Personalized Fuel Minimums

How to avoid saying, **"I am declaring min fuel"**

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Professional pilots consider regulatory and personal fuel minimums before answering the "How Much?" question.

The time to worry about fuel loads is before the fuel truck ever shows up, not when you are No. 5 in a holding pattern with your last alternate about to go below weather minimums. As a professional pilot you are also a part-time aeronautical engineer, meteorologist and risk management analyst. You can add petroleum scientist to that list. Don't believe me? Try this riddle on for size:

How can a Gulfstream V make it from San Francisco to Tokyo in a headwind routinely, but sometimes struggle to make Tokyo to San Francisco with a tailwind?

The answer does not have anything to do with routing, hemispheric altitudes or byzantine Japanese departure procedures. But it does have everything to do with fuel. And even if you're not flying an ultra-long-range aircraft, you need to understand how fuel density impacts how much Jet-A you can load on your aircraft, how your company fuel minimums may not be enough, how your flight-planning software can lie to you, and how your aircraft fuel measurement system can trick you into taking less than you need. You also need to know what to do when it all goes wrong.

About Fuel Density and Dictates

The answer to our GV riddle perplexed early Gulfstream pilots for years, so much so it was a common complaint against the airplane's fuel system. Every aircraft was tested for a full capacity of 6,118 U.S. gal. Aircraft attitude during refueling was found to have only a negligible impact on total fuel capacity. The fuel measurement system specification of +/-300 lb. was bested by every aircraft tested. The engineers had to dig further and came up with the answer: fuel density.

Studies reveal fuel is denser in the Western U.S. than in the Far East. Given the GV's maximum fuel volume is fixed at 6,118 gal., the highest allowed Jet-A fuel density of 6.99 lb./gal. would permit a fuel load of 42,764 lb. The lowest allowable density of 6.46 lb./gal. would leave a fully loaded GV with only 39,522 lb. of fuel. This variation of 3,242 lb. could reduce the aircraft's range by almost 2 hr. There's nothing you can do to fix low fuel density except be forewarned: Never count on a full load of fuel leaving airports in Asia.

If you aren't topping off your tanks, then you're going to need a quick answer for the fuel truck driver's next question: How much?

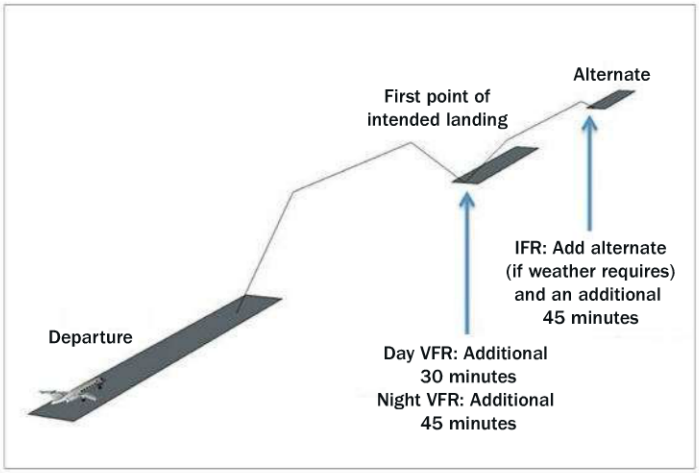
The first consideration in responding to that question is a matter of physics: getting the airplane from Point A to Point B. Obviously, this isn't the only consideration, which is why we have rules and regulations to ensure we exercise at least a minimum level of caution.

For N-registered aircraft, FAR Part 91.151 says we must have at least enough fuel to fly to our first point of intended landing and then for another 30 min. (day) or 45 min. (night) at normal cruising speed. Part 91.167 adds the requirement to fly to an alternate airport under some weather conditions.

Commercial flag carriers are required by Part 121.645 to be able to fly for an additional 10% of the total time from departure to destination when flying outside the continental U.S. FAA Order 8900.1, Volume 3, Chapter 25, encourages non-flag commercial operators to include similar fuel allowances for all overwater, passenger-carrying flights. While not specifically included in this guidance, general aviation operators would be wise to do the same.

If you are flying outside the U.S., International Civil Aviation Organization (ICAO) Standards and Recommended Practices (Annex 6, Part I, Paragraph 4.3.6) require turbine aircraft also be able to hold for 30 min., 1,500 ft. above the destination airport (VFR) or alternate airport (IFR) prior to landing.

Armed with these minimums we can turn to our flight-planning service to churn out fuel computations printed to the nearest pound, including alternate, holding and reserve fuel. But before you stake your pilot's license on the number listed under "Total," consider that one or more of these lines could be wrong.



U.S. Fuel Minimums begin with 14 CFR 91.151 and 91.167.

Flight-Planning Software

Your flight plan's en route fuel is probably based on an immediate climb and a perfectly scripted descent, as if you owned the airspace. But if you are descending into Teterboro (TEB) and get the SLAM DUNK ONE arrival to sneak below LaGuardia, JFK and Newark traffic, your ideal fuel burn can go up thousands of pounds. Even a graceful profile descent can include expect crossing clearances that will rob you of fuel. If your flight plan doesn't adjust your arrival altitudes accordingly, you need to adjust your arrival fuel burn.

That isn't the only problem: Many flight plan providers compute alternate fuel based on flying a straight line from the destination airport to the alternate — no muss, no fuss.

But your odds of getting a straight line shot to your alternate are not just less than slim; it isn't going to happen. If the weather is such that you need to file an alternate airport, you should have a good idea of how much fuel it will really take, including the missed approach, the expected climb-out instructions and the expected arrival to the alternate airport.

A G450 crew, for example, could plan a trip to San Francisco International Airport (SFO) with San Jose International (SJC) as an alternate, and expect to arrive at the latter with 5,000 lb. of fuel to meet all Part 91 IFR requirements. But typical flight-planning software counts on getting from the missed approach point at SFO to landing at SJC as the crow flies using less than 400 lb. But the crow doesn't have to negotiate with NORCAL approach; the actual maneuver could take over 2,000 lb. of fuel. It would be nice to know that before you find yourself at minimums on the SFO ILS Runway 28R.

Knowing how much fuel you need to get from Point A to Point B, go missed approach, shoot an approach and land at Point C, and then have the legally required fuel reserve gets you an answer to the "How Much?" question. You should compute that answer with the total required minus the fuel on board. Why not just start pumping and stop when the number on the gauge matches the number in your computation? Because the gauge can lie.

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FLIGHTPLAN          KBED TO KSFO
COMPUTED 2229Z FOR ETD 1200Z   PROGS

            FUEL   TIME   DIST ARRIVE
DEST KSFO   016356 05:45  2379  1745Z
RESV        001829 00:45
ALTN KSJC   000337 00:06  0026  1751Z
HOLD        001309 00:30
BALLAST     000000
REQD        019831 07:06
TAXI        000400
XTRA        001525 00:38
TOTL        021756 07:44

KBED DCT HYLND SYR Q812 AGDOX Q816
J148 OAL MOD5 KSFO

FLIGHTPLAN          KSFO TO KSJC
COMPUTED 2234Z FOR ETD 1745Z   PROGS

            FUEL   TIME   DIST ARRIVE
DEST KSJC   002341 00:37  0164  1822Z
RESV        002220 00:45
ALTN        000000 00:00  0000  0000Z
HOLD        001290 00:30
BALLAST     000000
REQD        005851 01:52
TAXI        000000
XTRA        000000 00:00
TOTL        005851 01:52

KSFO SHOR6 SAC CAPO3 KSJC
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Divert fuel often fails to consider real world routing.

Fuel Measurement

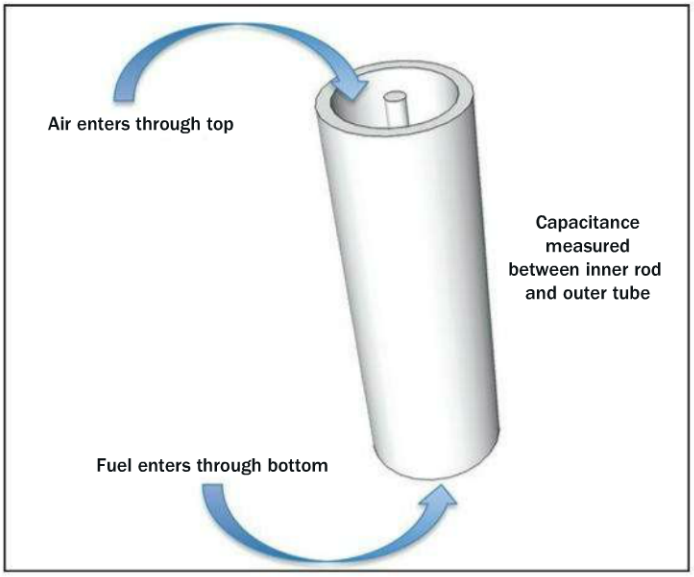
Most aircraft fuel quantity measuring systems use fuel capacitance probes that eliminate the problems attendant to the old float designs. A capacitance probe is a metal rod surrounded by a hollow metal tube with an insulator that prevents the inner rod from contacting the outer tube. The probe is mounted vertically so fuel can flow in and out from the bottom and air flows in and out of the top. An electrical charge is applied and the capacitance is measured. The ratio of fuel to air affects the capacitance and a fuel quantity is derived.

Modern systems tend to use several probes in each tank and multiple computers to ensure the result is accurate. The design specification in a GV, for example, is +/-300 lb. Still, these modern systems can be fooled when the temperature of the fuel in the truck is appreciably warmer than the fuel in your wings. Even the best fuel quantity computers can be compromised by variations in temperature within the same tank.

Let's say you spent several hours in your GV at high altitudes and landed with fuel tank temperatures somewhere south of -10C. If you take on a full load of fuel from a truck that has been sitting for hours at a higher ambient temperature, the fuel will become stratified: The layer on top will be less dense than the layer below. Fuel computers will tend to think the fuel quantity is higher than it really is. A 2007 Gulfstream study revealed the fuel quantity in a GV could be 800 to 1,200 lb. low under these conditions.

If the airplane sits for about 10 hr. on the ramp, the discrepancy goes away. But what if you don't have 10 hr.? You still need to add a known quantity of fuel, but don't stop the truck just because the gauge says you have enough. (You might not.)

Even after 10 hr., you could still find yourself unable to take on a full fuel load because of high ambient temperatures. The warmer fuel gets, the more space it



Modern fuel capacitance fuel probes are accurate, but can be fooled.

occupies and you could run out of tank volume before you have the necessary fuel by weight. A 2005 study showed that every 10C increase in temperature can reduce a GV's total fuel capacity by 200 lb. While we assume our jet engines burn fuel by volume, this isn't true; our range is determined by the weight of fuel. Density is even more critical than temperature.

The fuel truck driver wants his "How much?" question answered by volume, be it gallons or liters. But again, your aircraft burns the fuel by weight, measured either in pounds or kilograms. And just because 3,000 U.S. gal. of fuel weighs in at 20,000 lb. most of the time in the U.S., that doesn't mean the equation will hold everywhere else. Going from the lowest to highest density can change the weight of 3,000 U.S. gal. by over 1,500 lb. So, don't let the fuel truck pull away until the fuel total by weight equals or exceeds that on your flight plan.

When Enough Isn't Enough

Even when your tanks have what you need to fly from A to B, then make it to C, and still have enough to satisfy all published fuel minimums, you still cannot relax. If you see a line of airplanes waiting for takeoff, your first thought is likely to be about your estimated time of arrival. But don't forget your excess engine idle time will eat into the expected fuel remaining when you reach your destination.

While en route, fuel remaining becomes a concern again when confronted with stronger than expected headwinds or when deviating around weather systems. Finally, remaining fuel on landing needs to be considered after every lap around the holding pattern, and especially after a missed approach. The time to compute this fuel is right after the hold is given, not after four circuits of 10-mi. legs. Your options run the gamut from holding to finding another place to land. There may come a time when you need to let someone outside the airplane know you are not happy.

'Min Fuel' Versus 'I Am Declaring an Emergency'

According to the Aeronautical Information Manual (AIM), declaring, "Minimum fuel," does not imply a need for traffic priority, but rather that you cannot accept any undue delay upon reaching your destination. In actual practice, it is a way of conveying your discomfort to ATC, nothing more. The AIM goes on to say that if you need traffic priority to ensure a safe landing, you should declare an emergency due to low fuel.

Fuel planning doesn't stop when the fuel truck has its order.

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Declaring an emergency doesn't cost you anything other than possibly being asked to send a written report in accordance with Part 91.3. If you need to declare an emergency, do it and be explicit. In 1990, an Avianca Boeing 707 bound from Colombia to New York ran out of gas while holding for over an hour waiting to land at JFK International Airport, killing 73 of 158 people on board. The crew let ATC know they were running out of fuel but never used the magic word, "emergency," and never got traffic priority

Customizing Your Fuel Minimums

The best way to avoid having to one day declare minimum fuel is to have a sound set of personalized fuel minimums and a logical approach to answering the question, "How much?" Your calculations should satisfy the following:

(1) Fuel required to fly the trip.

(2) Fuel required to execute a missed approach, fly to the alternate, shoot a second approach and land.

(3) Fuel to satisfy regulatory and company minimums.

(4) Fuel to satisfy personal minimums.

There are two views when it comes to minimums and the wrong thinking is this: "If the minimum wasn't good enough, it wouldn't be the minimum." You might be satisfied with an extra 30 min. of fuel in the day and 45 min. at night. But think that through. Modern airspace is more crowded today than when that regulation was written and a 30-min. delay can be considered a short one these days.

More fuel is better, to be sure, but to what amount? The answer will be different for an aircraft with a high allowable landing weight and good brakes versus another with narrow landing weight margins and fragile braking systems. Me? I start the bidding at 1 hr. of fuel and work my way higher. **B&CA**