Owner's Manual

W.H.A.T.'s Up?

By Guy R. Maher

Spring is officially upon us and it won't be long before those hot summer days will be affecting our aircraft performance. So I thought it might be a good time to refresh ourselves on the important factors to consider when performance planning.

I use the acronym **"W.H.A.T."** to guide me through the process. They stand for **W**eight, **H**umidity, **A**ltitude, and **T**emperature. We'll start with weight. This factor is the one that is most controllable by the pilot.

What many pilots don't realize is that the negative impact of added weight to take-off and climb performance is not a 1 to 1 ratio. Rather, the effect is squared as related to the amount of added weight. In clearer language, if you were to increase your take-off weight by 20%, this would yield a 44% increase in take-off distance.

For example, let's say at a weight of 2,400 pounds, our aircraft's published take-off distance - at sea level and standard conditions - is 1180 feet. Now let's say we add 400 pounds for a new take-off weight of 2800 pounds. This is a 16% increase in weight – or a factor of 1.16 times the starting weight. If you square 1.16, you get 1.345 or a 34.5 % increase in take-off distance. So you multiply the original take-off distance of 1180 feet by 1.345 and you get 1587 feet.

I know of a number of pilots who carry everything they can think of in their planes – their anvil collection, tools to do a major overhaul, enough spare parts to put Preferred out of business – you get the idea. Now please don't misunderstand me – I'm all for carrying what one really needs. When I owned a Cardinal RG for 8 years, I had a plastic carry case that fit nicely in one of the sections of my baggage compartment that contained all sorts of support items – jumper cables, oil, tools, chocks, tie-down kit, cleaning supplies, etc. The total weight of the box and its contents was 25 pounds.

For the majority of my flying, I was alone or with my wife and that kit never interfered with my performance or load carrying ability. But on a particular 4-day trip in the middle of the dog days of summer to Florida with my wife, daughter and son-in-law, that kit was the first thing to get left behind. If I needed help, I would be at the mercy of whatever FBO I selected. Those 25 pounds removed meant I could add a suit case, or 24 more minutes of fuel at cruise, or just provide for a small performance cushion. The 310 I own and fly now can handle even for more "stuff" if needed. But the necessities still don't exceed 25 pounds.

As a very general rule, at sea level you can improve your climb performance by about 180 feet per minute with a 10% reduction in take-off weight. At 5,000 and 10,000 feet, a 10% take-off weight reduction should yield an approximate 150 and 120 feet per minute, respectively, increase in climb rate.

Next we have **H**umidity. I call humidity the often ignored thief of aircraft performance. When density altitude (DA) is discussed in training or other venues, it's usually related to temperature versus altitude. Typically, the examples used are high country airports in the summer heat. For sure, this is a killer scenario. I was an expert witness on the legal fall out for one such high country summer related fatal crash. But what I believe to be an even more dangerous situation - because conventional wisdom doesn't usually account for it – is a take-off in hot and very humid conditions.

We all know how miserable we feel when it's hot and humid out. Our engines feel the same way. Consider that for every bit of additional water vapor there is in a cubic foot of atmosphere, there is that much less oxygen. Our engines don't do well breathing water. Plus, the lower air density impacts propeller performance and aerodynamics as well.

The tough thing is, although the flight training books will briefly mention humidity, we really get no help in determining how much of an impact humidity really is. The automated broadcasts don't include humidity in their DA calculations. And our flight manuals usually specify the performance numbers are based on "dry air".

Those who are flying in the typical hot and high – and usually dry - conditions at least recognize the presence of higher density altitude conditions. However, many - if not most – of those who fly in the low country aren't quite so tuned in to the dangers that lurk regarding aircraft performance and humidity.

To help you give humidity the respect it deserves, I have included a correction table for adding humidity to your DA calculations. [**See photo 1**] Notice that it says correction for 100% humidity. If your conditions are such that the humidity percentage is lower, then you can adjust the correction by the same percentage. [Note: I was recently directed to an on-line calculator that includes humidity. But when I used it, the numbers didn't nearly reflect the true impact of humidity – either compared to the chart or to the many times I verified the numbers the chart provided through flight test. So I'm not suggesting it to my training clients.]

As example of humidity effecting DA, let's say your airport temperature is 90 degrees, and the humidity is 90%. You would then go to the 90 degree line in the correction table and use just 90% of the indicated value for 100% of 1,421 feet – which would be 1,279 feet – and add that to your standard DA calculation, or what's reported by the automated systems.

Altitude is next on the list of our **"W.H.A.T."** factors. For considering take-off performance, we usually use pressure altitude [What your altimeter reads when set to 29.92"] as one of our data points. And that, combined with Temperature, yields our inputs for calculating DA directly, or inserting into various calculators for determining aircraft performance in the flight manuals.

So how do we get our "real" Density Altitude? Let's look at this example:

The pressure altitude at our airport is 1,000 feet. The temperature is 90 Degrees F. And like noted above, we'll say the relative humidity is 90%. If we use the standard chart for calculating DA, the result is 3,187 feet. Next, if we add the humidity factor of 1,279 feet [Remember 1,279 is 90% of 1,421 – the full correction for 90 degrees F] for a total DA of 4,466 feet.

So look at what just happened here: An airport with a field elevation of only 1,000 feet, on a 90 degree day with 90% humidity winds up having a density altitude of about 4,500 feet. Flying in the southeast I've had DA's exceed 5,000 feet by lunch time at low country airports. This is nothing to take lightly. I know specifically of some pilots who did, and hit the trees trying to leave on a hot and humid day – in sea level Florida.

(Correction for 100% Humidity)

Outside Air Temp (F)	Altitude Correction
60	522 feet
70	739 feet
80	1032 feet
90	1421 feet
100	1932 feet

Photo 1 - Adding humidity to your DA calculations

Now we need to apply this new found risk information to our take-off and climb considerations. If you are using just the flight manual, be careful. Normally the only performance information that is actually proven is what is given for sea level and standard conditions.

For example, a Cessna 182S Aircraft Flight Manual (AFM) indicates the take-off distance over a 50' obstacle at maximum weight in standard sea level conditions is 1514 feet, with a sea level rate of climb of 924 feet per minute. You can find similar information in the manuals of our legacy Cessna's, too. This was proven at flight test. The rest is number crunching.

Most of us have learned that in the real world, flight manual numbers are optimistic. The basic sea level numbers may have been proven at certification, but that was with factory pilots flying a new airplane that was tweaked to the max, on a perfect flying day to get the best marketing fodder they could. Then these planes enter the real world.

My technique for using the flight manual – if it's all I have – is to first add the humidity factor to the field elevation. Then I go into the performance section and follow the directions given but using my "new" airport elevation to get my calculated take-off performance. Once I get the results of that effort, I then add 25%. So if the flight manual said it would be 3,000 feet to clear the 50' barrier, my number would be 3,750 feet. Decades of doing it this way have shown this to be quite safe and accurate.

My favorite way to do these calculations, however, is by using the Take-Off Performance Computer, or **T.O.P. Comp**. [Sporty's has them. **See photo 2**] With this simple slide-rule type device, you load in all the factors of your take-off and then correlate it to the factory tested sea level published number.

For example, we'll use our 1,000 feet MSL airport with 90 degrees and 90% humidity. There is a center card that slides up so you can set the temperature in the top left window. [The card has one side for fixed-pitch props, and one for constant speed.] Then you set arrow on the first sliding strip that says "runway surface" under the field (pressure) altitude.

Notice it's at about 2,300 feet. Why, when the field is at 1,000 feet? I added the humidity factor we calculated above of around 1,300 feet. [This computer does not account for humidity – and even says so in the instructions. See what I mean about humidity getting no respect?!]

From here we move down lining up the arrows for runway slope, wind component, and take-off weight. I used a flat runway, zero wind, and gross take-off weight for this example. On the very bottom strip you see a take-off distance table based on sea level, gross weight and standard conditions. Some popular models are shown. But all you need to do is find the ground

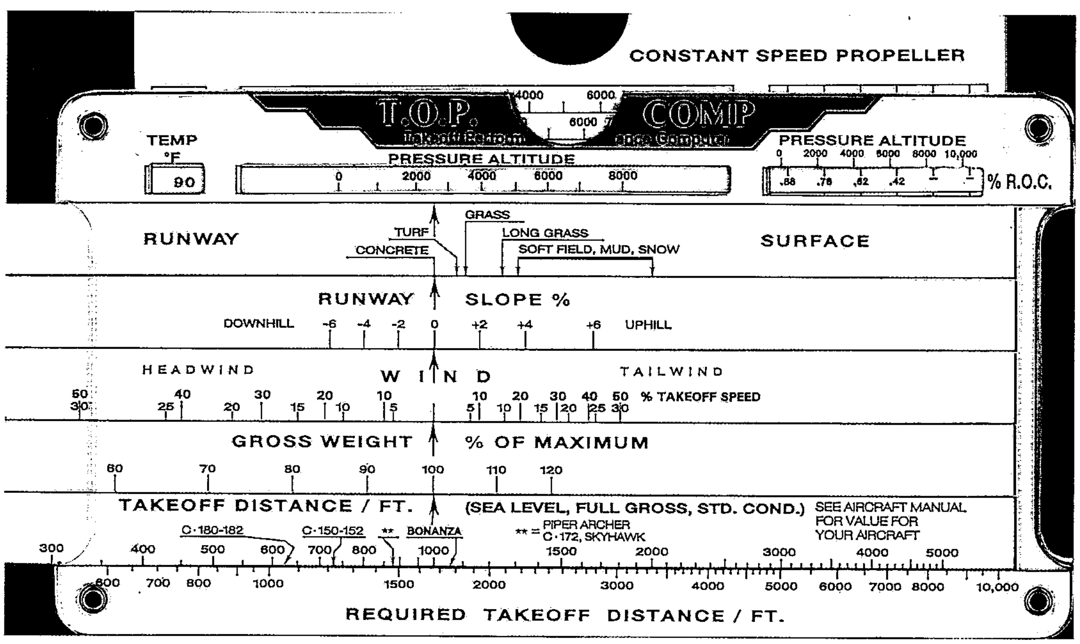

Photo 2 - Take-Off Performance Computer roll or 50 foot obstacle distances from your flight manual, find it on the slide, and see your corresponding real performance below it.

So here, our 182S with a standard take-off distance of 1514 feet as noted above would require 2,500 feet to clear the 50 foot obstacle according to the TOP Comp. [A fast look at the 182S AFM predicted roughly 2,100 feet for the same situation. I'll trust the TOP Comp, thank-you, or add that 25% just to be on the safe side.]

I also want to give a quick point out to wind. Most of us point our planes into the wind – or as close as we can get when taking off and landing. But if you are contemplating a downwind take-off for whatever reason, consider that in general for every 2 knots of tail wind component [up to 10 knots] you expose yourself to, your take-off distance will be increased by 10%. So even a light wind on the tail can prove to be deadly in the right circumstances.

Another "gotcha" is climb. It's not just about if you can get out of that runway – but also if you can then continue at a safe rate and/or angle of climb. I've seen many cases where the pilot figured they had enough runway length to get off, but then got into trouble by the lousy rate of climb.

It's one thing to get 200 feet per minute when climbing out of 10,000 feet with the ground being 9,000 feet below you. But it's a completely different story when you are only getting 200 feet per minute right after take-off in a high DA situation with the cactus out west – or southern pines in the east - just below your landing gear. A minimal down draft is all it would take to ruin your day.

I have an iron clad personal minimum for this. Any time I have any question about the conditions and climb performance of the plane I'm flying, I hit the calculator to prove to me on paper that I can obtain an initial rate of climb of at least one-half of the published sea level gross weight best climb rate for that plane, with a minimum climb rate of 400 feet per minute. If I can't, then it's no-go.

For example, our 182S AFM says the best gross weight climb rate is 924 feet per minute. So it would be my goal to prove on paper that I can get at least 460 feet per minute after take-off. And I do these calculations well before I go into the intended airport. High density conditions should not be an overnight surprise.

I've used this minimum ever since 1974, when I flew my 1969 Cessna Cardinal on a 3-week across the US and back trip from NJ in August. This rule – along with a simpler calculator called the Denault Computer - worked like a charm, even when departing the Grand Canyon Airport. I was able to control my take-off and climb performance by reducing take-off weight with reduced fuel [pre-planned to be sure I had plenty for the intended leg], and leaving real early when the temperature was 80 degrees instead of 110. [At least humidity wasn't an issue!!]

Please don't write me to say if you followed that rule, you'd never be able to fly your 150 in the summer – or a similar example. First, remember, this is **MY** personal minimum that I am sharing. It's not an admonishment. But I will say that I've spent many hot, humid, sweaty summer hours in 150's with DA's exceeding 5,000 feet and was still able to coax 400 feet per minute out of them. If I can prove 400 FPM on paper, then I feel confident I should be able to get close to 400 FPM out of it in reality. In my opinion, anything less makes for a real risky climb gradient.

A couple of points on the climb aspect; remember my personal minimums are based on one-half of the gross weight, sea level performance. So you can use the advantage gained by reducing weight discussed at the beginning of this piece to improve the performance. Also, if you use the **TOP Comp**, notice that at the top right of the computer there is a place to help you determine your percentage of sea level rate of climb.

The only caution is that it doesn't consider humidity. So remember to add your humidity correction to the pressure altitude on the chart, and then get your percentage of climb. For our practice problem parameters noted above, we'd look at the approximate 2,300 feet mark on the pressure altitude [our field elevation with humidity correction], which gives us about a 78% of sea level rate of climb factor.

In conclusion, the major take-away points from all of this I'd like for you to consider are: [1] Please do more than casual performance planning for the hot season approaching; [2] Humidity is a major performance killer. Make sure it's seriously considered in your planning where applicable. [3] Employ some type of performance calculator at best. And at a minimum, add a strong safety factor if all you use is the flight manual. [4] Do your planning well in advance – days, weeks even months – of your intended operation(s).

I'm doing some preliminary planning now for a trip I intend to take out west this fall in my plane – runway lengths at intended destinations, typical temperatures, and safe leg lengths with reduced fuel for better performance. No surprises. [5] If you know the real sea level performance of your plane and it's less than book, use those as base line numbers. Otherwise, you are just kidding yourself.

Remember that our airplanes are a design of compromise - rare is the plane that can do it all. Even our turbocharged and/or twin-engine planes – with all their added performance benefits – still require DA planning respect. They are not immune.

Summer – by far – is my least favorite time of the year. I'm not a happy camper June through August. And neither is my airplane. But by knowing W.H.A.T.'s up with summer performance planning, I was able to minimize the risk through last year's miserable season. And I'll do my best to repeat that success this coming summer. Hopefully you will too.

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