Running On Empty

Fuel exhaustion is a preventable threat. Planning and in-flight diligence are key to ensuring healthy fuel margins. This article originally appeared in Aviation Safety Magazine.

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My flight school required us students to fill out a TOLD (takeoff and landing data) card with weight and balance, and fuel planning prior to each flight. Most of the time, our flight training was consistent: 1.0-1.5 hours of block time, full fuel, two passengers, a couple of flight bags. Plan it once and it's usually the same next time. Other than verifying the tanks were full and free of contaminates, we hardly even considered fuel unless we suspected a leak or imbalance.

Conservatively, that typical training flight left us with about 3.5 hours of reserve fuel. Since topping the tanks before an instructional flight is standard procedure for many training organizations, those same numbers often apply elsewhere. My longest flight during primary training was from New Bedford, Mass., to Lancaster, Penn., with a quick detour down NYC's Hudson River SFRA. The great circle distance is 260 nm, and quick-math fuel planning puts the one-way flight at around three hours, leaving two hours of reserve fuel at the ETA. Top the tanks again and motor back home, and the same ample fuel cushion applied.

It wasn't until I started flying professionally that I needed to balance realistic fuel planning with payload and just a dash of bargain hunting. Add in a plane where tankering fuel with no passengers can leave you forward of the CG envelope, and a full boat with luggage could leave you aft, and you are left with a nice preflight puzzle. Obviously, the number one priority when preflight planning is a safe fuel load, but being able to extract a useful payload out of the aircraft is part of why we play the game.

Realistic Vs. Legal

When we want to extract every ounce of payload out of an aircraft, we want to ensure at a minimum we meet the legal requirements for the flight rules we're operating under. Using a theoretical aircraft with a math-friendly 10 gph fuel burn, let us look at some legal fuel requirements for some different situations and scenarios.

Day VFR, one-hour flight: 10 gallons for the planned hour, plus a five-gallon reserve to give us 30 minutes at normal cruising speed for a minimum of 15 gallons. For night VFR, also a one-hour flight, but 10 gallons plus 7.5 gallons reserve to cover 45 minutes of normal cruise flight. Coincidentally, this is the same requirement for instrument flight when no alternate is required.

For an instrument flight, it's still one hour, with an alternate 20 minutes away: That's 10 gallons for the planned flight, 3.5 gallons (rounded up) to reach the alternate airport and 7.5 more gallons to meet the 45 minutes of reserve fuel required under IFR, for a grand total of 21 gallons.

Some of you may be thinking that the legal floor seems a little low, and I agree. This is where I factor in realistic fuel. My first major consideration is weather. Winds can vary substantially from the forecast, which can drastically change the fuel consumption. Routing around thunderstorms or changing altitude for icing or turbulence are options I like to exercise, which require a little extra fuel for breathing room.

An additional consideration exists for aircraft cruising in the flight levels. Most flight planning software will calculate the 30-45 minutes required at planned cruise flight, when more than likely you will not reach those same altitudes during a diversion. For example, when I was flying a Pilatus PC-12 and cruising at FL260, the fuel burn was about 350 pounds per hour, meaning 45 minutes at that altitude consumes about 262 pounds of Jet A. But if we were diverting to another airport at an altitude of, say, 4000 feet, we may have been burning 500-600 pounds per hour. The 262 pounds of fuel we computed for the 45 minutes the FAA wants us to carry disappears a lot quicker at lower altitudes. Also see the sidebar on the opposite page for a real-world example involving the editor-in-chief's airplane.

Speaking of breathing room, I always like to consider my options when fuel planning. Am I flying over several suitable airfields, or is my destination an hour away from civilization? It is worth considering the destination airport itself. One of my more unexpected diversions occurred on a beautiful day where an unlucky gear collapse shut down an airport's single runway for far longer than my reserve fuel load.

Factor in these variables with how difficult it can be to verify in-flight fuel quantity (as discussed in the sidebar below) and I think we all appreciate some margin. Realistic fuel could mean rounding up the fuel burn, calculating a contingency route or padding reserves to an hour (or more!). A technique I prefer is getting the anticipated payload sorted prior to the flight, which admittedly can involve asking some awkward questions about passenger weights and baggage. Once you know how much weight is required for payload, it boils down to max ramp/takeoff weight and performance. If the amount of fuel that you can load up is greater than your comfortable realistic fuel, full steam ahead. Otherwise, a fuel stop is the best option.

Fuel Stops

I am a lifetime member of “team fuel stop” because generally my bladder and my need to stand up at least once every two hours limits me more than my fuel range. Admittedly, there is a satisfaction in getting a tight trip done without it, especially if the aircraft is comfortable. I never push my luck and the older I get, the more I appreciate a quality fuel stop. Here is what I look for when shopping around for a pit stop.

- Fuel is available and affordable.
- There are ground services available, such as restrooms and maintenance.

- Good forecasted weather.
- If instrument rated and filing IFR, a good variety of approaches.

Bonuses include an on-field restaurant, crew car availability and proximity to a town or community. Unplanned overnights do happen, and I have been stuck in areas where I had to walk to a hotel because the only cab in town shut his phone off at 7pm.

Check Notams and call the FBO or airport manager if there are any questions. Nothing worse than making a fuel stop only to find the airport doesn't have fuel!

Pre-Flight Checks

All the preflight planning in the world will not help you if the airplane is mis-fueled. This can come in the form of an inappropriate quantity of fuel, wrong type of fuel or contaminants. The first concern can be mitigated with a proper dipstick and the latter two with sumping the fuel and/or being present while the aircraft is fueled. There are safeguards to prevent aircraft from being filled with the wrong type of fuel, but it can happen. Most of the stories I am aware of involve a type such as PA-46 which can be piston or turboprop, paired with an older fuel truck lacking different nozzles for specific fuel types.

Trust, but verify. Always check the quantity and quality of the fuel before departure. Sometimes, either a math error or a fueling error leaves you a few gallons short. It can be tempting to adjust your margins, especially if external pressures are pushing you to depart. There are times where I flew a few pounds or gallons short of the fuel I wanted, or the conditions changed right at departure time and I talked myself into departing with reduced margins. Even when it worked out, I spent a significant portion of the flight eying my fuel and weighing my options, which is never fun. Not once have I regretted adding a few gallons, even if it caused the fueler to roll their eyes.

Real-World Alternate Planning

As Ryan touched on in his article's main text, fuel burn at cruise altitude typically isn't the same as when missing an approach, climbing out and diverting to an alternate. It's usually much less, in fact. So, when we compute the fuel necessary to divert to an alternate, we probably shouldn't use cruise fuel flows alone. Some real-world numbers from my Beech Debonair can be instructive.

I typically cruise the airplane's IO-520 at around 13 gph. But it runs through 30 gph of avgas at full throttle, as when taking off or during initial climb. For most of my trips involving a climb to altitude (e.g., 8000 feet msl or higher), I'll burn 18 gallons during the first hour, and then 13 each hour thereafter. Most of that is from running the engine wide open and well rich of peak exhaust gas temperature during the climb to ensure it stays cool. The time spent at a reduced power setting while descending for the destination typically burns around 10 gph. A 500-fpm descent from 10,000 feet to a sea-level airport takes 20 minutes.

How much real-world fuel do I need to take off, climb to 10,000 feet, cruise for four hours, descend to sea level, climb back up to, say, 4000 feet, divert 50 miles, shoot an approach and land? Let's add it up:

Flight Phase	Duration	Fuel Burn (gph)	Gallons Required
Take Off, Climb	1 hour	18	18
Cruise	3 hours	13	39
Descend, Fly Approach	0.5 hours	10	5
Miss Approach, Climb to 4K	10 minutes	30	5
Cruise To Alternate	20 minutes	13	4.5
Reserve	45 minutes	13	11.5
Total Fuel Required		**(gallons):**	**83**

Compare this result to the typical math one might use: Four hours of cruise at 13 gph, plus 20 minutes to divert, plus 45 minutes is 05:05 hours @ 13 gph = 66.5 gallons. Unless you account for the initial climb, descent, maneuvering for the approach, the missed approach and subsequent climbout, you're underestimating the fuel required and limiting your options. And this presumes you don't forget to lean aggressively during the divert. As Ryan indicates, turbine engines also can see a sizable difference between simple-math planning and the real-world. — J.B.

In-Flight Checks

Aircraft and navigation logs offer several tools to monitor fuel consumption during flight. Even the most inaccurate fuel gauges are worth keeping in the scan and verifying against the expected burn at checkpoints along the route. Catching an imbalance early simplifies things and can be lifesaving if a fuel leak occurs. Additionally, higher than expected fuel consumption can trigger a closer look at the aircraft or the winds, which may warrant something as minor as an altitude change to something as major as a diversion short of the destination.

The more advanced avionics packages subtract known fuel flow from the starting fuel on board; others may tally the running fuel burn. If there is a winds aloft display, intermittently crosscheck the actual winds aloft with the forecast on your navlog to ensure there is not a substantial disparity. Many aircraft also can display the estimated fuel on board at the destination, which is a number that should be cross-referenced with the calculated landing amount. If that number falls below comfortable reserves, a change needs to occur. Long story short, use all tools available and constantly compare the actual fuel burn and fuel on board versus the preflight calculations.

Land And Live

Outside of major mechanical malfunction, every time an aircraft lands off-airport due to fuel exhaustion, there are several links in the chain that could have been broken with due diligence. If you find yourself stretching the range of an aircraft, maximizing the payload or being forced to use an undesirable alternate, alarm bells should be ringing.

Once in flight, if you are looking at the fuel remaining and feeling uncomfortable, you can always take the advice put forth by the Helicopter Association International and its "Land and Live" program. Developed by former HAI President Matthew Zuccaro, the program is designed to give helicopter pilots "permission" to set down somewhere when and where they need to help prevent an accident, whether caused by mechanical failure, weather or some other factor.

Of course, helicopter pilots may not have to fly as far as fixed-wing pilots to find a suitable landing area. But it's hard to go wrong following their advice.

Accurate When Empty?

One of the more enduring aviation myths is that the airplane's fuel gauges need only be accurate when empty. The FAA's *Pilot's Handbook of Aeronautical Knowledge* (PHAK, FAA-H-8083-5C) at page 7-26 directly states, "Aircraft certification rules require accuracy in fuel gauges only when they read 'empty.' Any reading other than 'empty' should be verified."

That's not the full story. Small airplane certification rules are in FAR Part 23 and large airplanes are covered in Part 25. For large airplanes, FAR 25.1337 states:

"Fuel quantity indicator. There must be means to indicate to the flight crewmembers, the quantity, in gallons or equivalent units, of usable fuel in each tank during flight. In addition—

(1) Each fuel quantity indicator must be calibrated to read 'zero' during level flight when the quantity of fuel remaining in the tank is equal to the unusable fuel supply

determined under § 25.959."

For small airplanes, FAR 23.2430 states each fuel system must provide "the flightcrew with a means to determine the total usable fuel available."

See FAR 91.205(b) and Advisory Circular AC 23-17B if you want to further muddy the waters. I see why the PHAK is phrased the way it is, but the fuel gauge should at least have the appearance of working. It does not need to be accurate to the gallon, but if the airplane is fueled to the tabs and indicating zero, even though it would *also* read zero with no usable fuel left on the plane, that should be fixed.