Fuel Awareness

In the past decade, more than 1,700 accidents have resulted from poor fuel management.

Almost home

You're almost home. Through your headset the engine beats louder as you wait for the sound of silence, and the knot in your stomach grows larger as time seems to slow down. Your last refueling opportunity is well behind now. It will surely take longer to turn around than to press on, and you wonder if backing off on the power will make a difference. But the airplane's going so slowly already that you decide to leave the throttle alone. One good thing about this groundspeed: It gives you plenty of time to pick out suitable landing sites—at least in daylight. But night fell an hour ago, and intuition tells you that surviving a forced landing now will be more a matter of luck than skill…

This is the kind of scenario that often leads to a fuel exhaustion accident. Through a combination of circumstances and poor decisions, otherwise prudent pilots crash short—often in sight of their destination. Most pilots can recall a time when they dipped into the reserves, and most vow never to do it again. But somebody always does.

In 2004, 79 fuel exhaustion accidents occurred, of which four were fatal. In the same year, another 39 accidents (seven fatal) were attributed to fuel starvation, and 18 (five fatal) were a result of fuel contamination.

There's a lot to know about fuel and fuel management. In the following pages we'll discuss these subjects in detail, but first let's look at a few things you can do to reduce your chances of having a fuel-related accident:

1. Know How Much Fuel You Have: You can't know your range unless you know how much fuel you have, but knowing that isn't always easy.

- **Think of fuel not in gallons or pounds, but hours and minutes.** Why? Because fuel burn is a constant. The engine, barring malfunction, will always burn the same amount at a given combination of altitude, power setting, and mixture setting, but range will vary constantly due to changing winds and ground speeds. To know how much time you have, you need to know how much fuel your engine really burns. The POH (pilot's operating handbook) figures will get you close, but only experience will tell you for sure.

Tip: The AOPA Air Safety Foundation recommends that pilots of unfamiliar airplanes add one or two gallons per hour to their computed fuel consumption until they see how much the airplane actually burns.

- **Know for certain how much usable fuel is on board.** Fuel computers will tell you how much you're burning and how much you have left, but the pilot still has to input the starting fuel quantity. A calibrated dipstick is a good way to measure fuel, but be sure it's calibrated for your airplane: Some airplane models have several options for fuel tank capacity.

  Departing with full tanks is a good tactic, but it isn't always possible. Most airplanes exceed weight and balance limitations with full fuel, all seats occupied, and maximum baggage. Some airplanes can be difficult to fuel completely. And what about the pilot before you who says, "I only flew an hour off of full tanks"? Were they really full? Did he/she lean the mixture? Trust but verify. It's **your** safety and certificate on the line.

2. Know Your Airplane's Fuel System: Pilots must also be familiar with and proficient in operating the fuel system on their airplanes. Fuel management on a Cessna 150 is easy. Two wing-mounted tanks simultaneously gravity feed fuel to the engine and the fuel selector is either on or off. Compare this with a low-wing single boasting two main, two wing auxiliary, and two aftermarket tip tanks with an engine-driven primary fuel pump, electric boost pump, and electric fuel transfer pumps. It's not surprising that pilots have made forced landings with fuel still available.

Accident Report: A student pilot was flying a Piper Arrow on a solo cross-country flight when the engine stopped due to fuel starvation. The student successfully navigated to a nearby airport and made a forced landing. Afterwards, it was discovered that although one tank was empty, the other contained enough fuel for at least 90 minutes of additional flight. The pilot recalled completing the engine failure checklist (which included switching tanks) twice, exactly as taught by her instructor. Unfortunately, in the heat of the moment, she took her training too literally: As she recited the checklist she touched each of the controls but ***didn't move them.***

3. Know What's in Your Fuel Tanks: Pilots must ensure that their tanks contain the proper grade of uncontaminated fuel. That means making sure that no water has gotten into the tanks, and verifying that the tanks haven't been filled with the wrong fuel. For more information, be sure to read ASF's *Misfueling Safety Brief*.

Take samples to verify that you have uncontaminated fuel of the proper type and grade.

4. Update Your Fuel Status Regularly: Winds are rarely exactly as forecast and weather deviations add miles and minutes to your trip. We recommend that pilots evaluate their fuel status each hour. If you know how many minutes of fuel you have and how long it will take to reach your destination or fuel stop, it's easy to know if you'll need your reserve.

Digital fuel computers and graphic engine monitors can make it easier to track fuel status and lean the mixture properly.

5. Always Land with Adequate Reserve Fuel: Federal Aviation Regulations (FARs) require different fuel reserves for different operations. Regardless, **the AOPA Air Safety Foundation recommends that pilots always LAND with at least one hour of fuel in the tanks.** This does not mean searching for an airport when approaching the one-hour reserve: It means being on the ground.

Now that we've hit the major points, let's add some detail.

Avgas

The earliest airplanes used automobile, motorcycle, or tractor engines, and low octane fuel was sufficient to power them. But with the introduction of high compression engines and the special requirements of flying machines, aviation gasoline (avgas) was developed. Volatile, low octane fuel burned too easily in high compression engines. This resulted in combustion before the spark plug fired while the piston was still compressing the air/fuel mixture. To prevent this damaging preignition or detonation, lead was added to avgas to slow down the combustion process. The combustion quality of fuel is expressed as an octane number. Effectively, the higher a fuel's octane rating, the more resistant it is to burning.

100 low lead (color dyed blue) is the most common avgas today, but 80 (red) and 100 octane (green) avgas can still be found.

Jet Fuel

Jet fuel is very different than avgas. Like kerosene, it burns at much higher temperatures than gasoline engines can withstand. Because jet fuel will damage or destroy gasoline engines, a number of safety precautions (color-coded wing decals, special nozzles for jet fuel, etc.) have been put in place to prevent misfueling.

Jet fuel nozzles are shaped like a duck's bill, and will not fit into standard avgas fueling receptacles.

Autogas

Although automobile gasoline (autogas) can be used in some airplanes, remember that aircraft engines are generally designed to run on avgas. For a number of reasons, your airplane might not be able to use automobile gasoline:

- It has looser manufacturing specifications and quality control is less stringent, so quality and performance vary widely.
- Because of less careful handling, the risk of contamination is greater.
- Physical and chemical property differences can lead to poor fuel distribution, poor anti-knock properties, and excessive motor oil dilution. Additionally, autogas is less stable and more likely to gum up.
- Because autogas is more volatile than avgas, it is more prone to loss through excess vaporization, vapor lock, and carburetor icing.

Nonetheless, many pilots use autogas in their airplanes successfully. This is because they've had Inspection Authorized (IA) mechanic perform aircraft modifications mandated by a Supplemental Type Certificate (STC). After the STC has been completed, the aircraft can be fueled with 80- or 100-grade autogas, depending upon the type of certification.

As pressure to supplement fossil fuels with renewable energy sources increases, more and more automobile gasoline is being blended with ethanol. Pilots operating aircraft with autogas STCs should be aware that they do ***not*** allow the use of alcohol-blended fuels (ethanol or methanol), as they can damage fuel system components and cause other problems.

Aircraft Fuel Systems

General aviation airplanes carry fuel in one or more main tanks; some have auxiliary tanks as well. Fuel tanks are predominately metal, but some airplanes have synthetic rubber bladders. In rare cases, a number of tanks may be interconnected and filled through one opening, but each tank generally has a capped opening for filling, a fuel line to the engine, and (in fuel injected designs) a return line to convey excess fuel from the engine back to the tank. Each tank also has one or more drains to sample fuel and one or more vents to admit air. If the tanks were not vented they would collapse as fuel is consumed.

All airplanes have a means of selecting which tank or combination of tanks is in use and of shutting off all fuel to the engine. Some airplanes, such as the Cessna 150/152, feed from two tanks at the same time. The fuel selector valve has an On and an Off position. Others (like the Cessna 172) have Off, Left, Both, and Right fuel selector positions. Most low-wing singles are not able to feed from both wing tanks at the same time.

Caution: The location of the fuel selector valve varies and in some designs the valve is hard to see. To avoid fuel starvation, pilots must be sure they are moving the fuel selector correctly. This may mean moving the pilot's seat and using a flashlight—especially at night. Switching tanks should not be done at low altitudes: Perform pre-landing fuel tank selection before reaching pattern altitude.

In most carbureted high-wing designs, gravity feeds fuel to the engine. Most higher power and high-altitude, high-wing designs also have an auxiliary fuel pump. If the fuel supply is lower than the engine, fuel must be pumped,

and most low-wing designs have at least two fuel pumps. The main pump is usually mounted on the engine and driven mechanically. The auxiliary electric fuel pump may be used for priming, high-altitude flight, or as an emergency backup should the mechanical pump fail.

Fuel selectors on some aircraft can be difficult to see and manipulate, particularly in a dark cockpit.

Caution: Fuel pump configuration and use varies from one model to another, and sometimes within a model. Some designs require the boost pump to be on for landing and takeoff; in other designs the boost pump is used only for high-altitude operation or when the mechanical pump fails. Pilots must be familiar with fuel pump operation for each airplane they fly.

Finally, some sort of fuel quantity indication is provided for the pilot. Some fuel gauges have a yellow arc. Because maneuvering on the ground or in the air could move fuel in the tank away from the outflow ports, fuel represented by the yellow arc should only be used in cruise. Even if there is no yellow arc on the fuel gauge, pilots should avoid sharp turns when entering the runway before takeoff if fuel tanks are not full.

In glass-panel aircraft, fuel quantity may be shown on a multifunction display.

Managing Fuel in Flight

To maintain lateral balance in airplanes that cannot simultaneously feed fuel from both wings, try to keep the tanks as equal as possible (within reason). For example: After takeoff, you might fly for half an hour on the left tank, and then an hour on the right tank, switching hourly thereafter. This should keep you from having more than a half-hour's fuel imbalance at any given time. Many pilots mount a timer in plain view to remind them to switch tanks.

Switch tanks regularly in aircraft that cannot use fuel from both wings simultaneously.

Leaning the Mixture

The performance, range, and endurance figures listed in the POH are based on a properly leaned engine. The POH can't tell you how fast, far, or long you'll fly unless you lean the mixture. Although many pilots think that leaning is only for high altitudes, the truth is that most engines can be safely leaned at any altitude so long as they are operating at less than 75 percent power. (Consult your POH for information on calculating percentage of power.)

If leaning is so important, you'd think that it would be one of the first things taught in flight training. Unfortunately, that's not the case. Some student pilots are never taught to lean the mixture, and that can spell trouble when they later try to get "book" range and endurance. Failure to lean is commonly cited as a factor in fuel exhaustion accidents.

Learn how to lean your engine, and make leaning a habit on every flight. Some general guidelines are presented below. For specific information, see your airplane's POH or the engine manufacturer's operating instructions.

It's impossible to achieve "book" performance, range, or endurance unless you lean the mixture.

Leaning manually: On basic airplanes, set cruise power and lean the mixture until the engine runs rough. Then slowly enrich the mixture until the engine smoothes out. You may see a slight increase in rpm before the engine starts to roughen. If you need to climb to a higher cruising altitude, enrich the mixture before adding power (if you're at or above 75 percent power) and then lean again when level at your new altitude.

Leaning with EGT: Many airplanes are equipped with exhaust gas temperature gauges, or EGTs. As the mixture is leaned, the combustion temperature increases until it peaks. If the mixture is leaned beyond that peak, combustion temperature decreases because there isn't enough fuel to maintain the high temperature. The most economical mixture setting is usually obtained near peak EGT. For best power, lean to peak and then enrich by 75 to 125 degrees Fahrenheit. *This varies with engine type and installation.*

Leaning for takeoff: At high-density-altitude airports, you'll have to lean before takeoff to maximize engine power. Consult your POH for details.

Tip: Two typical mixture settings are "best power" and "best economy." Best power provides the highest speed for a specific power setting. Best economy trades some of that speed for decreased fuel consumption, and gives the best mileage available at a particular power setting.

Carburetor Heat

As air moves through a carburetor its temperature drops and, if conditions are right, water vapor in the air can condense and form ice. Most carbureted aircraft are equipped with a control that routes heated air to the carburetor to melt the ice and keep it from re-forming.

Operating with carburetor heat results in a richer mixture because the heated air is less dense than ambient air. Pilots should lean while operating with carb heat and enrich when it's no longer needed.

Applying carb heat enriches the mixture and increases fuel consumption for a given power setting.

Accident Report: A private pilot was en route from Boston to an airport in northern Virginia. Shortly after passing Dulles Airport, the engine failed due to fuel exhaustion. The airplane was destroyed and the occupants were severely injured in the night, off-airport landing. The pilot stated that he had made the trip many times before with enough fuel to reach his destination but, on this flight, carburetor heat was applied shortly after takeoff and remained on until the landing. The richer mixture resulted in fuel exhaustion ten miles from his destination.

Estimating Fuel Consumption

Using tabular data, charts, or graphs, the POH shows fuel consumption for various power settings. This will give you some idea of what the fuel consumption will be, but remember: Fuel consumption figures are based on a properly leaned engine operating at a specific power setting.

Tip: One way to get to know your fuel consumption is to estimate how much fuel your airplane will take at each fuel stop. Comparing this estimate with what actually goes into the tanks is an excellent way to develop "fuel sense." Many pilots make a game of this—seeing how close the fuel bill is to their prediction.

In flight, recalculate range and endurance hourly. Compare your range calculation with the distance to your destination to make sure you maintain an adequate fuel reserve. By doing this, you can make timely adjustments to your flight plan for unforecast winds, or weather deviations. A GPS receiver can be a valuable aid in managing fuel consumption. The GPS provides accurate information about ground speed and time en route, which are essential parameters for determining adequate fuel reserves.

Accident Report: Before departing on a cross-country flight, the pilot of a Piper Cherokee Six requested that the two main tanks and two auxiliary tanks be "topped" (the FBO subsequently stated that only the mains were filled).

En route, the pilot became aware of a low fuel condition. A passenger stated that the pilot considered landing at a towered airport for fuel but, having a radio problem, elected to continue to a nontowered airport. The engine lost power about five miles from the field and an off-airport landing was made. The pilot and two passengers died. The three remaining passengers were seriously injured. **Note:** *This accident, and many other fatal fuel-related accidents, occurred at night. The added difficulty of making a successful off-field landing at night makes additional fuel reserves a very good idea when flying after dark.*

Extending Range

Long deviations around weather, stronger than forecast headwinds, or discovery of a low fuel condition may require you to maximize fuel economy. Let's take a look at some ways to conserve fuel.

- **Slow down:** You'll burn less fuel if you cruise at a lower power setting.
- **Fly with the wind:** If you have a choice of equidistant fuel stops, pick the one that's downwind. You may have to backtrack but you'll burn less fuel and get there faster.
- **Lean for best economy:** Consult the POH for best economy/long endurance power settings and leaning procedures.

Obviously, pilots should make adjustments to their flight plan before fuel becomes a critical issue, but if you're low on fuel or, worse, dipping into the reserve, land as soon as possible. Don't wait for the FBO with the best price or the preferred credit card.

Tip: Pilots coordinating with ATC and running low on fuel can declare a minimum fuel advisory. This means delays cannot be tolerated and will likely result in an emergency situation.

The Fueling Process

Most FBOs that provide fuel also have line personnel to dispense it, but self-service fuel facilities are becoming very common. Whether supervising the service or performing it themselves, pilots should know about the fueling process.

- The first thing is to make sure there will be fuel and some way of dispensing it when you arrive. This isn't likely to be a problem at large FBOs, but be sure to call ahead if you don't want to take a chance on spending a night in the airplane.
- Make sure the airplane is grounded. Static electricity in your hair or on your clothes can be annoying. Static electricity around gasoline can be explosive. This is why line personnel attach a ground wire to the airplane before fueling.

Always make sure that the airplane is properly grounded before beginning the fueling process.

- Make sure the proper type and grade of fuel will be used. Most fuel trucks and pumps are clearly marked. If not—or if you're in any doubt as to the quality of the fuel—sample it before putting it into your tanks.
- If you intend to fly with full fuel, make sure the tanks are absolutely full. If the airplane is not on a level surface it will be impossible to fill the tank completely. When fuel tanks are interconnected, as in many Cessna models, fuel will flow to the lower tank if the airplane is not level, possibly resulting in loss of fuel through the tank vents. Fuel expands when heated, so if your plane is filled with cool fuel from underground tanks, you may lose some fuel through the vents due to expansion. Similarly, a full tank in mid-afternoon may be less than full after it's cooled overnight.
- Some airplanes, such as the Cessna 210, require each tank to be fueled at least twice. Due to the geometry of the wing and internal tank baffles, it takes some time for the fuel to diffuse into the tank. Fill one tank, then the other. When the process is repeated, an additional four to five gallons can be added to each tank.
- Take a generous sample of the fuel you've received. It's a good idea to pay for the fuel and attend to other last minute details before sampling. That way any contaminants will have some time to settle to the fuel tank sumps before you check them.

Take a generous fuel sample after allowing time for contaminants to settle.

- Make sure that you have the proper fuel type and grade. For more information, read ASF's *Misfueling Safety Brief.*

- Finally, make sure the fuel caps are secure. If you lose a fuel cap in flight, fuel can siphon out of the tank at an alarming rate, and if you're in a high-wing airplane or flying at night, you won't be able to see it.

Double check that fuel caps are fastened securely.

Disposing of Fuel Samples

Apart from being a fire hazard, discarded fuel samples can destroy asphalt ramps over time, and evaporated fuel contributes to pollution. For those reasons (and because it's illegal in many places) it's not a good idea to throw fuel samples on the ground, or into the air. Some pilots shudder at the thought of pouring samples back into the tank; but if the fuel is uncontaminated, why not put it back? Some airports provide special containers for disposal of waste fuel, and pilots can purchase strainers to filter contaminated samples.

The Bottom Line

Of all the factors that lead to aircraft accidents, fuel is one of the easiest to address. If you know your fuel system, verify that you have the right type and quantity of fuel, lean your engine properly and stay alert to changing conditions, the odds of a fuel-related mishap are virtually nonexistent.

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