Determining Your IFR Fuel Reserves
Piston Engine

One of the critical elements in planning an IFR flight is fuel reserves. We identify the possible situations we might encounter and add fuel until we believe the risk of running out due to one or more of the possible events happening is, for practical purposes, nil. It seems like a simple decision process, but experience teaches us that, done properly, it deserves serious thought.

The base line for establishing reserves is FAR 91.167. It says we must have sufficient fuel (considering weather) to complete the flight to the intended destination, then fly to an alternate airport if conditions are forecast to be less than 2,000 feet and 3 miles, and then fly for 45 minutes after that at normal cruising speed.

Is the FAR requirement sufficient for daily practice? Most professional pilots think not and the National Business Aviation Association (NBAA) has long recommended considerable additional reserves. The legal fuel reserve minimums leave little margin for error. How much to increase the 45-minute reserve by requires reasoned consideration of the possible conditions the reserves are intended to cover. Many pilots I talk to use 1:00 hour as their reserve without a reasoned argument to back up their decision. They imply that this 1:00 hour is adequate for all situations. I believe such an approach is flirting with disaster. Fuel reserves should not be some arbitrary amount. Each flight is unique as is each pilot. What works for pilots in general may not be the best for us personally. We owe it to ourselves to establish our own personal IFR fuel reserves model rather than blindly copy someone else's and apply it to each flight. It's not hard to do and removes unnecessary risk from our flight.

Types of IFR

Flight conditions vary widely. To make the process manageable, I use two categories of IFR flight: *Easy IFR* and *Hard IFR*. The dividing line is based on two criteria: personal minimums, and assessment of the probability of having to divert to an alternate.

Easy IFR	**Hard IFR**
Destination is forecast to be above our personal minimums and we believe the probability of a missed approach and diversion to our alternate is essentially nil.	Destination forecast is at or close to our personal minimums and we believe there is at some possibility of a missed approach and or diversion to our alternate.

Our personal minimums set the threshold for what we will comfortably tackle in terms of terminal weather minimums. However, the dominant criteria will most often be our assessment of the accuracy of the weather forecast. Setting this dividing line is a very individual and a critical decision. It deserves serious thought and will change with our experience and competence.

Easy IFR is low stress and minimal concern weather-wise. With *Easy IFR* conditions, we fuel plan for an alternate, but we don't expect to go there. We should always plan an alternate, even when the FAA rules do not require it. It's a good habit and provides protection when the impossible happens. If you fly IFR in Canada, it is not an option. Canadian air regulations require an alternate for all IFR flights. For *Easy IFR*, I want to see 1,000+ ceilings and improving conditions at my destination.

Hard IFR tests our planning skills. We fully expect to land at our original destination, but we acknowledge that there is a possibility, even if only a small one, that the weather could go sour and force a change of plans. Since we know the situation is risky, we devise a backup plan that is iron clad both weather-wise and fuel-wise.

Contingencies

The key to reserve fuel planning is identifying the various situations that might present themselves to us on our flight.

Minimum Reserve, 45 minutes at Cruise: This is an FAR requirement. It's a given. It can be added to but not reduced. Some pilots like to increase this by an arbitrary amount, such as 15 minutes, to cover *all* contingencies except time to the alternate. I recommend working each contingency independently and then aggregating the result. Doing so keeps the individual contingencies visible and improves the quality of our decisions and risk taking.

Approach and Land: On arrival at our destination, the first order of business is to execute an approach and land. We need to account for the fuel to execute an approach and land. Don't bet on a straight in to the runway. At busy Class B and C airports you are almost guaranteed to get vectors for sequencing. In IMC, if the field does not have terminal radar, you may have to fly the full approach including the procedure turn. I find 20 minutes is a good allowance for the time for me to fly a full approach and land.

Missed Approach and Hold: If the approach falls apart, you are into a missed and potentially a hold. Expect 5 minutes in the holding pattern while you work out with ATC where you go next. Even if you have already decided on the next step, if things are busy, ATC may need some time to set up your next move. When things go bad for you, they are most likely so for others. Expect ATC to be very busy and be prepared to wait for your turn.

30 min Hold for Sequencing: Diversion to your alternate is not an automatic next step from a missed approach. We might want to have another try. ATC may need to park us for a few minutes for re-sequencing for another approach. In this case we need to be prepared for 30 minutes in the hold. This also applies during IMC conditions at uncontrolled airports where IFR traffic moves more slowly because ATC does not have direct positive control. We should not be surprised to have to hold for 20 to 30 minutes while other traffic departs and lands ahead of us. An RCO on the field helps a bit by letting pilots close their IFR flight plans by radio rather than waiting until they get to a telephone, but a lot of extra time and fuel can get used up operating in uncontrolled environments. All too often, pilots land and forget to close their IFR flight plan. While the problem is being resolved by ATC, others in line for the approach will be kept holding.

Fly to Alternate: The FARs do not recognize a standard alternate. However, using one simplifies the flight planning process. NBAA recommends 200 miles, which makes sense for corporate turbines that run carrier-like operations where they seldom cancel due to weather. I have found that 100 nm works well. My schedule requirements are not so demanding and I don't attempt flights when the weather is really ugly, especially over a large geographic area. I can usually find a suitable alternate 50-100 nm from my destination. The important thing is to use a distance for your type of flying that will almost always get you outside the weather system that will cause the diversion. Alternates less than 30 miles away are unlikely to be suitable. And, don't forget; to be legal, you still have to verify that your fuel is sufficient to reach the selected alternate, taking forecast winds into consideration. I find that adjusting a 100-mile, no-wind standard alternate is quick and simple.

Other Variables: This contingency is for other variables that can impact our flight. Most are small. Some can even work in your favor.

Actual Winds: We need an allowance for actual winds. They may be stronger or lighter but they are never the same as forecast. In practice, I find the variance due to actual winds to be

5 to 10 minutes on a 4-hour flight. It can be worse however. On one flight, the actual winds added 30 minutes to the trip.

Fuel Fill: The fuel tanks may be full but not all the way to the top. Line personnel often stop short to allow room for expansion. Sometimes they leave more than necessary. On my Bonanza, this can mean as much as 2 gallons off the maximum fuel. On the plus side, while 74 gallons is the legal definition of usable fuel for my Bonanza, the reality is that all the fuel in the 80-gallon tanks is actually usable. There is a 6 gallon cushion that is usable when the chips are down. For my aircraft, I add nothing for the *full fuel* contingency.

Enroute Deviations: ATC may change your routing due to traffic or to avoid enroute weather. This always adds time to your flight. I find these deviations add 5 to 15 minute to my flights. Even the “impossible” can happen. On a flight in late October, IMC conditions were not forecast at my destination and I was operating with *Easy IFR* reserves. Just 25 miles from my destination, ATC informed me the field was closed due to a thunderstorm and asked what were my intentions? I was totally surprised. I quickly estimated that I could hold for 30 minutes before I would need to seriously consider heading for an alternate. Fortunately, after 15 minutes, the airport reopened. I got to go first with the approach while an air carrier continued to hold. It worked out fine, but had I drawn the second approach slot, I would have been an interesting call as to whether or not I hung around for my turn.

Fuel Flow Variances: The figures for fuel flow found in the aircraft Pilot’s Operating Handbook (POH) are seldom exactly what you will get. Fuel flow changes as the aircraft engine ages, it varies with temperature and altitude changes, and it varies with your precision in leaning. The rates I get in my Bonanza are 1-2 GPH higher that the POH numbers and vary as much as 4 GPH depending on how I lean. Over time, I have refined my planning numbers to where my actual fuel flows run 0.2 to 0.5 GPH better than what I flight plan for.

After pondering this collection of *other variables*, I have concluded that an allowance of the greater of 10 minutes or 10 percent of the flight time is appropriate. Since the flights I make in the Bonanza are usually about 4 hours, I add 5 gallons to the reserve to cover the *other variables*.

One factor not included in the reserve calculation is the fuel used during taxi and climb. This is accounted for in the trip fuel calculation. For my A36 Bonanza, it’s 2 gallons for taxi and 3 gallons for climb and FlightStar is programmed to take this into account.

Adding It Up

To get the total fuel reserves for a trip we start by adding up all the above contingencies. For an *Easy IFR* scenario, we omit the fuel for the Missed Approach and Hold and the Climb to 5,000 feet and Hold contingencies. This is worst-case and where we want to start. It exceeds the FAR requirements by a considerable amount. In my case it’s 47% more for *Easy IFR* and 121% more for *Hard IFR*.

Now we examine the wisdom of scaling back on this total. We can legitimately scale back from our worst-case reserves when, after looking at the big picture, we determine conditions are less onerous than our all inclusive model. For example, if it is *Easy IFR* and you are really squeezed for useful load, then you can consider dropping the Alternate reserve. Whatever your decision, make it being fully conscious of how your margin for error is narrowing and what you are betting on not happening. Make it a calculated risk rather than an outright gamble.

Example Application

This computation may seem overly detailed. However, once you have worked through the numbers the first time, it is easy to apply it to real world flight situations. Let's use my A36 Bonanza as an example.

First we need some performance data. I generally fly at 8,000 to 11,000 feet at one of two power settings. These settings I designate NOL (Normal Operation Lean of Peak EGT), which is 65% power, and ECL (Economy Lean of Peak EGT), which is 50% power. Maximum usable fuel is 74 gallons. Taxi and climb requires 5 gallons. NOL gets me there faster than ECL: 157 vs. 138 KTAS. But ECL will take me further: 1000 vs. 825 nm in no-wind conditions. I seldom operate at 75% power. True air speed at 75% is 10 knots faster, but noise and vibration levels are noticeably higher and make long trips more tiring. I can pick up a few knots by leaning on the rich rather than the lean side of peak. I generally don't do this because it is not as fuel-efficient as running lean of peak. I can get the same airspeed at a lower fuel flow rate by running on the lean side of peak. Also, I'm convinced it is better for my particular engine to run on the lean side of peak.

NOL, at 8,000 feet, gives 157 KTAS at a fuel consumption of 13.0 GPH. Endurance at this power setting is 5:15 hr. ECL, at 8,000 feet, gives 138 KTAS at a fuel consumption of 9.5 GPH. Endurance at ECL is 7:15 hr. I often fly 4:00 hr, 600 nm trips non-stop with *Easy IFR* reserves.

As mentioned above, I use Jeppsen's FlightStar software to do my flight planning. It is easy to use, does a nice job of accounting for variables like fuel used in taxi and climb, calculates weight and balance, automatically adjusts the fuel burn rates for outside air temperature and altitude, and let me easily determine an optimum altitude for the flight as a function of operating cost, time enroute, and fuel. This is very helpful when fuel reserves are tight.

Taking this performance data and working through the contingency considerations result in the following fuel reserve table:

Example IFR Fuel Reserves A36 Bonanza (Gallons)				
	Easy IFR		**Hard IFR**	
8,000 ft Cruise	**NOL** 13.0 GPH 157 KTAS	**ECL** 9.5 GPH 138 KTAS	**NOL** 13.0 GPH 157 KTAS	**ECL** 9.5 GPH 138 KTAS
Minimum Reserve (45 min at cruise)	10	7	10	7
Approach and Land (20 min)	4	4	4	4
Missed Approach + 5 min Hold	-	-	7	7
30 min Hold for Sequencing	-	-	7	7
IFR Alternate (100 nm, no wind)	9	7	9	7
Other Variables	5	5	5	5
Total	28	23	42	37

My fuel reserves table shows that for *Easy IFR* at NOL power I need 28 gallons of reserve fuel. For *Hard IFR* at NOL power, I need 42 gallons. If I choose to pull the power back to 50%, reserve fuel needs drop to 23 gallons for *Easy IFR* and 37 gallons for *Hard IFR*.

For any given flight, I take the trip fuel requirements from FlightStar and verify that I have sufficient fuel remaining. At normal power (NOL), which is generally the case, if it's *Easy IFR* conditions, I check to see that I have 28 gallons for reserves. If it's *Hard IFR*, I look for 42 gallons for reserves. I also verify that the IFR Alternate fuel is sufficient for the specific alternate I have selected. I seldom need to adjust the Alternate reserve component. ECL power, while it's slow going, will, in some cases, provide enough extra range to make it non-stop and still have adequate IFR reserves. I prefer to go non-stop if possible.

A trip I often make is from Nashville, Tennessee to Princeton, New Jersey. It's 639 nm and at 65% or NOL power the no-wind flight time is 4:08 hr requiring 55 gal of fuel leaving a no-wind reserve of only 19 gal. This is below my 28 gal *Easy IFR* standard reserve requirement. Fortunately we generally have a tailwind going eastbound and arrive non-stop with 26 gal of fuel remaining, which is close enough to the target 28 gallons. At 50% or ECL power, it's a 4:30 hr trip using 50 gal of fuel leaving a no-wind reserve of 24 gal, which meets my no-wind reserve objective of 23 gal. Occasionally I will have to pull the power back to 50% or ECL to get the extra range needed to make it non-stop. If the weather at Princeton is *Hard IFR*, non-stop is out of the question. Then I stop for fuel half way, usually at Charleston, West Virginia. Coming westbound, the winds are seldom favorable and most of the time we need a fuel stop.

Forty-two gallons for *Hard IFR* reserves seems like a lot of fuel and it significantly cuts down on the non-stop range. However, for my A36 Bonanza, range with reserves is still a respectable 2:05 hr (330 nm) at NOL power and 3:20 hr (460 nm) at ECL power. The extra fuel reserve over the FAA required minimum is very comforting when the weather is really challenging and gives me good flexibility in dealing with unexpected situations enroute.

A nice feature of the Garmin 530/430 GPS unit when combined with an air data computer is the fuel planning function. It keeps track of the fuel required to get from your present position to your destination and the fuel that will be remaining when you get there. It displays this in gallons and time based on the current ground speed. If I run into unexpected headwinds or detours, I can quickly see what the impact is on my fuel requirements. No calculation or mental arithmetic is required. I monitor this page in flight and like to see the fuel remaining on arrival at my destination in the 2:00 hr range or about 26 gal.

Summary

Setting IFR fuel reserves is often tough decision-making. Putting some structure into it helps considerably. To utilize this model, take the contingency factors and customize them to your personal situation. Then build a fuel reserves table for the airplane you fly at the power settings you primarily use. Keep a copy of the table in your flight bag for reference when flight planning. Adjust the contingencies as appropriate for the specific flight.

Ultimately, the fuel reserve you have is what is left in the tanks after you calculate the trip fuel. If it is more than your estimated reserves, then you are ready to fly. More often than not though, the fuel available for reserves is less than the model recommends. In this case, carefully weigh the pros and cons of departing with the reserves you have or making a fuel stop.

Resist the temptation to simply add an arbitrary amount to the trip time for reserves. Work the details and fuel concerns won't become a stress maker on your flights.

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