



Fuel Management



CIVIL AVIATION AUTHORITY
OF NEW ZEALAND

Fuel Management

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CAA Web Site

See the CAA web site for Civil Aviation Rules, Advisory Circulars, Airworthiness Directives, forms, and more safety publications.



Fuel starvation and fuel exhaustion accidents and incidents continue to occur in New Zealand. The reasons for many of these preventable occurrences often relate to pilots' poor aircraft fuel system knowledge, lack of pre-flight planning, inadequate pre-flight checks, failure to accurately monitor in-flight fuel consumption, and inability to take decisive action when faced with a low-fuel state. This booklet examines these factors and others, and contains practical advice intended to make you more proficient at fuel management.

Fuel Identification and Handling

Ensuring that you have the correct amount and grade of contaminant-free fuel on board before getting airborne is an important aspect of fuel management. This section of the booklet covers the basics of fuel and gives advice on how to refuel your aircraft safely. Refuelling from drums, dealing with a fuel spill, and defuelling are also covered.

Fuel Characteristics

Fuel Types

Aircraft fuels come in two basic types: gasoline and kerosene. Aviation gasoline is known as 'avgas'; motor gasoline as 'mogas'; and the kerosene-type fuel is known as 'Jet A-1' commercially and 'avtur' in military use. Commonly, piston-engine aircraft run on avgas, and turbine-engine (turboshaft, turboprop and jet) aircraft run on Jet A-1. Many sport and private aircraft run on mogas. There are also aircraft diesel (or 'compression-ignition') piston engines that run on Jet A-1.

Octane Rating

Gasoline-type fuels are rated by octane number, which is a measure of their resistance to detonation ('knocking' or 'pinking'). The higher the octane rating, the more resistant the fuel is to detonation. A high octane rating does not imply that the fuel is any more 'powerful', just that



it is better suited to the more demanding conditions of high-compression-ratio, supercharged engines.

The octane numbers of avgas and mogas are not directly equivalent. They are obtained by different test methods, and one rule of thumb is to subtract 8 from a mogas rating to give the equivalent rating in an aero engine. Avgas contains tetra-ethyl lead (up to 0.89 grams per litre) to obtain the necessary octane rating, but both grades of mogas are unleaded. Using leaded fuel in an engine designed for unleaded fuel can cause damage.

The only grade of avgas currently available in New Zealand is 100/130 – note the dual rating, which indicates the fuel's performance under both lean and rich mixture test conditions respectively.

Volatility

Not to be confused with flammability, volatility relates to a liquid's boiling point, and hence its tendency to evaporate at normal ambient temperatures. Mogas is highly volatile, avgas slightly less so, and Jet A-1 much less so. Placing a drop of each of these fuels (and one of water) on a non-porous surface will demonstrate the difference.

Volatility is a desirable property of the gasoline fuels, as in a carburetted engine the fuel must evaporate to form the combustible fuel-air mixture. In a fuel-injected engine, evaporation of the fuel is greatly assisted by the atomising effect of the injector nozzles.

Mogas and avgas evaporate readily at what we refer to as 'room temperature' and form vapours more than three times as heavy as air – these can flow long distances, can pool in low-lying areas, and flow down drains.

Flammability

This is the term for a fuel's readiness to burn, which is an obviously desirable quality. The only place where you want fuel burning, however, is in the combustion chambers of your engine. Flammability is a hazardous property that must be managed when handling any fuel.

Use the Correct Fuel

Occasionally, aircraft are refuelled with the incorrect grade of fuel. Ideally, the error is detected before the aircraft takes off, but this is not always the case.

If an avgas-powered aircraft is refuelled with Jet A-1, there can be enough avgas remaining in the aircraft's fuel lines and carburettors to enable the aircraft to taxi and take off. When the jet fuel reaches the engine, it will probably cause the engine to fail. The anti-knock properties of Jet A-1 are very poor, and the resulting detonation can destroy an engine in a very short time.

On the other hand, a turbine engine will run quite normally on avgas, although its higher volatility could give rise to vapour lock problems at altitude. Engine manufacturers normally specify a time limit (typically 150 hours) in each overhaul period for avgas use, and aircraft manufacturers may specify procedures and limitations for when avgas is being used. Examples are the Beechcraft 1900, limited to 18,000 feet altitude; and the Hughes 369HS, start pump to be ON until the engine is shut down.

Pilots need to know the different fuel grades to prevent refuelling errors.

Fuel companies can provide fuel identification labels to place next to the fuel tank cap. Also, most Jet A-1 fuel nozzles have a flat, wide spout, whereas an avgas pump nozzle is round and narrower, so that if the aircraft fuel port is of a corresponding design, misfuelling is prevented. Not all aircraft (especially older models) have



Fuel Grade	Colour	Usage	Comments
Mogas 91	Purple/bronze	Some microlight, homebuilt, and vintage aircraft	More volatile than avgas, is not subject to the same degree of quality control and is prone to fuel line vapour lock. Can cause detonation if used in modern high-compression engines.
Mogas 95	Yellow/orange	Some microlight, homebuilt, and vintage aircraft	
Avgas 100/130	Green	Most light piston-engine aircraft	Can cause spark plug fouling and valve seat damage if used in older low-compression engines.
Jet A-1 (Kerosene)	Straw-coloured or clear	Turbine and jet-engine aircraft	Has a distinctive kerosene smell and will quickly ruin piston engines designed for avgas use.

appropriately sized fuel ports, and at least one fuel company does not use the wide spout on all their Jet A-1 pumps.

It is essential to confirm that the fuel identification on the pump being used matches the appropriate label by the fuel tank opening.

Hazards

Fire or Explosion Risk

During fuelling operations, air and fuel vapour are displaced from the aircraft fuel tanks. This potentially explosive mixture is expelled via tank vents and the fill point.

Combining fuel vapour and air (oxygen) forms an explosive mixture comparable to an equivalent mass of dynamite. A fuel explosion can be quite capable of

destroying a hangar or killing somebody.

An explosive fuel-air mixture can be formed by splashing a volatile fuel in an open container, as in washing oily components, or by pouring fuel from a sample bucket into another open container.

All it takes to initiate a fuel explosion is just a small spark or a hot surface, and not necessarily in the immediate vicinity, given the ability of fuel vapour to flow long distances.

In the event of a fire, extinguish using dry powder, foam or carbon dioxide extinguishers, or a water fog. Do not use a water jet, as this will spread the burning liquid and may make matters worse. Fires in confined spaces should be dealt with by trained personnel wearing breathing apparatus. Ensure an escape path is always available from any fire. For any fires, call **111** immediately.

Static Electricity

Commonly referred to as ‘static’, this is a major potential ignition source. The risk is **always** present, and must be managed, even in seemingly innocuous situations. The considerations apply equally to gasoline fuels and Jet A-1.

Static can be generated by the flow of fuel from the supply to the aircraft, and by the wearing of synthetic clothing (high-visibility vests can be a hazard here). The electrical charge can build up on an aircraft, a supply installation, or a human body, and when two unequally-charged objects are brought close enough together, the charge will equalise by means of a spark. Static spark voltage can be of the order of thousands of volts.

Combine this with the presence of fuel vapour of sufficient concentration, and an explosion will result.

Minimising Static Hazards

The most important thing to do before refuelling is to correctly bond the pump to the aircraft. When refuelling from drums, always ensure there is a bonding lead connected to both the aircraft and the drum in use. Make the necessary connections before removing **any** fuel caps. Additionally, it is safe practice to keep the fuelling nozzle in physical contact with the filler hole at any time fuel is being pumped.

This also applies to the filling of portable containers – place the container on the ground, and maintain contact between

the fuel nozzle and the container.

Containers complying with Australian/New Zealand Standard 2906:2001 have this instruction on the label.

Filtering fuel through chamois leather is not recommended. Studies have found that the use of a chamois can be a static hazard, synthetic chamois even more so.

A drum pump should be fitted with an appropriate in-line filter, and the delivery hose must be fuel-specific. Your fuel supplier will be able to advise on the correct equipment.

Contamination

Contaminants (especially water) in the fuel have been known to cause engine failures in New Zealand – usually just after the aircraft has become airborne. To minimise the risks of this happening, a fuel drain should always be carried out before the first flight of the day – and after refuelling. The following considerations apply to taking a fuel sample:

- After refuelling, allow the fuel to settle for as long as possible (a minimum of 15 minutes per 30 cm depth of fuel for avgas, and 60 minutes per 30 cm for Jet A-1 are recommended) before taking a sample. This gives any impurities a chance to settle into the drain sump of each tank. At an intermediate stop, it is a good idea to refuel the aircraft first, before attending to other business – this will normally allow enough time for any water in suspension to settle out.
- Know how many drain points your aircraft has. Some aircraft have belly

or cross-feed selector drain points. Know where these are and drain them daily. Other aircraft have long fuel lines meaning that contaminants can take some time to reach the drain point. Know what the recommended sample sizes are. Refer to the aircraft Flight Manual for details.

- Confirm that each spring-loaded drain valve shuts securely afterwards, as any leaks will result in higher than normal in-flight fuel consumption and could even lead to an engine failure due to fuel exhaustion. Take care with remotely-operated fuel drains, ensuring that they close properly after operation. Where possible, have a second person catch the sample if your arms are not long enough to operate the drain and hold the drain vessel in position at the same time.
- Ensure that the drain vessel is clean before taking a sample. Hold the sample to the light and inspect it for water (normally indicated by small globules sitting on the bottom, or a 'cloudy' appearance) and sediment. Check that it is the correct colour and smell for the intended grade of fuel – this will also confirm that you have not just drained a sample of pure water (it has been done).
- If the sample tests positive for water or other contaminants, empty the vessel and continue draining until a clean sample is obtained. Be sure to empty the sample into a fuel disposal container, not on the tarmac, as it can degrade bitumen surfaces. Do not tip the sample back into the aircraft tank, even if it is clean.



Water



Avgas



Mix of avgas and water

- Water often collects in wrinkles and low points within fuel bladders. Lateral shaking of the aircraft wing will help to work any trapped water down to the fuel drain sumps. Allow the fuel time to settle after doing this before taking a fuel sample. Repeat the process until a clean sample is obtained. Also, in cold winter conditions, small amounts of water can freeze the drain plug, rendering it inoperative. It will need to be warmed to drain any water that is present, for example, by moving your aircraft into the hangar.
- Consult an aircraft engineer if there are unusually large quantities of water present in the fuel.

The integrity of the fuel tank vents should be checked during the pre-flight inspection. A blocked or deformed vent – and there have been cases of insects building nests inside fuel vents – will mean that the engine-driven fuel pump has to work very hard because the fuel tanks are unable to equalise with the atmosphere. This could eventually result in a collapsed fuel tank and possibly engine failure.

First Aid

Fuels are toxic when inhaled in vapour form, or when ingested or absorbed in liquid form. Any inadvertent contact with fuel should be dealt with immediately.

Eyes – Contact with the eyes causes irritation. Flush eyes with copious amounts of water, ensuring that the eyelids are held open. Seek medical advice.

Skin Contact – Contact with the skin causes irritation. Wash skin thoroughly with soap and water. Remove contaminated clothing, but wet it beforehand to minimise the risk of a static spark igniting the fuel.

Ingestion – Because of its low viscosity, this material can directly enter the lungs if swallowed or if subsequently vomited. Once in the lungs, it is very difficult to remove and can cause severe injury or death. If fuel is swallowed, do not induce vomiting. Give the person a glass of water or milk to drink and seek immediate medical attention.

Inhalation – The vapour or fumes may cause respiratory irritation resulting in coughing and difficulty with breathing. High concentrations of vapour can cause nausea, dizziness, headaches and drowsiness. Move the exposed person to fresh air. If breathing is difficult, administer oxygen. If breathing stops, resuscitation will be necessary. Get medical attention if breathing difficulties persist.

Fuelling Procedures

There are safety precautions to take when refuelling. We should also remember the airmanship and courtesy aspects.

After refuelling, move your aircraft away from the pump before heading off for a cup of tea or comfort stop. Leave the area by the pump clear for other aircraft.

Be aware of the effect of your prop blast when you start up – if necessary move the aircraft away by hand to a more suitable area for starting.



Refuelling Safety

To minimise the risks of fire or explosion, there are a number of precautions that should be observed when fuelling an aircraft. The same precautions should be taken regardless of whether the fuel is avgas, mogas, or Jet A-1.

General

- Refuelling should not be carried out in a hangar.
- Fuelling should not be carried out during electrical storms.
- Ensure that all aircraft electrical sources are switched off.
- Check that the type of fuel is correct for the aircraft **before** starting delivery.
- Ensure there is no-one smoking or using a naked flame within 15 metres of the aircraft and no cellphones, radios, pagers or other portable electronic devices within six metres (unless they have been certified for use in fuelling areas).
- Position the aircraft so that it can be pushed clear of buildings or other aircraft if a fuel spill occurs. Helicopters should preferably be refuelled on their trolleys for the same reason.
- There must be nobody on board the aircraft when it is being refuelled (or defuelled) with avgas.
- Fuelling with avgas must not be carried out with engine(s) running (hot refuelling).

- Take extreme care if hot refuelling with Jet A-1.
- There should be a fire extinguisher available nearby. Make sure you know where it is, and also where to find the emergency cut-off switch for the fuel pump.
- Check that the fuel pump nozzle is clean and take care not to let water or dirt enter the tank filler neck.
- Support the nozzle while refuelling to avoid damage to the aircraft skin around the filler port.
- Secure the caps firmly when refuelling is complete.
- Ensure that the pump motor has shut off after the fuel nozzle is replaced.

Bonding

During fuelling, the prevention of fire risk due to static electricity discharge is dependent upon effective bonding between the aircraft and the fuel supply source. **It must not be ignored.**

- All bonding connections between ground equipment and the aircraft should be completed before tank filler caps are removed, and they should be maintained until the filler caps have been replaced.
- Ensure that the static bonding cable from the fuel dispenser is securely attached to the aircraft on a clean unpainted metal surface that will conduct current easily. The clip must make metal-to-metal contact with the aircraft structure.

- Equalise electrical potential by touching the nozzle to the metal wing surface or fuel cap **before** opening the cap. Keep the nozzle in contact with the side of the filler neck while refuelling. To avoid scratching the paint on the wing, use a mat, or take care to hold the nozzle clear and not rest it on the wing.



Fuel Spills

Fuel spills present a potentially serious fire hazard, as well as an environmental pollutant, and should be dealt with immediately. While each spill has to be treated individually – depending on many variables such as volume of fuel, type of surface and wind direction – the following actions should, at the very least, be taken:

- Stop the fuel flow immediately.
- Eliminate all sources of ignition in the vicinity of the spill or released vapour.
- Move all persons, and the aircraft, away from the spillage area.
- Smaller spills should be soaked up using non-combustible absorbent material (eg, sand, dry earth) while someone stands by with a dry powder or foam extinguisher in case a fire does break out. Be sure to dispose of the contaminated material in a safe place afterwards. Fuel companies supply response kits containing special absorbent pads and socks (long and sausage-like) plus protective gloves and a disposal bag. Very small spills can be left to evaporate or soak away.



- If the spill is larger than two metres in diameter the aerodrome fire service should be called. If the aerodrome does not have a fire service in attendance, call the local fire service instead – they will know what to do.

Refuelling from Drums

Care must be taken to correctly identify the type and quality (fuel does go stale) of the fuel before refuelling from drums. Ensure that the pump is fitted with a clean and serviceable filter (one that will filter particulate matter, as well as absorbing water) – rust, water and dirt can all be a problem when fuel is stored in drums.

Note: a chamois cloth, once traditionally used as a filter, should not be used, as it can be a potential source of static charge.

Fuel drums should be stored on their side with bungs and vents at three o'clock and nine o'clock positions. Make sure that the top of the drum (with the openings) is lower than the bottom. This will minimise 'breathing' (air and moisture exchange from outside). A partly filled drum is more likely to contain moisture because of increased 'breathing'.



When opening a drum:

- Stand the drum on end, but tilted slightly, and chock it with the high side positioned at 12 o'clock, the bung at three o'clock, and the vent at nine o'clock. This prevents water or dirty fuel from reaching the openings.
- Ensure that the standpipe cannot reach the lowest point in the drum. Thus, any small amount of water or dirt will remain in the drum. You should not need the last few litres badly enough to risk using it.



Proper bonding is critical. Connect the bonding lead from the drum to the aircraft before opening any fuel caps, and leave it in place until all fuel caps have been replaced.

Jerrycans

Use only jerrycans specifically manufactured as fuel containers. If you are able to obtain the traditional metal jerrycans, these are preferable to the plastic versions on the market. Plastic jerrycans intended for use with fuels will have been manufactured to a recognised standard; in New Zealand, this is Australian/New Zealand Standard 2906:2001, and this is embossed permanently on the side of the container.

Do not use plastic containers not designed for fuel, as they can pose several hazards, and some areas in which they may be deficient are:

- Tendency to accumulate static charge.



A plastic jerrycan that meets AS/NZS 2906. Various labels and warnings are moulded into the container during manufacture, and the white label details safety precautions and first aid procedures.



Look for evidence that the item was manufactured to a recognised standard.

- Fuel could degrade the container material.
- Inadequate structural strength and impact resistance.
- Lack of proper warning label and other required markings.
- Insufficient resistance to ultraviolet radiation and heat.
- Cap gaskets inadequately retained.

In particular, the cap gaskets have been identified as an actual hazard.

The Standard requires that these be physically restrained in the cap by a retaining ring, or other means of preventing accidental loss. Obviously, the gasket should also be fuel resistant.

Apart from simply falling out of the cap and preventing proper sealing, two ways in which the gasket can be hazardous are:

- Embrittlement and subsequent disintegration. The fragments can then be tipped into the aircraft fuel tank along with the fuel, and, over time, can either clog the tank outlet or the fuel system filter(s).
- Turning to 'mush' (possibly more likely in jet fuel), also resulting in filter clogging.

Transport

The transport of fuels is subject to several different sets of legislation, depending on the mode of transport. Fuels are **Dangerous Goods**, or Hazardous Substances, according to whichever laws apply, but if you need to transport

quantities of fuel in containers other than a dedicated and licensed tanker, you need to be aware of the relevant legal requirements.

Defuelling

Occasionally, weight-and-balance limitations mean that the aircraft has too much fuel on board and has to be defuelled. This may occur, for example, if the previous pilot left the tanks fairly full and you wish to load the aircraft up with passengers and baggage. If a larger and more suitable aircraft is not available, your only option may be to defuel.



The same precautions outlined for refuelling are applicable. You are dealing with a hazardous substance.

There are two ways to carry out the defuelling:

- By pumping the excess fuel into an approved fuel container with a suitable hand-operated pump. Take care that the suction end is clean before inserting it into the aircraft's tank.
- Via a fuel drain point. Hold a funnel (metal, not plastic) with a suitable length of hose attached under the tank drain point (or the 'gascolator'), remove the fuel tank cap, open the drain point, and let the fuel flow into an appropriate container. This method is normally only suitable for aircraft on which the fuel drain points can be locked open.

Fuel tanks should not be left to drain unattended, because of the risk of spillage, nor should the decanted fuel be used again in another aircraft – it may be contaminated. Fuel should **not** be siphoned, as sucking on the end of the hose to start the flow could mean ending up with a mouthful of toxic fuel.



Flight Fuel Management

This section of the booklet aims to improve pilots' overall fuel management knowledge and proficiency in order to reduce the number of fuel-related accidents and incidents. While the booklet is primarily targeted at pilots of piston-engine aircraft, pilots of turbine-engine aircraft will still find much of the information useful.

Fuel **contamination** is where there is a foreign substance (eg, water, dirt) in the fuel, and which may cause engine stoppage through incombustibility, or blockage or damage to fuel system components.

Terminology

Note particularly the difference between fuel starvation and fuel exhaustion – this important difference is not always understood.

Fuel **starvation** is where there is still fuel on board, but it is not getting to the engine. This may be a result of:

- A tank being run dry inadvertently, as a result of distraction or an incorrect fuel selector position.
- A mechanical problem such as a stuck fuel valve.

Fuel **exhaustion**, on the other hand, is where the aircraft has completely run out of fuel. This could be due to:

- Taking off with less fuel than was thought to be on board.
- Underestimating the fuel required for the flight.
- Losing fuel in flight (eg, from a stuck-open drain cock).

Fuel Systems Knowledge

Type Ratings

A number of fuel-related accidents in New Zealand can be traced back to the pilot's unfamiliarity with their aircraft's fuel system. This highlights the importance of thorough type-rating training. The more complex the aircraft type, the more critical any knowledge deficiencies become.

Pilots intending to gain a type rating need to ensure that they are thoroughly familiar with the aircraft's fuel system and associated procedures before undertaking any flying. The aircraft Flight Manual or pilot operating notes should be closely studied with particular attention to:

- Fuel grade, total capacity, and usable and unusable fuel quantities.
- Fuel drain points and fuel tank dipping procedures.
- Fuel selector operation, especially any cross-feeding procedures.
- Electric and mechanical fuel pump operation, and normal fuel pressure and fuel flow gauge readings.

- The actual purpose of fuel boost pumps.
- Correct leaning procedures, and consumption rates for different altitude and rpm combinations.
- Manifold pressure and rpm for maximum range.
- Consumption rates of fuel-powered cabin heaters.
- Learning the engine trouble checks.

The CAA Flight Test Standards Guide, **Type Rating** is a useful aid for both instructors and type rating trainees. It is available on the CAA web site, www.caa.govt.nz, see “Pilots”.



Currency

If you are not particularly current on an aircraft type, consider whether or not your fuel systems knowledge is up to scratch before you go flying. If not, then it is time to get the aircraft Flight Manual out and re-familiarise yourself – it’s amazing how quickly important details can be forgotten.

Extra care needs to be taken when transferring between aircraft types with

similar – but subtly different – fuel systems, as it is easy to make an incorrect selection or to revert back to a pre-learned response (ie, the incorrect one for that aircraft fuel system) when faced with an emergency.

Flight Planning Requirements

Determining Fuel Required

Many fuel-related occurrences are due to the pilot underestimating the fuel required to complete a flight safely. There are too many variables, often beyond the pilot’s control, to risk taking minimum fuel only – it is far better to offload some luggage and add more fuel, or to plan an extra fuel stop, than it is to cut the fuel calculations fine. Planning alternative refuelling points along the route, and using them if required, is good practice. At no stage during the flight should a fuel shortage become a concern.

Warm-up, Taxi and Climb

An allowance for warm-up, taxi and climb should always be factored into the fuel-required calculations. Warm-up periods in cold weather can be considerable, as can the taxi and holding times at busy controlled aerodromes. It is considered good practice for VFR operations to add 15 minutes at the cruise consumption rate to allow for this. An additional allowance should also be made for the higher fuel consumption rate experienced in the climb, which can be considerable (up to

50 per cent for some aircraft). This is normally accomplished by determining how long it will take to climb to the planned cruise altitude and multiplying that value by the climb-power consumption rate detailed in the aircraft Flight Manual.

Both these figures are then entered in the fuel-required column of the pilot's flight log.

A caution here for pilots unused to flying over mountainous terrain – time and distance spent in the climb can be considerably more than that over flat, low-lying terrain.



Legal Reserves

The minimum legal fuel reserves (ie, extra fuel over and above that required to complete the flight, taking into account the forecast weather) that must be carried on all flights are:

- 30 minutes for all aeroplane VFR operations by day, and 45 minutes by night.
- 20 minutes for helicopters.

- for non-turbine powered aeroplane IFR operations, sufficient to divert to a suitable alternate aerodrome (if so required) plus 45 minutes at holding consumption rate at 1500 feet.
- for turbine powered aeroplane and helicopter IFR operations, sufficient to divert to a suitable alternate aerodrome (if required) plus 30 minutes at holding consumption rate at 1500 feet.

While, for example, a 30-minute reserve for a VFR day flight might sound quite a lot, it doesn't necessarily translate to very much fuel in the tanks. The legal reserve of a Piper Tomahawk is just 12 litres (6 litres of usable fuel per tank), for example. Landing with such a small amount of fuel on board is questionable airmanship, especially when dipstick accuracy may be unreliable at such low fuel levels. The legal requirements are **minimums only**, and it is suggested that higher values be used where appropriate, depending on the type of operation being undertaken, the terrain to be crossed, and weather considerations.

Note: you **must** plan to land with your legal reserve still intact. You may not plan to complete the flight by using part of this reserve.

Contingencies

The fuel-required calculations should preferably include a 'variable reserve' in addition to the fixed legal reserve, to allow for the unexpected – eg, stronger-than-expected headwinds, fuel consumption greater than anticipated, or diversion due to weather. This amount is normally 10 to

15 per cent of the total fuel required for the flight.

Weather forecasts must always be carefully interpreted to determine the mean headwind component for the route and whether an alternative route should be planned. The effects of a strong headwind on time and total fuel burn should not be underestimated when planning a flight – doing so has cost a number of New Zealand pilots their lives. Choosing an appropriate altitude in relation to headwind, true airspeed, and leaning can make a difference – it is a good idea to do some calculations for varying conditions for the aircraft you normally fly.

Too often, pilots of VFR aircraft plan their flight making no allowance for an alternative route should they encounter unexpected weather conditions en route, and consequently they find themselves low on fuel when they are forced to divert. Marginal or changeable weather situations need to be treated with considerable caution when it comes to planning the fuel required.

EXAMPLE

You have planned a 200 NM flight in an aircraft that cruises at 90 knots. A 10-knot tailwind is forecast, and you calculate your time interval on that basis. You decide to carry fuel for 2 hours 30 minutes.

How much would the wind have to change for your reserve to be completely used up?

Answer on page 31.

Consumption Rates

Fuel consumption rates can vary considerably between different aircraft of the same type because of their condition, age, and the manner in which they are flown. An increase of just 100 rpm for a fixed-pitch propeller aircraft, for example, can increase fuel flow by 10 per cent or more (there goes your contingency). Similarly, operating at low altitudes with the mixture fully rich also substantially increases fuel burn. The cruise altitude and power setting required for the flight should therefore be decided on early in the flight planning phase, and the Flight Manual consulted to determine the fuel flow rate for that altitude/power combination. A conservative fuel consumption rate should then be used, making a further allowance for the age and condition of the engine concerned. Engines near the end of their operational life sometimes will burn more fuel.

For multi-engine aircraft, consideration must be given to the increased fuel flow on the live engine for engine-out operations.



Recording Fuel Requirements

Preparing a neat and tidy fuel log pays dividends when it comes to accurate pre-flight fuel management planning. There are many different ways of setting out a fuel log, but whichever method you use it should at least detail the following information:

- A **fuel-required** section should itemise the fuel necessary for warm-up and taxi, climb (if prolonged), each leg of the flight, legal reserve, and a contingency (variable reserve). For IFR operations, fuel for descent, approach, missed approach, holding, and diversion to an alternate aerodrome should also be itemised. The fuel-required figures are derived by multiplying the fuel consumption rate for each flight phase by the time required for each stage of the flight. These figures are added up to obtain the total fuel required for the flight.
- In a **fuel-available** section, the total usable fuel quantity carried and the fuel endurance (the usable fuel less the extra fuel required for warm-up, taxi and climb divided by the cruise consumption rate) are recorded. It is also good practice to record the safe endurance, which is the fuel endurance less the legal reserve. (You may want to factor in a contingency at this point as well.) By adding this safe endurance to the takeoff time, you can record a 'land-by' time once the flight begins – that way you will not be tempted to try to get to the destination using the legal reserve. There should also be a section

in which to record the time each tank selection is made, and a running total of the fuel remaining in that tank. Actual fuel gauge readings should also be noted at the same time in the neighbouring column. Advice on how to keep this record while in flight is covered later in the booklet.

See the accompanying sample fuel log for further details.

A Useful Tool

An alternative fuel planning tool is the "Time in Your Tanks" fuel log developed by the Australian Civil Aviation Safety Authority (CASA). It is a laminated card, on which fuel figures are entered according to the simple instructions, and which gives a readily understood picture of your fuel state at any time during flight.

To obtain copies of these cards, email: info@caa.govt.nz, or contact your local CAA Field Safety Adviser.



Calculating 'Land-By' Time Example

As part of the pre-flight planning, you need to calculate the 'safe endurance' of the aircraft as outlined here:

Total fuel loaded (160 litres) minus unusable fuel (10 litres) = total usable fuel carried (150 litres)

Cruise consumption rate = 40 litres/hr

Fuel for warm-up and taxi (15 min @ 40 litres/hr) = 10 litres

Extra fuel for climb (15 min @ 20 litres/hr) = 5 litres (over and above cruise consumption rate)

Fuel endurance = 150 litres minus 10 litres minus 5 litres = 135 litres @ 40 litres/hr = 3.37 hr (3 hr 22 min)

Legal reserve = 30 min

Safe endurance = 3 hr 22 min less 30 min = 2 hrs 52 min

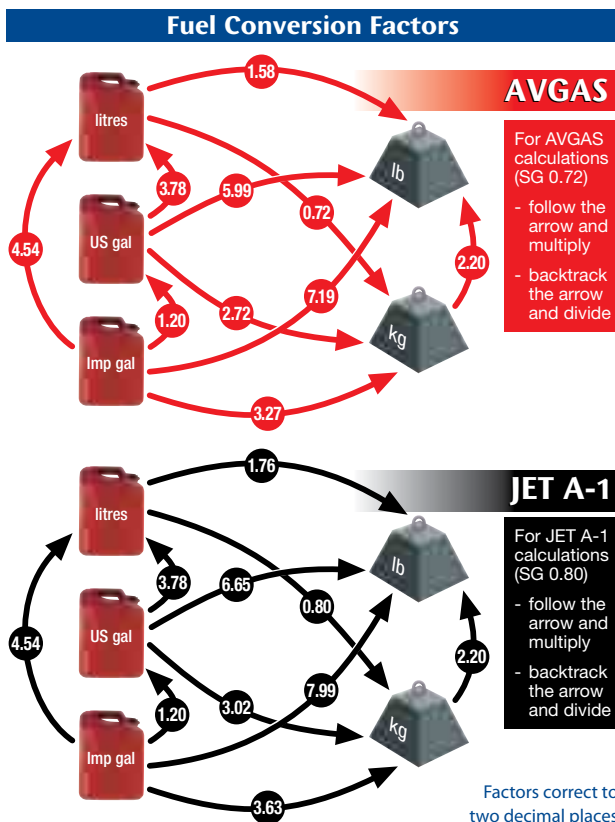
Note the takeoff time and add the safe endurance to it. This will give a 'land-by' time, which should be noted on the fuel log. If, for example, your takeoff time was 01:15 UTC, the 'land-by' time will be 04:07 UTC. Landing by this time will mean you still have the 30-minute legal reserve left in the tanks, provided that your fuel management calculations were done accurately to begin with. During the flight you might become lost, get caught in bad weather, or encounter stronger-than-expected headwinds – or a combination of these factors. This sort of situation can make it difficult for pilots to make even the most basic of fuel calculations correctly – but at least you have a 'land-by' time telling you that once 04:07 has passed you are eating into the legal reserve, and are therefore **in an emergency situation**.

Note: we have chosen not to include a contingency when calculating the safe endurance in this example. Your own personal minimums may differ from this.

FUEL MANAGEMENT LOG							
FUEL REQUIRED				FUEL AVAILABLE			
	Time (hr, min)	Consumption Rate (l/hr)	Quantity (l)	Total Usable Fuel Carried (l)			
Warm-up and Taxi	Standard allowance, eg 15 min @ cruise consumption		10	150			
Climb	Extra required (typically time to climb at difference between climb power and cruise power consumption rates)		5	Fuel Endurance (hr, min) (usable less extra for warm-up, taxi and climb)	3hr 22		
Flight Time (takeoff to landing)	1 hr 15	40	50	Safe Endurance (hr, min) (excludes fixed reserve)	2hr 52		
Fixed Reserve	30	40	20	Land By Time (UTC)			
Approach	-	-	-	Tank Selection Time (UTC)	Main (l)	Aux (l)	Fuel Gauge Reading
Alternate Aerodrome	-	-	-		L	R	
Approach	-	-	-		75	75	
Minimum Fuel Quantity Required			85				
Contingency (eg. 10% of the fuel required)			9				
Total Fuel Quantity Required			94				

Weight and Balance

The amount of fuel that can be carried is often limited by weight and balance considerations. Determining the maximum permissible takeoff weight and the C of G position is an important part of the fuel management process. Some aircraft types have a maximum zero fuel weight (see the accompanying table for a definition). Takeoff and climb performance should be borne in mind here – particularly when operating off a short strip or over high terrain. Definitions and conversion factors that relate to pre-flight fuel planning are shown here to assist you.



Stickers showing the Fuel Conversion Factors can be obtained from: info@caa.govt.nz.

Term	Definition
Aircraft Standard Empty Weight	The weight of a standard aircraft including the unusable fuel and full operating fluids.
Maximum Zero Fuel Weight MZFW	The maximum weight (for structural reasons) exclusive of the usable fuel, ie, any weight above the MZFW must be fuel.
Maximum Ramp Weight	Maximum weight permitted for ground movements (includes weight of fuel for run-up and taxi).
Maximum Certificated Takeoff Weight MCTOW	Maximum weight permitted for takeoff.
Maximum Landing Weight	Maximum weight permitted for landing.

Pre-Flight Fuel Checks

Determining Fuel Available

Accurately determining what quantity of fuel you have on board is important. Assuming the fuel required for the flight has been calculated correctly, it should be a simple matter of uplifting it and completing the flight with a comfortable margin to spare.

It is good practice to check the fuel available before flight by at least **two separate methods** (in Australia, this is a legal requirement). We can do this by referring to the fuel gauge(s), loading a known quantity and, in many aircraft, by dipping the tanks. There are a number of considerations that should be borne in mind when determining the fuel available.

Unusable/Usable Fuel

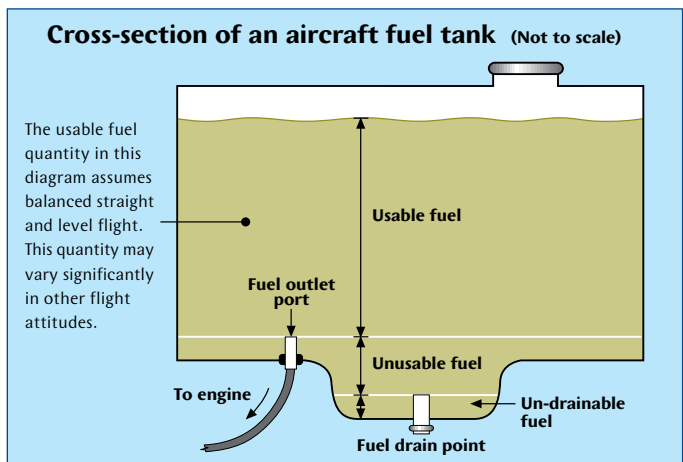
Understanding the difference between the terms usable and unusable fuel is important in determining the fuel available for flight.

The unusable fuel is the quantity of fuel that **cannot** be used in level flight. It is the quantity remaining in each tank after the tank outlet becomes uncovered in level and balanced flight. The amount of unusable fuel can vary considerably

from aircraft type to aircraft type – refer to your aircraft Flight Manual for specific figures. The fuel tank outlets on some aircraft types are very susceptible to becoming un-ported during prolonged unbalanced flight, which eventually leads to fuel starvation and engine failure.

Extreme care must be taken to ensure that the unusable fuel quantity is **not** included in the fuel available, as it can equate to as much as 20 minutes extra flying time that you don't actually have.

It follows that the usable fuel is the quantity of fuel available for flight planning purposes. This is the **only** figure that should be used when calculating fuel endurance. Most dipsticks are calibrated to read the total fuel quantity in the tank, which means that the unusable fuel must be subtracted to determine the fuel available for flight. Care must be taken when converting between litres, and US or imperial gallons. Calculations should always be double-checked.



Fuel Gauges

Most fuel gauges read reasonably accurately, and if they don't, they must be fixed. Gauge accuracy can easily be checked before the flight by dipping the tanks (if that is possible) and comparing the figures with the actual gauge readings. Any discrepancies must be allowed for until the problem can be fixed.

Be aware that fuel gauges can stick or fail in flight, sometimes in a subtle way, so don't rely on higher-than-expected readings which seem at odds with expected consumption as the flight progresses. Also, in some common aircraft types, fuel gauge indications will vary widely according to the direction and degree of any slip or skid.

Some aircraft have tank designs where a dipstick reading can't be obtained at certain fuel levels, so the use and accuracy of the fuel gauges becomes even more important to the pilot.

Fuel Dipsticks

Using a fuel dipstick to dip the tanks is the most accurate way of determining the fuel on board. It is therefore important to ensure that you have the **correct dipstick for your aircraft**. Keep the dipstick clean (don't place it on the ground, for instance).

Each dipstick has been specifically calibrated to its aircraft's fuel tanks and is therefore not interchangeable with that from another aircraft, even of the same type – which is why it should be carefully marked with the aircraft registration. Aircraft of the same type may have had

fuel tank modifications carried out (eg, long-range tanks fitted) meaning that only a dipstick specifically calibrated for that aircraft can be used. Unfortunately, dipsticks are sometimes in poor condition and their markings hard to read. If this is the case, double-check readings to make sure that they seem sensible and arrange to get the dipstick re-marked.

Tank Dipping

There are several points to consider when dipping fuel tanks, which will help to ensure reasonably accurate readings are obtained:

- The aircraft should be parked on level ground – if this is not possible, dip each tank, turn the aircraft through 180 degrees, dip each again, and take the average of the two values. This may not be accurate, but it will be better than either of the two single readings.
- Ensure that the fuel system is not cross-feeding during dipping. Slope and uneven fuel quantities in each tank can cause this on some aircraft types. The trap here is that, when you are refuelling the aircraft with the fuel selector set to BOTH, the tank that you are filling can be cross-feeding to the other tank. By the time you have finished filling the second tank, the quantity in the first tank will have reduced, and it should be checked again and topped up as required. The amount involved is not large, but it could cause a problem if the flight requires both tanks to be full.

- Note that cross-feeding during refuelling, or at any other time, can be prevented in most single-engine aircraft by selecting either the LEFT or RIGHT tank only.
- A further point to note is that some light twins have two or more interconnected fuel cells in each wing, which are refuelled from a single filler neck. In this case, time must be allowed for the fuel to transfer to the other cell as the aircraft is being refuelled, in order to prevent under-fuelling. This is especially important for aircraft using Jet A-1, as pump delivery rates can be considerably higher than for avgas.

- The dipstick should be inserted in the filler neck perpendicular to the wing surface – unless there is another method specified in the Flight Manual (some aircraft fuel tanks must be dipped on an angle as the main spar is directly below the filler neck).
- Withdraw the dipstick quickly and check the indicated fuel level before evaporation or ‘wicking’ occur. (Wicking can occur on a wooden dipstick; the fuel can soak into the grain and cause an over-reading indication.)
- Beware of false readings where the dipstick may be resting on a fold or wrinkle in a bladder-type tank.
- Fuel tanks should always be dipped after refuelling to establish the exact amount of fuel on board – even after adding a known quantity of fuel.
- **Do not** rely on someone else to confirm your aircraft’s fuel state. You are the pilot in command, and you must complete this task yourself.



No Dipstick?

It is sometimes difficult to determine the fuel on board aircraft on which the fuel tanks cannot be accurately dipped. The safest way is to start the flight with the tanks either full or filled to a fixed reference point, and to keep an accurate in-flight fuel log. If this is not possible, however, due to weight and balance or performance considerations, the only way to know exactly how much fuel is on board is to add a known quantity (ie, a reading taken from the fuel pump counter) to a

predetermined reference point inside the tank. Consult the aircraft Flight Manual for specific details.

Fuel Thefts

Fuel thefts do occur (especially avgas) when aircraft are left outside overnight. Fuel theft could mean your getting airborne with considerably less fuel on board than was planned – a very dangerous scenario. This is why dipping should be done just before departure, not the day before. Fuel theft can also mean the introduction of contaminants (such as water) into the fuel system, as caps are often not replaced correctly or are left off completely after the theft. A thorough fuel drain before flight is recommended if foul play is suspected.

Pre-Takeoff Checks

The worst possible time to have an engine failure is just after takeoff. Unfortunately, many engine failures (or partial power losses) after takeoff are caused by a fuel problem.

Most such incidents are caused by the selection of a near-empty tank, with pilots of aircraft with more than two fuel tanks being more likely to make such a mistake. A contaminated fuel supply or the mis-selection of a tank (eg, the fuel selector inadvertently being placed between a tank setting and the OFF position) are other common causes.

These types of incidents can be avoided if the pre-flight and pre-takeoff checks are

strictly adhered to. The following are commonly used pre-takeoff checks to verify fuel supply integrity – they relate to aircraft with a fuel tank selector and an electric fuel boost pump. Consult the aircraft Flight Manual or talk to a senior pilot or instructor for checks that are specific to your aircraft type.

- Always check that the fuel selector is in the actual ‘detent’ for the tank required.
- Select the least-full tank for engine start – this will ensure that there are no fuel flow problems associated with that tank. Confirm the operation of the electric fuel pump by listening for a ticking or whirring noise and by observing a slight rise in fuel pressure prior to starting. Confirm that the engine-driven fuel pump(s) are operating properly after start by checking that fuel pressures are stable with the electric fuel pump(s) turned OFF.





- Change to the fullest tank before carrying out the engine run-ups. This allows time for the fuel flow to stabilise and for any contaminants (eg, water) to pass through to the engine(s) before the takeoff run starts. It also ensures that there are no fuel flow problems associated with that tank. It is important to do both a **visual** and a **hands-on** physical check of the fuel selection lever(s) here to minimise the chances of a mis-selection. Cockpit checks, such as confirming the position of the fuel selector, should not be carried out in an automatic fashion; it requires a moment's thought as to whether the selection you are about to make is going to achieve the desired result. Pilots of twin-engine aircraft should also check that the fuel cross-feed is **not** selected. (Selecting the fullest tank should be part of your pre-takeoff checks – if you then discover that you are on the least-full tank, do not change tanks immediately before takeoff – wait until you are at a safe height. If there is any problem with that tank, you don't want to find out shortly after getting airborne.)
 - Double-check that the fuel gauge readings for each tank are what you think they should be, that electric fuel pumps are on, and that fuel pressures are normal.
 - Quickly scan the fuel pressure at the start of the takeoff roll, and don't be too hasty to turn the fuel pump(s) off on climb-out. Wait until you have cleaned the aircraft up, with climb power set, and are at a safe height (one that you feel comfortable with if the engine should stop – this will depend on the terrain). Monitor the fuel pressure for a brief period afterwards.
- If the engine(s) are fuel-injected, be totally familiar with the likely symptoms, and required actions, in the event of an engine-driven fuel pump failure during climb-out or in cruise.

In-Flight Fuel Management

Log Keeping

Keep an accurate fuel log. This, in combination with fuel gauge readings, is an important part of monitoring your fuel status in flight. Be sure to make regular reference to it as part of your cruise checklist – that way you will not forget to monitor consumption and change tanks when appropriate.

You will have recorded your engine start time, your takeoff time, which tank(s) were selected, and have determined a 'land-by' time. After a suitable period (30 minutes is a suggested figure), change tanks, noting the time and the tank(s) selected. Deduct the fuel used over this period (using the

planned consumption rate) from the known tank quantity recorded on the fuel log. This kind of running total (which can be recorded in litres and/or in time) should be kept for all tanks – that way it is possible to see how much fuel (and/or time) should be in each tank at any given time.

Some means (eg, circling the current tank selection in the fuel-available column) of recording which tank or tanks were selected at the noted time should be employed to avoid the possibility of confusion. Accurate log entries are essential to avoid arithmetical errors occurring.

Fuel gauge readings should be recorded at the same time in the neighbouring column, so that any discrepancies can be noted. Any significant discrepancy is a good indication that something is wrong.



FUEL REQUIRED				FUEL AVAILABLE					
	Time (hr, min)	Consumption Rate (£/hr)	Quantity (£)	Total Usable Fuel Carried (£)				150	
	Standard allowance, eg 15 min @ cruise consumption		10	Fuel Endurance (hr, min) (usable less extra for warm-up, taxi and climb)				3hr 22	
			5	Safe Endurance (hr, min) (excludes fixed reserve)				2hr 52	
			50	Land By Time (UTC)				0407	
			20	Tank Selection Time (UTC)	Main (£)		Aux (£)		Fuel Gauge Reading
			-		L	R	L	R	
			-	0100	75	75			75/75
			-	0130	55	75			55/75
			85	0200	55	55			55/55
			9	0230	35	55			35/55

Re-check your log entries, and re-work your fuel calculations if necessary. Actions in the event of a low fuel state are discussed later in this booklet.

For an inexperienced pilot, the cockpit workload can be high with all the tasks associated with a cross-country flight. If you are becoming overloaded and lose track of what is in each individual tank, remember that the important figure is your overall fuel quantity (and hence your 'land-by' time).

See the accompanying sample fuel log for further details.

Leaning

Several fuel exhaustion accidents have highlighted the fact that correctly leaning the mixture in the cruise is an important part of in-flight fuel management. Planned fuel consumption rates, and thus range, will not be achieved if the mixture is not correctly leaned.

The mixture should always be leaned during the cruise (provided that the desired altitude will be maintained for a reasonable period of time). Most aircraft engines can be leaned **at any altitude** provided the power set is 75 per cent or less. (The oft-quoted figure of 5000 feet is based on the engine being unable to produce more than 75 per cent power, even at full throttle, at that altitude.)

On some aircraft types, a properly leaned engine, at say 4500 feet, can increase your still-air range by as much as 20 per cent compared with not leaning at all at the same altitude.

A more specific example: a Piper Cherokee 140 normally uses 32 litres per hour when correctly leaned with 65 per cent power set, giving it an endurance of over five hours. A combination of increased rpm and incorrect leaning, however, could increase consumption by as much as 15 per cent. This equates to a 45-minute reduction in endurance – there goes your reserve, and then some.



Leaning procedures vary considerably between aircraft. Some aircraft engines have very basic instrumentation and require the pilot to lean the mixture by ear and reference to rpm, whereas others have exhaust gas temperature and fuel flow gauges, which allow a far greater degree of accuracy. It is important that you are familiar with the correct Flight Manual leaning procedure for the aircraft you fly.

Changing Tanks

Where fitted, the electric fuel pump would normally be turned on before a new tank is selected – but make sure you know if this applies to your aircraft type. It should be left on for a short period after selecting the new tank and the fuel pressure monitored. To prevent having to make a hasty tank selection, and to provide continuity of flow, a tank should never be allowed to run dry. This will introduce air into the fuel lines and cause the engine to falter. On some aircraft types, it can be difficult to restart the engine after running a tank dry – a good reason for avoiding this practice.

Don't change tanks over stretches of inhospitable terrain or water, and be sure of your fuel endurance before committing yourself to flying over such areas. Fuel tank selection at low altitudes (such as when carrying out low flying training) is also not recommended, since it leaves little recovery time in the event of an erroneous selection.



Monitoring Fuel Quantity

As many pilots fly hired aircraft, it can often be difficult to know precisely the fuel

consumption figures for the aircraft they are using. As we have mentioned before, fuel consumption rates can vary between different aircraft of the same type due to their condition, age and the manner in which they are flown.

An accurate fuel log should be kept and the figures regularly cross-checked with fuel gauge readings. After the first landing, usage figures can be compared with the planned figures. At any stop on a cross-country flight, the tanks should be re-checked with the dipstick.

It should be borne in mind that a fuel log alone should not be relied on for monitoring fuel status. Fuel log calculations may not take into account such factors as: higher-than-expected fuel consumption rates (from changed power settings, non-standard fuel-leaning techniques or from flying at different cruising levels from that planned); inaccurate flying; loss of fuel in flight (eg, a leaking fuel drain, cap or fuel vent); and under-fuelling before the flight. In addition, your fuel log calculations will be flawed if you have made any arithmetical errors. Total reliance on inadequate fuel logs has resulted in some aircraft running out of fuel.

If you can estimate fuel remaining from reading the gauge(s), then recording such a figure in a fuel log gives a direct comparison, even if only an approximate one. A useful benefit may be a feel for what the fuel gauge is telling you; or it might be that a higher-than-expected fuel consumption can be spotted early.



The bottom line is that every method and aid you have for monitoring fuel quantity should be used.

It is interesting to note that a culture of dismissing fuel gauges as unreliable – and therefore ignoring them – seems to have developed among New Zealand general aviation pilots. This is most unfortunate, when you consider the number of fuel starvation or exhaustion incidents where pilots have pressed on with low gauge readings.

Make regular reading of fuel gauges an integral part of your fuel management strategy.

Diversion and Precautionary Landing

If a diversion due to enroute or destination weather becomes necessary, you may need to re-plan in flight to a new destination. Be sure that you apply the same fuel requirements with respect to flight time, legal reserve and preferably contingency to the flight to the new destination.

If it becomes apparent that you are running low on fuel, an early decision should be made to divert to the nearest suitable aerodrome before the fuel state becomes critical. This decision should not be delayed. Be familiar with the procedure for setting correct power and rpm for best range.

If, despite doing this, your fuel situation becomes critical, and it is doubtful whether there is enough fuel to reach the diversion aerodrome safely (by 'safely', we mean with your legal reserve intact), then a precautionary landing is the best course of action.

Too many accidents have occurred because pilots pressed on thinking that they could make it. The fact that the aircraft may be damaged in a precautionary landing should not influence this decision – aircraft can always be repaired.

A PAN PAN call should be made on a Control or Flight Information frequency, advising of the low fuel state and intentions. Do not hesitate to request a landing priority if the nearest aerodrome is a controlled one, otherwise controllers may not realise the urgency of your situation.

It is human nature that, when faced with marginal situations, we feel the pressure to reach our intended destination.

“My passengers need to get to the destination today, the aircraft has to be back tomorrow, I don't want anyone to know that I stuffed up,” are the types of thoughts that usually run through our minds. Ignore these, and take decisive action to divert or land. Once again, don't wait until the fuel state becomes critical. Always take the safer option of uplifting more fuel en route if there is the slightest doubt about safety margins being maintained. Passengers are normally fully supportive of ample fuel being carried!

Emergencies

If the worst does happen and your engine stops due to a suspected fuel problem, remember the old adage 'Aviate, Navigate, Communicate'. Control the aircraft before planning an approach to a forced landing area and commencing trouble checks. Regardless of whether you suspect it's fuel starvation or fuel exhaustion, if there is

sufficient time available, close the throttle, turn the electric fuel pump on, change tanks (select another tank or cross-feed the failed engine from an opposite tank if flying a twin) and wait for the fuel pump to restore the flow. It is important that the new selection be given a reasonable amount of time (up to 15 seconds) to take effect, as the distance that the fuel has to travel can be quite considerable on some aircraft types. Vapour lock (air drawn into the fuel lines) can exacerbate this problem. The remainder of the trouble checks should then be completed. Refer to your aircraft Flight Manual or talk to an instructor/senior pilot about type-specific engine failure checks.

If, after having completed these checks, you are unsuccessful in restoring power, communicate your position and intentions and concentrate on flying a safe approach – don't let yourself become distracted with further trouble checks.

Make sure that you are thoroughly familiar with the aircraft's emergency procedures.

Pre-Landing Checks

Ensuring fuel flow integrity for the approach and landing is an important part of the pre-landing checks. Check the mixture control is in the rich position. The fuel pump(s) should be switched on, if applicable, and the fullest tank(s) selected before commencing an approach. The fuel pressure should also be checked to ensure it is normal.

Post-Flight Actions

Determining Consumption

It is a good idea to compare the actual fuel burn with the planned fuel burn by dipping the tanks and reading the gauges after the flight (or on landing at an intermediate aerodrome en route). This will provide you with a good consumption figure for future reference, and allow you to see how accurate your flight planning was. It also gives you the opportunity to get to know the accuracy of the fuel gauges.

Refuelling

Ideally, the aircraft should be topped up with fuel after the last flight of the day to minimise the chances of condensation forming inside the tanks, particularly if it is going to be parked outside overnight. Condensation can form inside a fuel tank when water vapour present in air trapped in the tank condenses as it is cooled.

Leaving the tanks full, however, may create a weight-and-balance or climb performance problem for the next pilot, either limiting their intended operation, or requiring defuelling the aircraft.

A further problem with filling the tanks right up is that, if the temperature rises, the fuel will expand and overflow from the tanks, creating a possible fire hazard (not to mention being a waste of fuel).

Fuel theft is also a consideration.

Try to determine what the aircraft will be next used for before deciding whether or not to top it up.

Summary

When handling fuel:

- Understand the characteristics of fuel.
- Minimise the chances of a fire or explosion when refuelling by observing the general precautions and appropriate bonding actions that have been outlined.
- Know what to do in the event of a fuel spill.
- Be careful when refuelling from drums or jerrycans, as these can be susceptible to water and dirt contamination.
- Always take a fuel sample before the first flight of the day and after refuelling (wait for the tank contents to settle first).
- Above all, don't let yourself become complacent about refuelling.

To minimise the chances of unexpectedly running out of fuel:

- Become thoroughly familiar with the fuel systems for the aircraft you fly.
- Know the fuel consumption rates for different altitude and rpm combinations.
- Know the manifold pressure and rpm for maximum range.
- Exercise care when flight planning, and ensure that your fuel-required calculations allow for forecast headwinds, possible diversions, legal reserves and a contingency.

- Always plan for en-route refuelling stops, and use them to ensure safe margins of fuel are maintained at all times.
- Be thoroughly familiar with the usable and unusable fuel quantities for all the aircraft types you fly, and be sure to dip the tanks accurately with the aircraft's own dipstick before every flight. Always know exactly how much fuel is on board before getting airborne.
- Be aware that fuel theft can and does happen, and take appropriate measures to minimise the chances of it occurring.
- Do your pre-takeoff checks thoroughly.
- Know the correct mixture leaning procedure for the aircraft, and lean the mixture in the cruise whenever possible.
- Keep an accurate in-flight fuel log, and regularly cross-check it with fuel gauge readings.
- Don't hesitate to divert or carry out a precautionary landing should you become uncertain about your fuel state.
- You must always plan to land with your legal reserve intact.
- Be familiar with the trouble checks, and know how to prioritise your actions in the event of an engine failure.
- Regularly dip the tanks after flight to determine the aircraft's actual fuel consumption rate.

Answer to question on page 17: It would take a headwind of only 10 knots for this to happen. Note, however, that any reduction in the originally anticipated tailwind would require either more fuel to start with, or an enroute fuel stop to ensure that the reserve is not compromised.



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Fuel Management was revised in March 2013.
See our web site, www.caa.govt.nz, for details of more CAA safety publications.