

Landing Considerations

V_S—stalling speed or the minimum steady flight speed at which the airplane is controllable.
V_{S0}—stalling speed or the minimum steady flight speed in the landing configuration.
V_{REF}—reference speed. It is normally 1.3 x V_{S0}.

Even with all the aircraft's high lift devices extended, a typical air carrier airplane has a high approach speed and a long landing roll. An airplane is normally flown at 1.3 times the V_{S0} speed for the aircraft's weight. Of course, 1.3 times V_{S0} is an indicated airspeed and the ground speed will vary depending on wind, altitude and temperature. A high temperature or high altitude approach will increase an aircraft's ground speed for any given approach speed.

Once an airplane has touched down on a runway there are 3 ways of slowing it to a stop: aerodynamic braking, use of the wheel brakes, and reverse thrust.

The typical technique for stopping an aircraft on a normal landing is to apply reverse thrust (or prop reverse) once the nosewheel is on the ground. This takes maximum advantage of reverse thrust when it is most effective and it saves wear on the wheel brakes, which heat up very rapidly at high ground speeds. Shortly after touchdown, the spoilers are deployed. This reduces lift and increases drag. As the aircraft slows, the main wheel brakes are applied to bring it down to taxiing speed. The brakes are most effective when lift has been reduced (by spoilers and low airspeed) and more of the aircraft's weight is carried by the landing gear.

Water on a runway will increase the landing rollout because the reduced coefficient of friction makes the wheel brakes less effective. This is particularly true at high ground speeds.

A very dangerous possibility when landing on a wet runway is **hydroplaning**. When hydroplaning occurs, the wheel brakes are almost totally ineffective. This not only greatly increases the landing rollout, but also introduces the possibility of losing directional control on sliding off the side of the runway. There are three types of hydroplaning:

Dynamic hydroplaning occurs when a tire rolls through standing water, forms a bow wave, and then rolls up on top of the wave, losing all contact with the runway. The minimum speed at which dynamic hydroplaning can start is related to tire pressure. As a rule of thumb, dynamic hydroplaning will start at speeds of greater than nine times the square root of the tire pressure in pounds per square inch. The practical application is that your nose wheel can hydroplane at a lower speed than the mains because of its lower pressure. Once dynamic hydroplaning has started, it can continue to much lower speeds.

Viscous hydroplaning occurs when there is a thin film of water covering a smooth surface such as a painted or rubber-coated portion of the runway. Viscous hydroplaning can occur at much lower speeds than dynamic hydroplaning.

Reverted rubber hydroplaning occurs during a locked wheel skid. Water trapped between the tire and the runway is heated by friction, and the tire rides along a pocket of steam.

When landing on a water-covered runway, fly the approach as close to "on speed" as possible. Landing at a higher than recommended speed will greatly increase the potential for hydroplaning. After touchdown, use aerodynamic braking and reverse thrust to maximum possible extent, saving the use of wheel brakes until the speed is low enough to minimize the possibility of hydroplaning.

Regulations (14 CFR §121.195) require that when a turbojet aircraft is dispatched to an airport where the runways are forecast to be wet or slippery, the effective length of the landing runway must be 115% of what is required under dry conditions. Since runways cannot be lengthened, the effect of this rule is to lower the maximum allowable landing weight of aircraft on wet runways for dispatch purposes.

Landing Performance Tables and Graphs

FAA Figures 457 and 458 are examples of landing performance charts. These are used to calculate both the appropriate landing reference speeds and landing distances. As in most performance charts, OAT, pressure altitude, wind and runway slope are the determining factors for calculating speeds and distances used. As a general rule, always move to the next reference line on the chart, before making any adjustments.

Miscellaneous Performance

V_C—design cruising speed.
V_{MO}/M_{MO}—maximum operating limit speed.

An encounter with strong turbulence can result in structural damage to an aircraft, or inadvertent stall. The sudden changes in wind direction and speed can result in very rapid changes in an aircraft's angle of attack. A sudden increase in angle of attack will cause the airplane to accelerate upward, increasing both the load factor and the stalling speed.

For any combination of weight and altitude there will be a recommended "rough air" speed that provides the best protection from stalls and from the possibility of overstressing the aircraft. When clear air turbulence has been reported in the area, a pilot should slow to the rough air speed upon encountering the first ripple of turbulence.

In severe turbulence, it may be impossible to maintain a constant airspeed or altitude. If this happens, the pilot should set the power to that which would maintain the desired airspeed and maintain a level flight attitude, accepting large variations in airspeed and altitude.

Engine-Out Procedures

V_{MC}—minimum control speed with the critical engine inoperative.
V_{XSE}—best single engine angle-of-climb speed.
V_{YSE}—best single engine rate-of-climb speed.

When an engine fails in flight, the effect on aircraft performance is drastic. For example, the loss of one engine on a two-engine aircraft will result in a loss of climb performance in excess of 50%. Climb performance is determined by the amount of power available in excess of that required for level flight. The one remaining engine must provide all of the power required for level flight. It may be able to develop little or no excess power that would allow for a climb.

When an engine fails in cruise flight, the pilot should slow the aircraft to its best single-engine rate-of-climb speed (V_{YSE}) and apply maximum continuous power on the remaining engine. The airplane may or may not be able to climb. If it cannot climb at the present altitude, at least it will descend at the minimum possible rate of sink and level off at its maximum engine-out altitude. It may be necessary to dump fuel to improve the altitude capability of the aircraft.

A multi-engine airplane should never be flown below its minimum control speed (V_{MC}). If it is below V_{MC} and an engine failure occurs, it may be impossible to maintain directional control with the other engine operating at full power. V_{MC} will vary with the aircraft's center of gravity location. V_{MC} will be highest with the CG at its most rearward-allowed position.

A three- or four-engine turbine-powered airplane, used by an air carrier, may be ferried to a maintenance base with one engine inoperative if certain requirements are met. These requirements include:

- The airplane model must have been test flown to show that such an operation is safe.
- The operator's approved flight manual must contain performance data for such an operation.
- The operating weight of the aircraft must be limited to the minimum required for flight plus any required reserve fuel.
- Takeoffs are usually limited to dry runways.
- The computed takeoff performance must be within acceptable limits (this will vary depending on the type of aircraft).
- The initial climb cannot be over thickly-populated areas.
- Only required flight crewmembers may be on the aircraft.
- Weather conditions at the takeoff and destination airports must be VFR.

Cessna 208 Performance Tables

The Cessna 208 performance tables start with FAA Figure 392 and continue through Figure 403. With Cessna charts, be sure to always read closely the "Notes" associated with a particular chart. A good example of why it's important to read the Notes is shown in the "Engine torque on takeoff" charts in Figures 392 and 393. The inertial separator is set to "Normal" for the chart readings, but when it is placed in bypass, adjustments need to be made. For example, in Figure 392, if you calculate a maximum torque setting of 1,750, you will have to decrease the torque setting by 15 (see Note 3).

The takeoff and landing distance charts (FAA Figures 395 and 402) are tabular charts that often require interpolation to obtain accurate results. For example, a landing ground-roll distance is needed (Figure 402) for a sea level airport at 20°C. Examining the chart, this distance is 930 feet. But it gets more complicated if the pressure altitude is 1,000 feet. In this case, the value would be halfway between the sea level value of 930 and the 2,000-foot value of 1,000-or, 965 feet (930 + 1,000 = 1,930 ÷ 2 = 965).

Sometimes the interpolation requires a calculation beyond the simple "halfway-in-between" two published values. There are a few techniques available for solving these problems but the basic idea is to set up a ratio. Let's say the pressure altitude in the above example is a field elevation of 683 feet. We know from the chart that between sea level and 2,000 feet (a difference of 2,000), the ground roll increased 70 feet. That makes a ratio of 70/2000, or, for every 2,000 feet, the ground roll increases by 70 feet. (Note that this relationship only works at this altitude, and will change at the higher altitudes.)

In the example, calculate how many feet the ground roll increases when the pressure altitude increases 683 feet. To do this, we cross-multiply: just multiply 683 by 70, and divide by 2,000. This yields 24 feet. Therefore, add 24 to the 930 sea level value, and calculate a ground roll of 954 feet at a pressure altitude of 683 feet. Interpolation can also work between temperature settings.

Again—don't forget to read the Notes in these chart figures; sometimes they can be found on a further page as in FAA Figure 401.

Flight Planning Graphs and Tables

Aircraft manufacturers publish flight planning graphs or tables that enable flight crews to quickly estimate the time and fuel required to fly certain trips. These tables or graphs allow adjustments for aircraft weight, wind, altitude, cruise speed, and other variables.

FAA Figure 399 represents a performance chart that is often used for performance questions on the Cessna 208: the "time, fuel and distance to climb" chart. This chart is fairly easy to use in that you simply find your weight, and the altitude you are climbing to. Just make sure to subtract your departure elevation altitude. For example, if you were departing from a field elevation of 4,000 feet and climbing to a cruise altitude of 16,000 feet, you would first calculate everything at the 16,000-foot level and then subtract the 4,000-foot field elevation.

In this example, at 8,750 pounds and standard temperature, you would expect to spend 23 minutes in the climb; however, subtract the 4,000-foot time of 5 minutes, which yields a time-to-climb of 18 minutes.

Typical Flight Logs

Flight logs are used to accurately plan the time and fuel required for a flight. In the following paragraphs we describe all the steps required to complete a flight log.

1. Determine the magnetic courses for each leg and determine the leg distances.
2. Apply variations to the winds aloft.
3. Determine the temperature in relation to ISA.
4. Determine Mach number and convert to TAS.
5. Compute ground speed.
6. Calculate and record the time for each leg.
7. Compute fuel flow.
8. Compute total fuel.
9. Determine the reserve fuel.
10. Compute fuel burn to alternate.
11. Add the en route, reserve, and alternate fuel to find the total fuel required for the flight.

Computation of Temperature at Cruise Altitude

Temperature is often expressed as a deviation from ISA which is the standard day temperature (i.e., ISA -2°). This temperature can be computed by the following procedure:

1. Compute ISA by multiplying the altitude in thousands of feet times -2° and then adding 15°. For example: ISA at 27,000 feet= 27 x (-2°) +15 = -39°

2. Apply the deviation from ISA. ISA -2° at 27,000 feet= (-39°) + (-2°) = -41°

Computation of True Airspeed Using Mach Number

True Airspeed (TAS) can be computed from Mach number and Outside Air Temperature (OAT).

Using the CX-2 computer, select "Plan Mach#" from the menu, then enter the OAT and the Mach number at the appropriate prompts.

Using an E6-B computer, follow these steps:

1. In the small window labeled "Airspeed Correction" or "True Airspeed," align the arrow labeled "Mach Number" with the OAT on the scale adjacent the window.

2. Find the Mach number on the inner of the two main scales and then read the TAS opposite it on the outer scale.

Note: Some "CR"-type mechanical computers have a window in which a Mach Index is aligned with a Mach number inside the window. Don't use this scale. It is designed to use Indicated Temperature and will give an inaccurate TAS when OAT is used.

See the instruction manual of your individual computer for more detailed instructions.

Specific Range

Specific range is the term used to describe the rate of fuel burn per nautical air mile flown. It is calculated by using TAS and fuel flow only. Wind has no effect on specific range. To calculate specific range in nautical air miles per 1,000 pounds, use the formula:

NM/1,000 = TAS x 1,000 ÷ PPH.

TAS should be calculated from the Mach number as in the paragraph above. PPH can be taken directly from the flight log.