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# Fuel management

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# Contents

<b>Introduction</b> .....	3	<b>Hazards</b> .....	17
<b>Fuel types</b> .....	4	Fire or explosion .....	17
Octane rating .....	5	Static electricity .....	17
Use the correct fuel .....	5	Water contamination .....	18
Dangers of using ethanol in mogas.....	5	In a fuelling emergency .....	18
<b>What the rules require</b> .....	6	<b>Handling fuel to reduce risk</b> .....	20
Transport.....	6	Fire or explosion .....	20
<b>Know your fuel systems</b> .....	7	Static .....	20
Type ratings.....	7	Contamination .....	22
Currency.....	7	Detecting water and other contamination.....	23
<b>Flight planning requirements</b> .....	8	Hot fuelling of turbine-powered aircraft .....	25
Determining how much fuel is going to be needed ...	8	Fuelling from drums .....	25
Recording fuel requirements .....	10	Jerry cans .....	26
Weight and balance.....	12	Defuelling .....	27
<b>Preflight fuel checks</b> .....	13	<b>Flight fuel management</b> .....	28
Determining how much fuel you have .....	13	Preflight checks.....	28
		Inflight fuel practice .....	29
		Postflight actions.....	34
		<b>Summary</b> .....	35

**Cover photo:** CAA/Jess Jennings

See the CAA website for Civil Aviation Rules, advisory circulars, airworthiness directives, forms, and more safety publications. Visit [aviation.govt.nz](http://aviation.govt.nz).

Every effort is made to ensure the information in this booklet is accurate and up-to-date at the time of publishing. But numerous changes can occur with time, especially in regard to airspace and legislation. Readers are reminded to get appropriate up-to-date information.

Our thanks to the staff at Wellington Aero Club, particularly Christopher Hodgson, who allowed the CAA to interrupt their busy schedule and take photos to illustrate this booklet.

# Introduction

Forty percent of engine failures are caused by fuel exhaustion, starvation or contamination.

Of that 40 percent, starvation occurrences are the most common. The fact that most of those likely result from pilot error illustrates the need to improve preflight planning, inflight fuel monitoring and aircraft knowledge.

Fuel starvation is where there's still fuel on board, but it's not getting to the engine.

That may be the result of:

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

Fuel exhaustion is where the aircraft has completely run out of fuel.

This could be due to:

- taking off with less fuel on board than was thought
- underestimating the amount of fuel required for the flight
- losing fuel in flight (eg, from a stuck-open drain cock).

Fuel contamination is where there's a foreign substance such as water, dirt or fungi – *Cladosporium resinae*, for instance – in the fuel. The contaminant may cause the engine to stop because it has inhibited combustion or blocked the fuel lines or damaged the fuel system components.

The reasons for these occurrences often relate to:

- the pilot's poor knowledge of the fuel system of the aircraft they fly
- preflight planning was inadequate
- preflight checks were inadequate
- the pilot has failed to accurately monitor inflight fuel consumption
- when faced with a low-fuel state, the pilot is unable to take decisive action quickly.

This booklet examines all these factors, and others, and contains practical advice to make you more proficient, and safer, in handling and managing fuel.



# Fuel types

Aircraft fuels come in two basic types: gasoline and kerosene. Gasoline also comes in two types: aviation gasoline, known as avgas, and motor gasoline, known as mogas.

The kerosene-type fuel is known commercially as Jet A-1, and 'avtur' in the military.

Commonly, piston-engine aircraft run on avgas, and turbine-engine (turboshaft, turboprop and jet) aircraft run on Jet A-1.

There are also aircraft diesel (or 'compression-ignition') piston engines that run on Jet A-1

Many sport and private aircraft run on mogas.

// As pilots, you need to know the different fuel grades to prevent fuelling errors. //

Fuel grade	Colour	Usage	Comments
Mogas 91	Purple/bronze, or red/orange	Some microlight, amateur-built, 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, amateur-built, 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.
Avgas 100LL	Blue	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.



## 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 the fuel is any more powerful, just that it's better suited to the more demanding conditions of high compression ratio, supercharged engines.

The grade of avgas available in New Zealand is 100LL, the 'LL' standing for 'low lead'.

## Use the correct fuel

If an avgas-powered aircraft is fuelled 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. But when the jet fuel reaches the engine, it will likely 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 may run on avgas, although its higher volatility could lead to vapour lock problems at altitude. An engine which has been operated using an alternate fuel type may require additional maintenance to ensure airworthiness. You should consult manufacturers information before operating an aircraft on an alternative fuel type.

As pilots, you need to know the different fuel grades to prevent fuelling errors. Fuel companies can provide fuel identification labels to place next to the fuel tank cap.

Always confirm that the fuel identification on the pump matches the appropriate label by the fuel tank opening.

## Dangers of using ethanol in mogas

Ethanol is a liquid alcohol used either as a main fuel or blending ingredient in fuel. It was introduced to reduce the burning of fossil fuels. However, most aircraft engine manufacturers' type certificate data sheets, and flight manuals prohibit its use.

That's because ethanol tends to absorb and combine with water, a major contaminant of fuel. A fuel/water mixture can lead to partial or total power loss.

There are several other reasons ethanol-blended fuel is prohibited from use in aircraft. Read Continuing Airworthiness Notice 28-001 *Ethanol blended fuel* on the CAA website.



## What the rules require

The operator shall have documented procedures for fuel management, fuel supply, aircraft fuel quality control and aircraft fuelling. These procedures should be informed by the company's safety management system.

Those procedures include requirements regarding vehicle and driver standards. See Advisory Circular AC91-22 4.5 *Driving and positioning of vehicles*.

The procedures should also detail how fuel supplies and individual aircraft quality samples will be quarantined and guarded if there's an emergency involving any aircraft that's drawn fuel from those supplies. That applies even if the aircraft is operated by another operator or the emergency is not thought to be fuel-related.

Fuel transfer equipment shall include a system to prevent contaminants making their way into fuelling nozzles. Fuel filter element bowls with a replaceable filter element shall be clearly marked with the date the element replacement is due.

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

# Know your fuel systems

## 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 risk related to any gaps in the pilot's knowledge.

Pilots intending to get a type rating need to make sure they're thoroughly familiar with the aircraft's fuel system and associated procedures. You should closely study the aircraft flight manual or pilot operating notes, 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/auxiliary pumps
- the function of hi/low pump selection
- correct leaning procedures, and consumption rates for different altitude and rpm combinations.

You should also closely study:

- manifold pressure and rpm for maximum range or endurance
- consumption rates of fuel-powered cabin heaters
- the engine trouble checks.

The CAA Flight Test Standards Guide, *Type Rating*, is useful for both instructors and type rating trainees. It's available on the CAA website.

## Currency

If you're not particularly current on an aircraft type, consider whether or not your knowledge about its fuel systems is up-to-scratch. If not, it's time to get out the aircraft flight manual and refamiliarise yourself. It's amazing how quickly important details can be forgotten.

You need to be especially careful when you're transferring between aircraft types with similar – but subtly different – fuel systems. In an emergency it's easy to make an incorrect selection or to revert to a pre-learned response – ie, the incorrect one for that aircraft's fuel system.

 A number of fuel-related accidents in New Zealand can be traced back to the pilot's unfamiliarity with their aircraft's fuel system. 

# Flight planning requirements

## Determining how much fuel is going to be needed

Many fuel-related occurrences are due to the pilot underestimating the amount of fuel needed to safely complete their journey.

There are too many variables, often beyond the pilot's control, to take minimum fuel only.

It's far better to offload some luggage and add more fuel, or to plan an extra fuel stop, than it is to finely cut the fuel calculations.

Planning alternative fuelling points along the route is good practice. At no stage during the flight should a shortage of fuel 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's 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 percent for some aircraft). This is normally done by determining how long it'll 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 those figures are then entered in the fuel-required column of the pilot's flight log.

### *Legal reserves*

According to rule 91.305, the minimum legal fuel reserves (ie, extra fuel over and above that required to complete the flight, taking into account the forecast weather) 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 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 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, for example, is just 12 litres (six litres of usable fuel per tank). 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. It's good practice to fly with more fuel, depending on the type of operation, terrain to be crossed, and the forecast weather.

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

Photo courtesy of  
Matt Morris-Jenkins

Pilots of VFR aircraft get into trouble when they plan their flight making no allowance for the time and distance spent in the climb, which can be considerably more than that over flat, low-lying terrain. They may also fail to recognise how much time they can spend flying in a poor visibility configuration, if the weather deteriorates.

### Contingencies

The fuel-required calculations should preferably include a 'variable reserve' in addition to the fixed legal reserve, to allow for the unexpected – for instance, stronger-than-expected headwinds, fuel consumption greater than anticipated, or diversion due to weather. The amount is normally 10 to 15 percent 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. Doing so has cost a number of New Zealand pilots their lives.

Choosing an appropriate altitude in relation to headwind, true airspeed and leaning for best efficiency can make a difference. It's 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 extra time spent flying in a poor visibility configuration. Consequently, they find themselves low on fuel when they're forced to divert. Marginal or

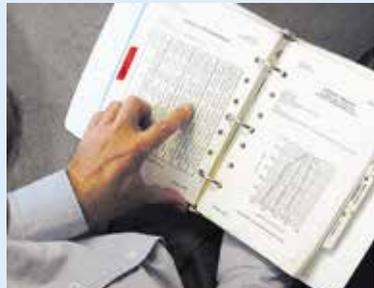
changeable weather situations need to be treated with considerable caution when it comes to planning the fuel required.

### Example

You've 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 35.**



## Consumption rates

Fuel consumption rates can vary considerably between different aircraft of the same type. That's due to their condition, age and the manner in which they're flown. An increase of just 100 rpm for a fixed-pitch propeller aircraft, for example, can increase fuel flow by 10 percent 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 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 will sometimes burn more fuel.

For multi-engine aircraft, consideration must be given to the increased fuel flow on the live engine if training for engine-out emergencies or in a real engine failure.

## Recording fuel requirements

Preparing a neat and tidy fuel log pays dividends in accurate preflight fuel management planning. There's no hard and fast way to set out a fuel management log. Sometimes it's part of flight plan paperwork. Many operators and aero clubs have designed their own. It doesn't matter how you do it, as long as you do have some sort of fuel calculation document.

Whichever method you use, your log should contain the following elements:

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 detailed. To get the fuel-required figures, multiply 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's 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 take-off time, you can record a 'land-by' time once the flight begins. That way you won't 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 example fuel management log on page 11.

### Calculating 'land-by' time – example

As part of preflight 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 mins at 40 litres/hr) = 10 litres

#### Extra fuel for climb

(15 mins at 20 litres/hr) = 5 litres  
 (over and above cruise consumption rate)

#### Fuel endurance

= 150 litres minus 10 litres minus 5 litres  
 = 135 litres at 40 litres/hr = 3.37 hrs  
 (3 hrs 22 mins) Legal reserve = 30 mins

#### Safe endurance

= 3 hrs 22 mins less 30 mins = 2 hrs 52 mins

Note the take-off time, and add the safe endurance to it. That will give a 'land-by' time, which should be noted on the fuel log. If, for example, your take-off 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 in the tanks, provided your fuel management calculations were done accurately to begin with.

During the flight you might get lost, or caught in bad weather, or encounter stronger-than-expected headwinds – or a combination of those factors. That sort of situation can make it difficult for pilots to make even the most basic of fuel calculations accurately. But at least you have a 'land-by' time telling you that once 04:07 UTC has passed you're eating into the legal reserve, and are therefore in an emergency situation.

**Note:** We've 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	3 hr 22				
Flight Time (takeoff to landing)	1 hr 15	40	50	2 hr 52				
Fixed Reserve	30	40	20	Land By Time (UTC)				
Approach	-	-	-	Tank Selection Time (UTC)	Main (l)	Aux (l)		
Alternate Aerodrome	-	-	-				L R	L R
Approach	-	-	-					
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 take-off weight and the centre of gravity 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).

Take-off and climb performance should be borne in mind here – particularly when operating off a short strip or over high terrain.

Definitions and conversion factors relating to preflight fuel planning are shown here to help you.

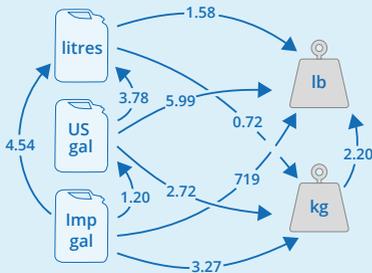
Stickers showing the fuel conversion factors can be obtained from: [publications@caa.govt.nz](mailto:publications@caa.govt.nz).

### Fuel conversion factors

#### AVGAS

For avgas calculations (SG 0.72)

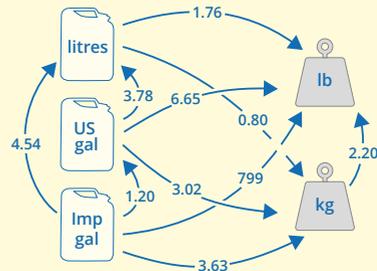
- Follow the arrow and multiply
- Backtrack the arrow and divide



#### JET A-1

For Jet A-1 calculations (SG 0.80)

- Follow the arrow and multiply
- Backtrack the arrow and divide



Term	Definition
Aircraft standard empty weight	The weight of a standard aircraft including the unusable fuel and full operating fluids.
Maximum zero fuel weight	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 take-off weight	Maximum weight permitted for take-off.
Maximum landing weight	Maximum weight permitted for landing.

# Preflight fuel checks

## Determining how much fuel you have

It's good practice to check the fuel available before flight by at least two separate methods. 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 things to consider when you're determining the fuel available.

### Unusable/usable fuel

Understanding the difference between the terms 'usable' and 'unusable' fuel is important.

According to FAR 23.959(a), the unusable fuel supply for each tank must be established as not less than that quantity at which the first evidence of malfunctioning occurs under the most adverse fuel feed conditions.

For conventional aircraft with a forward-mounted engine, that's usually nose up at best angle of climb attitude.

The amount of unusable fuel can vary considerably from aircraft to aircraft – refer to your aircraft flight manual which should show specific figures.

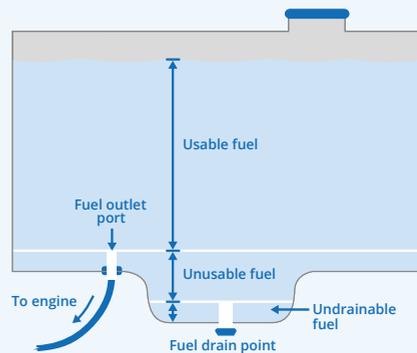
The fuel tank outlets on some aircraft types are very susceptible to becoming un-ported during prolonged unbalanced flight, which eventually leads to fuel starvation and engine failure.

Extreme care must be taken to make sure 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. That's 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. Take care when you're converting between litres, and US or imperial gallons. You should always double-check your calculations.

### Cross-section of an aircraft fuel tank

The usable fuel quantity in this diagram assumes balanced straight and level flight. This quantity may vary significantly in other flight attitudes.



(Not to scale)



Each dipstick has been specifically calibrated to the fuel tanks of a particular aircraft and is therefore not interchangeable with those of any other aircraft, even of the same type.

### **Fuel dipsticks**

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

A good habit is to always keep the dipstick in your hand, or make sure you place it back in the aircraft after use. Leaving it on some part of the aircraft, while you attend to other duties, runs the risk of it clattering from the fuselage, once you begin to move.

Each dipstick has been specifically calibrated to the fuel tanks of a particular aircraft and is therefore not interchangeable with those of any other aircraft, even of the same type.

That's why it should be clearly marked with the aircraft registration and also show whether the figures are total or usable fuel. 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. Any change to the tank will require a new dipstick.

Unfortunately, dipsticks are sometimes in poor condition and their markings hard to read. If that's the case, double-check readings to make sure they seem sensible and arrange to get the dipstick re-marked. Ensure the dipstick shows usable and unusable fuel. Or at least know if it doesn't!

## Tank dipping

The aircraft should be parked on level ground. If that's not possible, dip each tank, turn the aircraft through 180 degrees, dip each again, and take the average of the two values. This will ensure an accurate fuel reading is possible.

Make sure the fuel system is not cross-feeding during dipping. Slope, and uneven fuel quantities in each tank, can cause this on some aircraft. The trap here is that when you're fuelling the aircraft with the fuel selector set to BOTH, the tank you're filling can be cross-feeding to the other.

By the time you've finished filling the second tank, the amount of fuel in the first tank will have reduced. It should be checked again and topped up as required.

Cross-feeding during fuelling, or at any other time, can be prevented in most single-engine aircraft by selecting either the LEFT or RIGHT tank only.

Some light twins have two or more interconnected fuel cells in each wing, which are fuelled from a single filler neck. In that case, time must be allowed for the fuel to transfer to the other cell as the aircraft is being fuelled, to prevent under-fuelling. This can also be the case with single-engined aircraft. Some are baffled to the degree that they suffer from the same issue.

Allowing time for the fuel to transfer from one cell to the other 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 another method is specified in the flight manual. Some aircraft fuel tanks, for instance, must be dipped on an angle, as the main spar is directly below the filler neck.

Quickly withdraw the dipstick and check the indicated fuel level before evaporation,

or 'wicking' occur. (Wicking where fuel soaks into the grain of a wooden dipstick, causing an over-reading.)

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 fuelling to establish the exact amount of fuel on board, even after adding a known quantity of fuel.

Always take a fuel sample from each drain point after fuelling, to check for correct fuel grade, and any impurities.

Do not rely on someone else to confirm the state of your aircraft's fuel. You are the pilot-in-command, and it's your responsibility to do it.

## No dipstick?

If the fuel tanks cannot be accurately or easily dipped, start the flight with the tanks either full, or filled to a fixed reference point, and keep an accurate inflight fuel log. If that's not possible, 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 of avgas, when aircraft are left outside overnight. That's 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 they've been left off completely, after the theft.

A thorough fuel drain before every flight is recommended.



Withdraw the dipstick quickly and check the indicated fuel level before the fuel evaporates, or 'wicking' occurs.

### Fuel gauges

Most fuel gauges read accurately. If they don't, they must be repaired. Gauge accuracy can be easily checked before the flight by dipping the tanks (if that's possible) and comparing the figures with the actual gauge readings. Fuel gauges should always read accurately – they will also give a trend of any excessive use and/or leaks.

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.

You can also monitor the gauge during flight, and compare it with your flight path. Does it make sense that you've used such-and-such a quantity of fuel for such-and-such number of kilometres flying?

If you find that fuel is draining from one tank only, when selected for both tanks, you may have a venting issue.

# Hazards

## Fire or explosion

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 so be especially cautious around those areas.

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 a small spark or a hot surface – and not necessarily in the immediate vicinity, given the ability of fuel vapour to flow long distances.

## 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. That applies to both 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).

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 thousands of volts.

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



## Water contamination

Water is a major contamination of fuel. Rainwater gets in through faulty fuel tank seals; it gets in through insecure storage tanks and truck-mounted tanks. Condensation develops in less than full tanks, especially if the aircraft is parked outside overnight. Water can be trapped, even during sump draining, in wrinkles in rubber bladders in some fuel tanks.

Wherever the water comes from and however it gets mixed in with the fuel, one thing is for sure: it's not good for flying.

A water-fuel mix can lead to partial or total power loss. This often happens just after take-off.

To learn how to minimise the chance of water remaining in your fuel, read "Detecting water and other contamination" on page 23.

// Wherever the water comes from and however it gets mixed in with the fuel, one thing is for sure: it's not good for flying. //

## In a fuelling emergency

If a fire breaks out, call 111 immediately, and extinguish using dry powder, a foam or carbon dioxide extinguisher, or a water fog. Do not use a water jet, as that will spread the burning liquid.

Properly trained personnel wearing breathing apparatus should deal with fires in confined spaces. They should always first make sure an escape path from the fire is available to them.

### *Fuel spills*

Fuel spills are 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, at the very least, should be taken.

- Stop the fuel flow immediately.
- Eliminate all sources of ignition in the vicinity of the spill or released vapour.
- Move everyone, and the aircraft, away from the spillage area.
- Smaller spills should be soaked up using non-combustible absorbent material (eg, sand or 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 – or public – fire service should be called.



### First aid

**Ingestion** – Fuel that’s accidentally ingested may end up in the lungs – particularly following vomiting – where it can cause severe inflammation and breathing difficulties. If fuel is swallowed, do not induce vomiting. Give the person a glass of water or milk and phone 111 for immediate medical attention. If the contamination is not significant, phone the National Poisons Centre for advice, 0800 764 766.

**Inhalation** – Fuel vapour or fumes may cause respiratory irritation resulting in coughing and difficulty breathing. High concentrations of vapour can cause nausea, dizziness, headaches and drowsiness. Move the exposed person to fresh air, administer oxygen if necessary. If breathing remains difficult or gets worse, get immediate medical help.

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

**Skin** – 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.

FUEL  
100LL AVIATION  
GRADE MIN.  
MAXIMUM CAPACITY  
60.8 LITRES  
CAPACITY TO BOTTOM OF  
FILLER NECK INDICATOR  
38 LITRES



# Handling fuel to reduce risk

## Fire or explosion

You should take a number of precautions when you're fuelling an aircraft. You should take the same precautions, regardless of whether the fuel is avgas, mogas, or Jet A-1.

### General

- Fuelling should not be carried out in a hangar.
- Fuelling should not be carried out during electrical storms.
- Make sure all aircraft electrical sources are switched off unless they are required for indications of fuel uplift.
- Check that the type of fuel is correct for the aircraft before starting delivery.
- Make sure there's no-one smoking or using a naked flame within 15 metres of the aircraft. There should be no cellphones, radios, pagers or other portable electronic devices within six metres (unless they've been certified for use in fuelling areas).
- Position the aircraft so that it can be pushed clear of buildings or other aircraft.
- There must be nobody on board the aircraft when it's being fuelled (or defuelled) with avgas.
- Fuelling with avgas must not be carried out with engine(s) running (hot fuelling).
- Personnel involved in the fuelling should wear personal protective equipment.
- Take extreme care if hot fuelling with Jet A-1. Operate in accordance with aircraft flight manual or exposition SOPs.
- There should be a fire extinguisher 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 fuelling, to avoid damage to the aircraft skin around the filler port, or to the internal top of the fuel tank.
- Secure the caps firmly after fuelling. Even if they seem securely fastened, check them. The wire clip attached to the fuel cap securing chain has been known to wedge under the cap, allowing fuel to escape, leading to fuel exhaustion.
- Make sure the pump motor has shut off after the fuel nozzle is replaced.

## Static

The most important thing to do before fuelling is to correctly bond the refuelling equipment to the aircraft. When fuelling from drums, always ensure there's a bonding lead connected to both the aircraft and the drum.

Make the necessary connections before removing any fuel caps. Additionally, it's safe practice to keep the fuelling nozzle in physical contact with the filler hole at any time fuel is being pumped.

That also applies to filling 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. See page 26 for more information.

Filtering fuel through chamois leather is not recommended. Studies have found using 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.

### Bonding

During fuelling, minimising the risk of fire associated with static discharge is dependent on 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.

Make sure 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. Attaching the clip to the exhaust stack is the most common procedure, but some owners don't care for the cosmetic damage that does to their chrome stacks.

Some manufacturers designate the best bonding spot on their aircraft, so check the maintenance manual.

Wherever you choose, make sure the metal is clear of paint. Many people will use the tie-down clip because the electric bond path is closer to the fuel tank(s) in most aircraft, but the tie-down ring is often painted, which degrades conductivity.

It's especially important that composite aircraft bonding is carefully considered. There must be a low-resistance path from the chosen grounding point to the filler neck of the aircraft fuel tank(s).

Equalise electrical potential by touching the nozzle to the metal wing surface or fuel cap

The static bonding cable from the fuel dispenser should be securely attached to the aircraft on a clean unpainted metal surface that will conduct current easily.



Photo: CAA/Jess Jennings



Water



Fuel



Mix of water and fuel

Always be very careful that you identify exactly what's contained in your fuel tank sample. It's not always easy to identify pure fuel, a mix of fuel and water, or pure water.

before opening the cap. Keep the nozzle in contact with the side of the filler neck while fuelling. To avoid scratching the paint on the wing, use a mat, or make sure you hold the nozzle clear and not rest it on the wing.

Also ensure metal parts of clothing, such as zips or buttons, don't make contact with the leading edge of the wing. They can damage the paintwork, and even dent the wing.

## Contamination

Contaminants in the fuel, especially water, have been known to cause engine failure – usually just after the aircraft has taken off.

Regularly check that the fuel tank cap seals are in good condition. Rainwater frequently enters aircraft fuel tanks through defective seals, so if you notice that the cap does not fit tightly, get the seal replaced. Postpone fuelling the aircraft when it's raining heavily, and use a rag to wipe off water around the cap and filler area.

You should carry out a fuel drain after each fuelling. It should also be done before every flight. You should know how many drain points

your aircraft has. If one of the drain points is blocked by contaminants such as sludge or ice, or it fails to work, before flying get the system checked out by your maintenance provider.

After fuelling, allow the fuel to settle for as long as possible. A minimum of 15 minutes per 30 cm depth of fuel for avgas is recommended. For Jet A-1, that recommendation is 60 minutes per 30 cm. This gives any impurities a chance to settle into the drain sump of each tank.

At an intermediate stop, it's a good idea to fuel the aircraft first, before attending to other business. That will normally allow enough time for any water in suspension to settle out.

Some aircraft have long fuel lines, meaning 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, especially drain valves that are hard to reach. Any leaks will result in higher-than-normal inflight fuel consumption, and could even lead to engine failure due to fuel exhaustion.

Fuelling in remote locations increases the risk of contamination. Operators should take every precaution they can to prevent debris entering the fuel supply chain, from the initial fuel supplier to the aircraft fuel tank.

Rolls-Royce cautions against fuelling from remote sites – such as drums – without the use of an external low-pressure fuel filter. Such a filter will prevent contamination of the engine fuel system. If you don't use an external low-pressure fuel filter, the engine can malfunction and even become damaged.

## Detecting water and other contamination

By whatever method available, ensure your sample of 'fuel' is not, in fact, pure water. It has been done! The trouble is, the mild tint in avgas can be 'bleached out' if you hold the sample to the light, so trying to identify it as avgas or water can be quite difficult.

Holding the sample to the light, however, will allow you to detect small globules of water sitting on the bottom of the testing vessel.

Detecting water in Jet A-1 can be even more difficult, because it isn't tinted. When checking for the possibility of water in Jet A-1, use fuel testing capsules or paste, which are good for identifying water contamination. If the sample has a cloudy appearance, there could be a lot of water suspended in the fuel.

Make sure your drain vessel is clean before taking a sample. Hold it to the light and against a white background, and look at it from the side, rather than from above. You should be able to detect any debris, and you can also see if the contents are tinted. If you're in reduced natural light, check the sample under bright lighting and against a white background, such as a fuselage. That will make it easier to identify the colour and detect any debris or contaminants.

A cautious smell of the sample may be enough to indicate the fuel is stale or contaminated.

If the sample does test positive for water – or any other contaminant – empty the tester and continue draining until you get a clean sample. Be sure to empty the sample into a fuel disposal container. Don't tip the sample fuel:

- onto the tarmac because it can degrade bitumen
- onto grass because it can burn the grass, killing it off
- back into the aircraft tank, even if you think it's 'clean'. It just may contain contaminants, given the sample would have been taken from the lowest point in the fuel system.

After you finish sampling, ensure each drain valve closes securely, so you don't lose fuel inadvertently.

If you're using a portable fuel source, such as a jerry can, check a sample from that source before fuelling the aircraft. Truck-mounted tanks also need to be checked regularly for water or other contaminants.



Photo: CAA/Jess Jennings

Make sure the drain vessel is clean before taking a fuel sample.



Always check the fuel tank vents during the preflight inspection. A blocked or deformed vent could lead to engine failure.

Water often collects in wrinkles and low points within fuel bladders. If the aircraft isn't on a level surface and you suspect water or other contamination, move the aircraft to a level surface, and allow the fuel to settle. Then carry out water/other contamination checks. Keep checking until you get a clean sample.

The above procedure may not be appropriate for all aircraft. There are specific ways of doing this for various aircraft, according to manufacturers instructions.

In cold winter conditions, small amounts of water can freeze the drain plug, making it inoperative. It'll need to be warmed to drain any water, for instance by moving your aircraft into the hangar.

Talk to an aircraft engineer if there's an unusually large amount of water in the fuel.

Note that in aircraft with little or no wing dihedral, any contaminants will tend to spread more evenly across the bottom of the fuel tank. Similarly, when checking the fuel on anything other than a perfectly flat surface, the drain point may not be the lowest point in the tank – so a clear fuel sample may not accurately indicate the quality of the fuel throughout the tanks.

Never fuel, therefore, on anything other than a level surface. A large number of high-wing Cessna single engine aircraft have a bladder or metal tank in each wing, but only have one external vent, the outlet of which is commonly located immediately rear the centreline of the wing lift strut. This is to help prevent ice forming in the vent opening. It does not have ram air in the vent opening location.

The vent tube commonly goes into the left-wing tank via a check valve into the tank. A cross-over vent line connects the left and right tank. The right-hand tank has a vented tank cap. The check valve in the left-hand tank prevents the fuel spilling for the tanks in the event that the aircraft is parked one wing low.

During the preflight, check the fuel tank vents are sound. A blocked or deformed vent – and there have been cases of insects building nests inside fuel vents – will mean the engine-driven fuel pump has to work very hard because the fuel tanks are unable to equalise with the atmosphere. That could eventually result in a collapsed fuel tank and possibly engine failure.

Check the vent seals. A perished or damaged seal may also affect the venting of the tank, and therefore the flow of fuel to the engine.

Also, the cap not securely screwed back in place may lead to poor venting. In turn, that may lead to fuel being available from just one tank.

## Hot fuelling of turbine-powered aircraft

Refer to your aircraft flight manual or exposition SOPs about whether you should be hot fuelling.

Never hot fuel with avgas.

Hot fuelling may be a practical measure in certain circumstances. But pilots – and everyone else involved in the procedure – need to remember it can also be extremely hazardous if not done with robust safety precautions in place.

Accidents have happened when improperly trained staff have tried to hot fuel an aircraft. If you're involved in fuelling you should know what you should be doing and when. You need to have been at least briefed – and preferably properly trained – on the procedure for the specific aircraft make and model, the fuelling equipment to be used, and safety and emergency procedures.

Fuelling units should be well clear of the radius of the moving rotor blades of helicopters. Anyone not directly involved with fuelling should also stay well clear. For what are obvious reasons, smoking must be prohibited in and around the aircraft.

Operators need to be mindful that hot fuelling can encourage loose particles and dust entering the fuel system from rotor wash.

## Fuelling from drums

Rust, water, and dirt can all be a problem when fuel is stored in drums.

Fuel drums should be stored on their side with bungs and vents at the three o'clock and nine

o'clock positions. They should have minimal contact with the ground (using wooden pallets for instance) and be stored under cover. The bungs must be tight and seals unbroken before use.

Care must be taken to correctly identify the type and quality (fuel does go stale) of the fuel before fuelling from drums.

Make sure the pump is fitted with a clean and serviceable filter (one that will filter particulate matter, as well as absorbing water).

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 it 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. Ideally the drum should be brought to the vertical three hours before testing. That allows maximum opportunity for any contaminants to settle.

If the standpipe cannot reach the lowest point in the drum, 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.

Sampling the fuel for water and other impurities is a must.

Pump a small amount of fuel into a container to remove any impurities from the hose and nozzle.

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.

## Jerry cans

Traditional metal jerry cans are preferable to ones made of plastic, as long as the linings are regularly checked for corrosion. Plastic jerry cans are acceptable, however, if they're intended for use with fuels and have been manufactured to the Australian/New Zealand Standard 2906:2001. That's embossed permanently on the side of the container.

Do not use plastic containers not designed for fuel. They pose several hazards, including the tendency to accumulate static charge, or the fuel degrading the container material.

Degradation of the gasket in the non-standard jerry can cap is a particular hazard. The fuel can make it brittle and disintegrate, with the fragments then tipped into the fuel tank along with fuel. Over time it can either clog the tank outlet or the fuel system filter(s). Or it can turn



A plastic jerry can that meets AS/NZS 2906:2001. Various labels and warnings are moulded into the container during manufacture, and the white label details safety precautions and first aid procedures.

to mush – and this is possibly more likely in jet fuel – also resulting in clogging of the filter.

In any portable container, water can mix with fuel and other contaminants. You can buy filters which will also separate out water.

The grey mat on the fuel tank of this Tiger Moth, with the red fuel cap resting on it, is a conductive anti-static mat. The pilot is standing on a larger anti-static mat, on the nose. The funnel also has a filter inside it.





A fuel drain should be carried out before the first flight of the day, and after each fuelling.

### Preventing static

Bond the container to the aircraft before opening the caps on either. A jumper lead could be used here if there's no dedicated bonding lead available.

Some portable containers have an integral pouring spout with which contact can be maintained. If a funnel is used, make sure there's continuity between the container, the funnel, and the aircraft.

### Courtesy

After fuelling, and before heading off to complete other duties, it's considerate to move your aircraft away from the pump, clearing the area 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.

### Defuelling

Occasionally, weight and balance limitations mean the aircraft has too much fuel on board and has to be defuelled. This could happen, for example, if the previous pilot had left the tanks fairly full and you want 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.

You must take the same precautions as for fuelling – including doing it outside only and taking all anti-static measures.

There are two ways to defuel: by pumping the excess fuel into an approved fuel container with a suitable hand-operated pump. Make sure the suction end is clean before inserting it into the aircraft's tank.

The second way is from a fuel drain point. Check the valve is seated correctly once you've finished.

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

## Preflight checks

The worst possible time to have an engine failure, or partial loss of power, is just after take-off. Many such events 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.

Those types of incidents can be avoided if the preflight and pre take-off checks are strictly adhered to. The following are commonly used pre take-off checks to verify the integrity of the fuel supply. 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 specific to your aircraft type.

Always check that the fuel selector is in the actual 'detent' for the tank required.

Select the emptier tank for engine start. That will ensure there are no fuel flow problems associated with that tank. Confirm the operation of the electric fuel pump, before starting, by listening for a ticking or whirring noise, and by observing a slight rise in fuel pressure.

After starting, confirm the engine-driven fuel pump(s) are operating properly, by checking that the fuel pressure is stable with the electric fuel pump(s) turned OFF.



Change to the fuller tank before carrying out the engine run-ups. That allows time for the fuel flow to stabilise, and for any contaminants – for instance, water – to pass through to the engine, before the take-off run starts. It also ensures there are no fuel flow problems associated with that tank. It's important to do both a visual and a hands-on 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're about to make is going to achieve the desired result. Pilots of twin-engine aircraft should also check the fuel cross-feed is not selected.

Selecting the fuller tank should be part of your pre take-off check. If you discover that you're on the emptier tank, do not change tanks immediately before take-off. Wait until you're at a safe height. If there's 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 the electric fuel pumps are on, and that the fuel pressure is normal.

Quickly scan the fuel pressure at the start of the take-off roll, and don't be too hasty to turn the fuel pump(s) off on climb-out. Wait until you've cleaned the aircraft up, with climb power set, and are at a safe height. That's one you feel comfortable with, if the engine should stop. That will depend on the terrain.

Monitor the fuel pressure for a brief period afterwards.

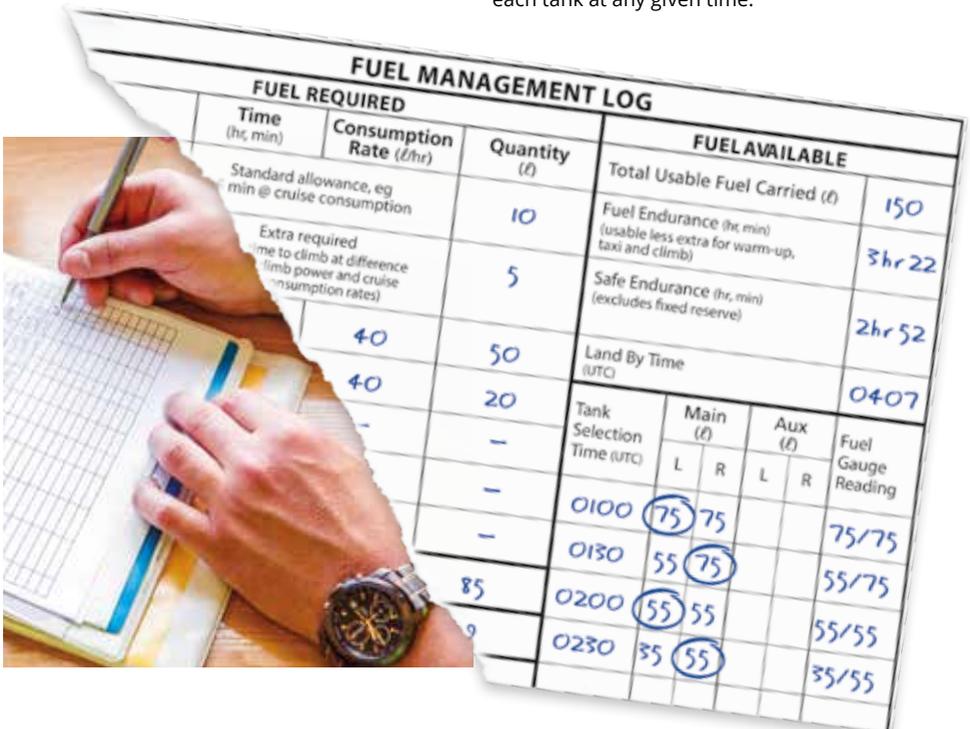
If the engine(s) are fuel-injected, be totally familiar with the likely symptoms of, and the actions required in, the event of an engine-driven fuel pump failure during climb-out or in cruise.

## Inflight fuel practice

### 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 won't forget to monitor consumption, and change tanks when appropriate.

You'll have recorded your engine start time, your take-off time, which tank(s) were selected, and have determined a 'land-by' time. After a suitable period (30 minutes is suggested) 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's possible to see how much fuel (and/or time) should be in each tank at any given time.



FUEL MANAGEMENT LOG						
FUEL REQUIRED			FUEL AVAILABLE			
Time (hr, min)	Consumption Rate (l/hr)	Quantity (l)	Total Usable Fuel Carried (l)			
Standard allowance, eg min @ cruise consumption		10	150			
Extra required time to climb at difference climb power and cruise consumption rates		5	3hr 22			
	40	50	2hr 52			
	40	20	Land By Time (UTC)		0407	
Tank Selection Time (UTC)	Main (l)	Aux (l)	Fuel Gauge Reading			
	L	R	L	R		
0100	75	75			75/75	
0130	55	75			55/75	
0200	55	55			55/55	
0230	35	55			35/55	

If you circle the current tank selection in the 'fuel-available' column you should prevent any confusion over which tank or tanks were selected at any particular time.

You should record fuel gauge readings at the same time, in the neighbouring column, so that any discrepancies can be noted. Re-check your log entries, and re-work your fuel calculations if necessary. What to do in the event of a low fuel state is discussed later in this booklet.

For an inexperienced pilot, the cockpit workload can be high during a cross-country flight. If you're becoming overloaded and lose track of what's in each individual tank, remember that the important figure is your overall fuel quantity, and therefore your 'land-by' time.

### *Leaning*

Several fuel exhaustion accidents have highlighted that an important part of inflight fuel management is correctly leaning the mixture. Planned fuel consumption rates, and therefore range, won't be achieved if the mixture isn't correctly leaned.

The mixture should always be leaned during the cruise (provided 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 percent or less. (The often-quoted figure of 5000 feet is based on the engine being unable to produce more than 75 percent power, even at full throttle, at that altitude.)

On some aircraft, a properly leaned engine, at say 4500 feet, can increase your still-air range by as much as 20 percent 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 percent power set, giving it an endurance of more than five hours.

A combination of increased rpm and incorrect leaning, however, could increase consumption by as much as 15 percent. That equates to a 45-minute reduction in endurance – there goes your reserve, and then some.

Leaning procedures vary considerably between aircraft. Some engines have very basic instrumentation and require the pilot to lean the mixture by ear and reference to rpm. Others have exhaust gas temperature and fuel flow gauges, which allow a far greater degree of accuracy. It's important you're familiar with the correct flight manual leaning procedure for the aircraft you're flying.

### *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 that applies to your aircraft type. It should be left on for a short period, after selecting the new tank and monitoring the fuel pressure. To prevent having to make a hasty tank selection, and to provide continuity of flow, a tank should never be allowed to run dry. That would 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.

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 time to recover if you select the wrong tank.

### *Monitoring fuel quantity*

If you fly hired aircraft, it can often be difficult to know precisely the fuel consumption figures for the aircraft you're using. As we've 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're flown.



/// Several fuel exhaustion accidents have highlighted that an important part of inflight fuel management is correctly leaning the mixture. ///

Incorrect mixture leaning can cause symptoms that mimic fuel starvation.

You should keep an accurate fuel log, and regularly cross-check the figures with fuel gauge readings. After the first landing, compare usage figures with the planned figures. At any stop on a cross-country flight, re-check the tanks with the dipstick.

You should not rely on a fuel log, alone, for monitoring fuel status. Fuel log calculations may not take into account such factors as:

- higher than expected fuel consumption (because of changed power settings, non-standard fuel leaning, or flying at different cruising levels from those planned)
- inaccurate flying
- loss of fuel in flight (eg, a leaking fuel drain, cap, or fuel vent)
- under-fuelling before the flight.

Your fuel log calculations will also be out if your calculations are flawed. Total reliance on inadequate fuel logs has led to 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. It may give you a feel for what the fuel gauge is telling you, or it might be that higher-than-expected fuel consumption can be spotted early.

The bottom line is that you should use every method and aid you have to monitor fuel quantity.

Keep a close eye on the fuel gauge. Some pilots dismiss gauges as unreliable. That's possibly unwise, considering 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.

### ***Diversions and precautionary landings***

If you have to divert due to en route or destination weather, you'll need to re-plan fuel consumption. Make sure you apply all the same fuel requirements: flight time, legal reserve, and preferably, contingency.

If it becomes apparent you're running low on fuel, an early decision should be made to divert to the nearest suitable aerodrome before the lack of fuel 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 does become critical, and it's doubtful there's 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 the decision – aircraft can always be repaired.

A PAN PAN call should be made on a control or flight information frequency, advising of low fuel, and your intentions. Don't 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's 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 usually running through our minds. Ignore them, and take decisive action to divert, or land. Once again, don't wait until the lack of fuel becomes critical.

Always take the safer option of uplifting more fuel en route if there's the slightest doubt about safety margins being maintained. Passengers are normally fully supportive of ample fuel being carried!

### ***Inflight 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 start trouble checks.

Regardless of whether you suspect it's fuel starvation or fuel exhaustion, if there's sufficient time, 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's 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. 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 the checks, you're 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.

If the engine restarts, consider options for an immediate and safe landing at the nearest aerodrome that is suitable for the machine.

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

### ***Things to check before landing***

Ensuring fuel flow integrity for the approach and landing is an important part of 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 beginning an approach. The fuel pressure should also be checked to make sure it's normal.

## Postflight actions

### *Determining consumption*

It's 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. That 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.

// Condensation can form inside a fuel tank when water vapour in the air trapped in the tank condenses as it cools. //

### *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's going to be parked outside overnight. Condensation can form inside a fuel tank when water vapour in the air trapped in the tank condenses as it cools.

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.

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).

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 fuelling, by observing general precautions and appropriate bonding actions
- know what to do in a fuel spill
- be careful when fuelling from drums or jerry cans, as they can be susceptible to water and dirt contamination
- always take a fuel sample before each flight, and after fuelling (wait for the tank contents to settle first).

Above all, don't ever become complacent during fuelling.

## To minimise the chances of unexpectedly running out of fuel:

- become thoroughly familiar with the fuel systems of the aircraft you fly
- know the fuel consumption rates for different altitude and rpm combinations
- know the manifold pressure and rpm for maximum range
- plan your flight carefully and ensure 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
- don't forget your fuel swipe card(s). Check AIP Vol 4 that fuel is available for the cards you carry

- be thoroughly familiar with the usable and unusable fuel quantities for all the aircraft types you fly. 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 and impact of it occurring
- do your pre take-off checks thoroughly
- know the correct mixture leaning procedure for the aircraft and lean the mixture in the cruise whenever possible
- keep an accurate inflight 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 the state of your fuel
- you must always plan to land with your legal reserve intact
- be familiar with the trouble checks and know how to prioritise your actions if the engine fails
- regularly dip the tanks after flight to determine the aircraft's actual fuel consumption rate
- always leave the aircraft parked on level ground to avoid cross-feeding or overflow. If that's not possible, turn selector to the uphill tank.

### Answer to question on page 9:

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 en-route fuel stop to ensure that the reserve is not compromised.

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**Good Aviation Practice**

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See the CAA website for Civil Aviation Rules, advisory circulars, airworthiness directives, forms, and more safety publications.

To request publications such as GAPs and posters email: [publications@caa.govt.nz](mailto:publications@caa.govt.nz).

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