How High Can You Fly?

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According to FAR 91.211(a), "No person may operate a civil aircraft of U.S. registry […] At cabin pressure altitudes above 12,500 feet (MSL) up to and including 14,000 feet (MSL) unless the required minimum flight crew is provided with and uses supplemental oxygen for that part of the flight at those altitudes that is of more than 30 minutes duration; […]

In other words, the FAA limits flight for the typical General Aviation pilot to 12,500 feet. Flying at higher altitudes up to 14,000 feet for 30 minutes or less is permitted, but then the airplane must return to an altitude of 12,500 feet or lower.

That sounds pretty simple and straightforward. The FAA has made the rule, and will enforce it. No doubt there is experience and research to justify those specific altitude limits.

But arguments and cautionary statements exist from other sources that make the answer to the question of how high you can fly more complicated.

For example, it is claimed that at 8,000 feet your blood oxygen level will drop to about 90 percent. 90 percent is considered a recommended minimum. To fall below that is considered unhealthy.

Clearly, that statement and FAR 91.211(a) would seem to be at odds with each other. If any altitude above 8,000 feet results in your blood oxygen level going below 90 percent, is flying at any altitude between 8,000 and 14,000 feet safe?

The FAR is a legal mandate, but which is right?

On long flights, we typically fly well above 8,000 feet. So we decided to do a little flying as research. We would head up to 14,000 feet with an oximeter, to learn what the facts really are.

Blood oxygen levels

For most people, their blood oxygen level is above 95 percent. That number declines slightly as a person gets older.

90 percent is considered a minimum reasonable and healthy value for the blood oxygen level. Below that is cause for concern. "Hypoxemia" is the term used for low blood oxygen levels.

Symptoms of hypoxemia include shortness of breath, chest pain, coughing or wheezing, confusion, headache, and rapid heartbeat.

According to available documentation[1], If your blood oxygen level falls below 80–85%, **visual and cognitive changes** may start to develop. At 67%, you're at risk of developing **symptoms of cyanosis**. The hallmark sign of this is a blue discoloration of your nail beds, skin, and mucus membranes. Cyanosis may also lead to respiratory failure, which can be life threatening. If you experience symptoms you should get medical attention immediately.

The documentation, however, relates low blood oxygen levels to health problems, such as "COPD, including chronic bronchitis and emphysema, acute respiratory distress syndrome, asthma, collapsed lung, pneumonia, anemia, congenital heart defects, heart disease, pulmonary embolism."

[1] https://www.healthline.com/health/normal-blood-oxygen-level#symptoms

In other words, with regard to low blood oxygen levels in day-to-day life at normal altitudes as a symptom of a significant health issue.

Information regarding blood oxygen levels for healthy individuals at various altitude levels is not readily available.

We also fly those altitudes at night. According to those with medical expertise, lowered blood oxygen at night can also affect your vision

Real-life, real-world experience meets theory

Theoretical discussion is fine, but what really happens when the rubber meets the road – or in this case, when the general aviation pilot flies at high altitudes?

We decided to find out.

The purpose of our flight was to provide solidly-objective information in a relevant structure for the consideration and benefit of ourselves and all General Aviation pilots.

Background history: our experience

On long flights In our Cessna 182 – i.e., flights of three to five hours duration, we routinely fly at 9,000 feet east-bound, and 10,000 feet west-bound. On occasion, to pick up a good tailwind or to stay above weather, we have flown at 11,000 feet eastbound and 12,000 feet westbound.

We like to finish our flights by noon, to avoid build-ups and turbulence – particularly when a homeward-bound flight to South Carolina will take us over the Smokies.

Clouds typically start to build each morning from Knoxville, Tennessee, eastward. After 11:00 a.m., the ride over the Smokies grows increasingly bumpy. Afternoon turbulence and storms over the Smokies are typically severe. When planning a flight over the Smokies, the tragedy of astronaut Scott Crossfield's flight should serve as a clear warning never to be forgotten.

Quite often, that means taking off by 4:00 a.m. So by some standards, we break all the rules: high-altitude flights of 3- to 5-hour duration, at night.

We have never experienced any of the symptoms described for hypoxemia at any altitude. Nor have we ever experienced any night-related symptoms.

When flying from Iowa to South Carolina, for example, a 20-knot tailwind means a 5-hour non-stop flight (using 60 gallons of 75 gallons of fuel on board). Without a good tailwind, the trip requires 6 total hours of flying, plus a stop to refuel halfway, at Terre Haute (HUF). That stop adds almost an hour to our start-to-finish flight time. That extra time includes flying an approach or pattern, refueling, paying the bill, taxiing twice between the runway and the FBO, delays while awaiting IFR release from the control tower, the climb back to altitude, etc.

Saving an hour or two can be important when it means getting across the Smokies in smooth air.

Too, I like flying at higher altitudes over the Smokies for another reason: should the engine fail, a glide to one side or the other will most likely be possible. A forced landing in a farmer's field is preferable to an inaccessible forested ravine.

But 11,000 or 12,000 feet is way up there, so we stay alert to any problems. I increase my scan rate of the instruments, say the alphabet backwards, and do calculus in my head ("the integral of acceleration is velocity; the integral of velocity is distance; falling from 11,000 feet would mean …") as a constant test of my own mental functioning.

My wife spends most of our flight time knitting. Even at the highest altitudes she rarely naps – despite that I wake her at three in the morning so we can cross the Smokies in calmer morning air. Flying can be boring for a passenger, but high altitudes are clearly not affecting her either.

But watching the sunrise from 11,000 feet over Illinois on a cloudless day with the ground below still in darkness punctuated by town lights is a beautiful and unforgettable sight!

Day flying or night flying, those high altitudes do not seem to affect either of us in any way.

Your mileage, as they say, may differ. A certain friend who flies with us on local flights has asthma; 5,500 feet is her absolute limit. When she says, “Get me down, now,” we take that seriously. On the other hand, the Sherpa guides who live near Mount Everest thrive at altitudes far higher than what you and I could tolerate.

The oximeter test

Sporty’s sells an oximeter for about $35, including shipping. It measures your pulse rate and your blood oxygen level.

The accuracy of the oximeter could not be verified. However, all readings to date have been consistent with normal expectations as well as with that of historical medical check-ups.

Further, the values obtained during the flight were internally consistent.

The Test Flight

We laid out a flight plan that would include using the oximeter and recording the results. We measured and recorded the blood oxygen levels and pulse rates for each of us at 1,000 foot increments, starting from ground-level at 1,000 feet all the way up to the legal maximum of 14,000 feet. Descending, we made the same measurements at each thousand feet as well.

Taking measurements on both the ascent and the descent would not only provide redundancy, but would also show us to what degree, if any, the blood oxygen level from the previous altitude affected that of the current altitude.

The morning of the flight, the weather was severe clear. I telephoned Greer (GSP) Approach Control, to make them aware of our intentions and to get their help: the altitudes we wanted to fly are, after all, IFR altitudes. At 10,000 feet, we would be in Atlanta Center's airspace – again, at IFR altitudes.

Both Greer and Atlanta were completely supportive and very helpful throughout the flight. We were only interested in being at each altitude long enough to obtain results from the oximeter. We gave Greer and Atlanta total discretion for the direction of our flight, in order to keep us away from other traffic. Throughout our flight we called out each altitude change to keep them informed.

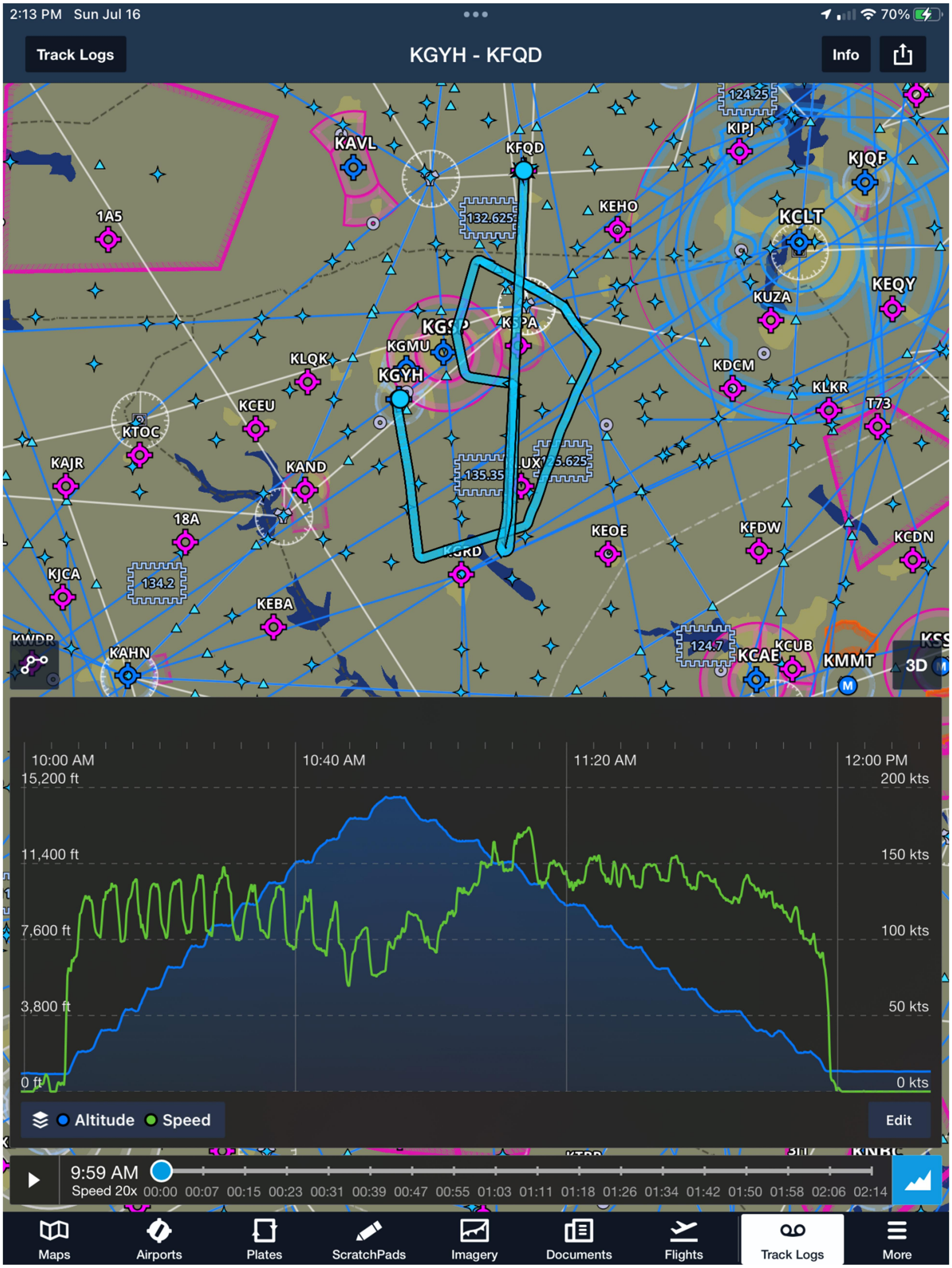
Kudos and a big thank-you of appreciation to Greer Approach and Atlanta Center!

Our 182 is a 1978 Q model, with a Continental O-370 230hp carbureted engine. It has the standard two-blade variable-pitch prop. The prop stayed in climb configuration with the cowl flaps open for the entire ascent. The outside air temperature at the higher altitudes was in the 40s. With the reduced power the engine produced above 5,000', the EGT and cylinder head temperatures stayed on the cool side. On the descent, the cowl flaps were closed and the propeller was put in cruise configuration, until we approached the destination airport. There I reconfigured for the landing, setting the prop back to climb configuration as always, in case a go-around should become necessary.

We recorded the 182's manifold pressure at each altitude (from 500 feet AGL to 5,000 feet, throttled back to stay at the top of the green arc), along with the oximeter's values. That gave us an additional comparative benchmark, to help assure that our records made sense.

See the chart for the full set of results.

The flight lasted two hours. A few additional minutes of flight allowed us to land at Rutherford Airport (FQD) for lunch at 57-Alpha, an on-field restaurant with great burgers and Mexican food.



Our flight profile, as recorded by Foreflight

Altitude	Scott – pilot		Manifold Pressure	Rhoda – recorder		Notes
	Pulse Rate	Blood O_2 %		Pulse Rate	Blood O_2 %	
1000	89	94	28	78	94	max power
2000	88	90	23	79	93	max cruise power
3000	81	93	23	77	93	
4000	85	91	23	77	92	
5000	82	90	23	78	92	
6000	84	91	22	78	91	
7000	83	90	21	78	91	
8000	84	91	20	76	91	
9000	81	87	19	74	89	typical long-distance cruise altitudes
10,000	77	86	19	74	89	
11,000	82	83	18	74	87	occasional cruise altitudes
12,000	81	77	17	77	83	
13,000	81	82	16	77	83	
14,000	82	75	16	78	83	max altitude
13,000	77	77	16	76	82	
12,000	76	79	17	73	83	occasional cruise altitudes
11,000	75	82	18	72	85	
10,000	75	83	19	73	87	typical long-distance cruise altitudes
9000	74	84	20	72	88	
8000	74	87	20.5	71	90	
7000	72	91	21	71	92	
6000	77	91	22	70	93	
5000	77	93	23	69	93	max cruise power
4000	75	94	23	72	94	
3000	78	93	23	74	94	
2000	83	93	23	73	95	
1000	82	95	28	73	92	engine off

Interpreting the test results

As noted, Greer Approach and Atlanta Center assigned our headings at all times. I kept the 182 on autopilot (heading but not altitude), guided by the heading bug on the DG, which I adjusted to match the requested heading.

Our procedure was to (1) climb or descend to the next altitude, (2) adjust trim to establish level flight at that altitude, (3) engage altitude hold, (4) use the oximeter on the pilot's forefinger of the right hand, (5) record the pilot's oximeter readings, (6) use the oximeter on the passenger's left hand, (7) record the passenger's oximeter readings, (8) record the 182's manifold pressure.

All recording of data was performed by the passenger. She was sitting in the right seat; the manifold pressure gauge is on the right panel, directly in front of her.

As the pilot, my pulse rate remained high throughout the flight. When relaxed, my pulse rate drops into the 60s. With activity, it rises. Even though piloting an airplane does not include significant physical activity, mental activity becomes pretty intense. The recorded pulse rate reflects that.

The less demanding role of the passenger is reflected in her lower pulse rate.

Blood oxygen level versus altitude

The claim that 8,000 feet will be the altitude where blood oxygen levels are about 90% turned out to be accurate in our case. The test results matched the published norm.

On the descent, stair-stepping down from 14,000 feet, the pilot's blood oxygen level tended to be slower in its return to higher percentages. At 8,000 feet on the descent, the oximeter reported only 87%. Perhaps given more time (note our procedure described above) it would have been greater.

Not surprisingly, at the highest altitude, 14,000 feet, the oximeter reported my lowest levels for blood oxygen level: 75%. However, no impairment of my actions and skills was noted by me, my wife, nor ATC.

The passenger's lowest blood oxygen level remained solidly above 80 even at its lowest level: 82% at 13,000 feet, after descending from 14,000 feet.

The blood oxygen level of the pilot was consistently lower than that for the passenger. Reasons could include any combination of four factors: greater pilot's workload using more oxygen; male vs. female oxygen consumption; breathing habits (e.g., shallower vs. deeper breathing, and consciously taking deeper breaths); differences in personal physical body operation.

Age did not seem to be a factor: despite being four years older than me, my wife's blood oxygen levels were consistently higher than mine.

No connection between body type (one slim, one average) and blood oxygen levels seemed apparent either.

Throughout the flight, no symptoms of hypoxemia appeared, no symptoms of cyanosis occurred, and no impact to visual and cognitive functioning was noted for the pilot nor the passenger.

Conclusion

As our test showed, blood oxygen levels clearly vary from one individual to another. Anyone running the same test would get results with personal variations. Variations could also be expected in repeated testing.

The impact of lower blood oxygen levels will also vary from person to person.

Our conclusion should be no surprise: every pilot must exercise conscious judgement, considering himself and his passengers, about altitude as well as all of the other factors that might affect his flight.

For some people, that 90% blood oxygen level at 8,000 feet may need to be established as a personal altitude limit.

The admonition that blood oxygen levels below 90% are problematic would seem to be derived solely from the perspective and experiences of health-care professionals dealing with subjects who are experiencing more fundamental health problems.

Obviously, there is never a health-care professional at an FBO to record blood oxygen levels of incoming General Aviation pilots and their passengers as soon as they land, let alone riding along in-flight to perform testing at actual altitudes. So there can be no data on which to base judgement of whether blood oxygen levels in the 80s or upper 70s is acceptable or not.

The number of reported flying accidents which can be attributed to insufficient blood oxygen levels is effectively nil. That, FAR 91.211(a), and our own experiences indicate that flights at 11,000 or 12,000 feet are not putting us in any danger. But now that we have the oximeter, it will be kept in the flight bag, and checked in-flight on occasion.

Objective information is always conducive to greater safety. The data presented here removes some of the guesswork in choosing how high to fly. Safety and achieving the goal of making the same number of landings as take-offs are the criteria for every choice we as pilots make. We are all different, so those choices must vary from one pilot to another.

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