How to ballast in a TD competition.

Application to F3J and F5J

Sommaire

After few articles on yawing studies and yawing stabilities (RCSD Nov 2011), I created the Genoma family planes. The new F5J category allows me to improve my first design into a new and optimized plane for this category (RCSD Nov and Dec 2012). After a year of F5J practices, this was time to make a first assessment and to talk about how to get in altitude in F5J (RCSD Oct 2012). It is time now to go a bit further: Do you know how to ballast a plane in a Thermal Duration (TD) contest.

Very few modelers know how to do it and why. Very few articles were published on the subject. Same on the net: Very few tricks! So, what else?

I’m very interested in F5J categories. As already said, the Genoma² had been specifically designed for it. And it flies pretty well! In my personnel opinion, better than the other planes and for sure, better that the pilot I’m.

Unfortunately, at the time I create it, I didn’t have any rational for ballasting. I only make the room for a 1 kg steel. So I flew it at 20 to 30g/dm² where the other planes flew at 30g/dm² and over. And my results were not so bad. So, where is the truth?

In F3J categories, but also in F3K or F3B, ballasting is something quiet current. But once again, very few data are available. Is it something quiet secret, or quiet too complex?

Well, I needed to establish a rational to put accurate lead in the plane. I started by very simple rational.

The Genoma² was created for F5J. This plane empty weight could be from 17g/dm² to 45 g/dm². During the 2 of the 3 F5J local contests made during a year, the plane finished at the third and at the second place. Don't think the pilot is good! The plane is better.

Do we need to ballast in order to fly upwind?

The flight speed is defined as followed:

$V=4*racine(Ch/Cz)$.

Where « Ch » is the wing load in Kg/dm², "Cz" is the lift coefficient of the plane, and of course, "V" is the speed in m/s.

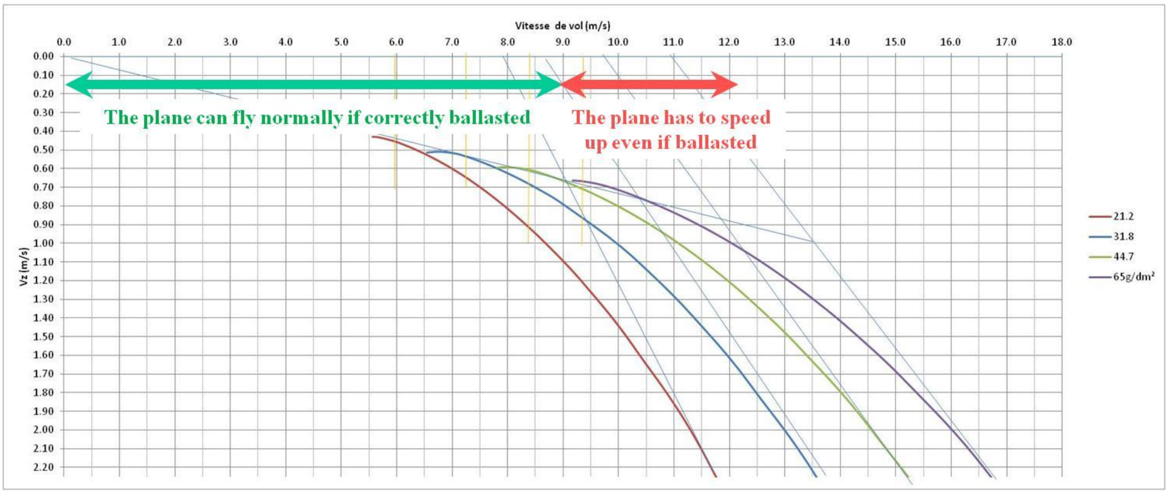
Since the lift coefficient is to be constant in order to be always at the same flying point (ex: max gliding ratio, minimum sinking rate…), the only way to go faster is to increase wing load.

So, starting at the minimum wing load (ex: for the Genoma², it may be 15g/dm²), the minimum speed is about 5m/s.

At the maximum wing load of 75g/dm² the minimum speed is 10.5m/s.

It is then not possible to fly at minimum sinking rate with the maximum wing load in a wind greater than 10m/s. And the FAI maximum wind is 12m/s.

So ballasting is not made in order to fly “as usual” in the wind.



Up to 9m/s wind, a plane can be ballasted as per FAI regulation and flew in a standard way. It is possible to fly at minimum sinking rate… Over 9m/s, this is no more true, and even if fully ballasted (at 75g/dm² as allowed), the plane has to speed up to go upwind. This then requires a specific trimming (pitching) for such occasion.

Do we need to ballast in order to transit without much sinking rate?

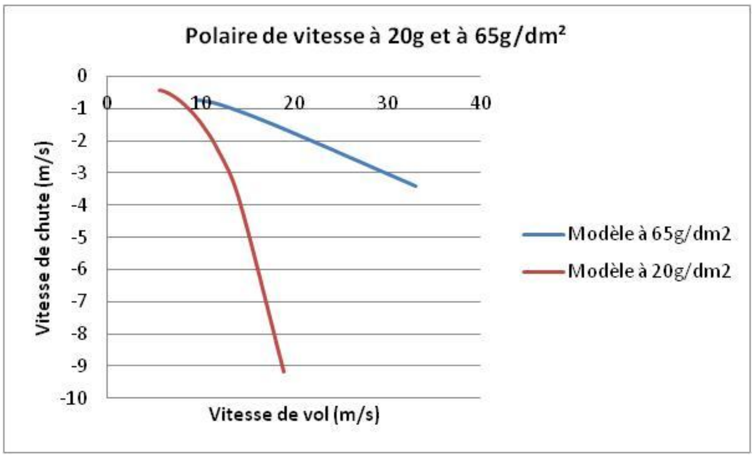
Sinking rate is defined by the following formula:

Vz = V*Cx/Cz

Where Cx is the total drag of the plane associated to the plane Cz (lift coefficient).

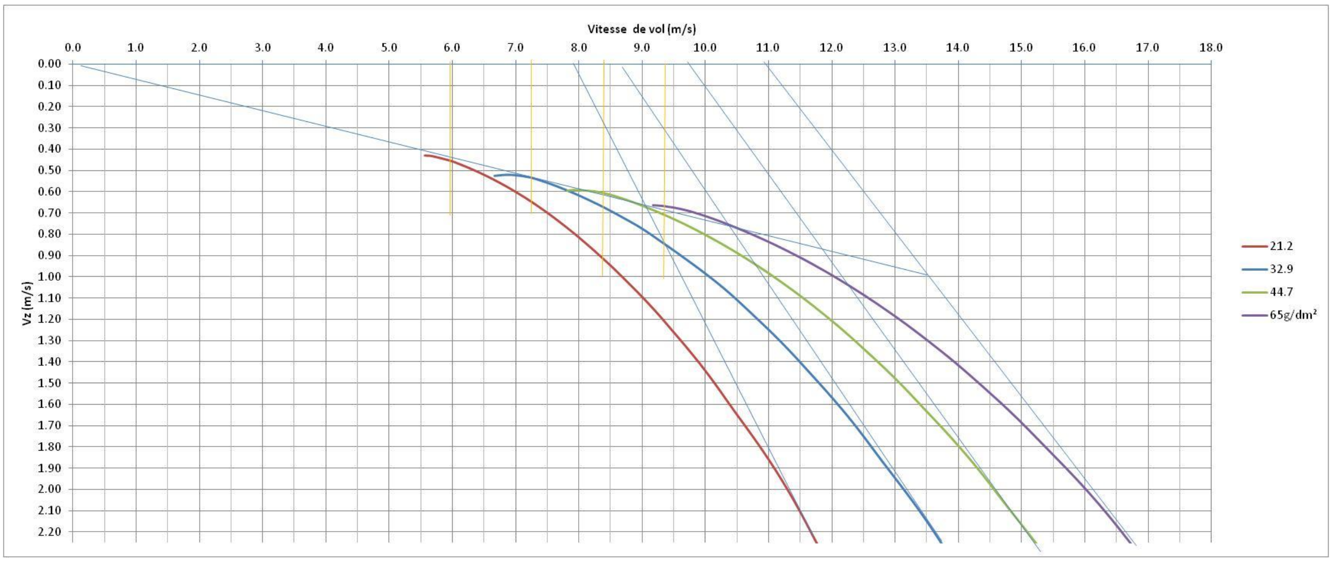
As we can see, if you multiply by 4 the wing load, you multiply by a factor of 2 the speed and the sinking rate.

The general polar of a light plane and a heavy one is then a bit different:



A very light plane could not fly at a speed of 10m/s without sinking drastically (over 2m/s). A heavy plane could go over 20m/s for the same sinking rate.

As a consequence, the light plane will never come downwind in a wind greater that 9m/s. But a heavy one will do it very easily.



Sinking rate = f(speed) of the Genoma² plane for different wing load. If you know a polar for one wing load, you can deduct the others ones for any wing load by changing it in the speed and sinking rate formulas. The error made by not taking into account the Reynolds variation effect will not be so important.

As a consequence, we can start to establish a rational based on the sinking rate and the flying speed.

But this do not provide us with enough rational.

We need to go a bit further.

A way to transform a F3J plane into a F5J one: Take a standard 4m F3J wing (here a Xplorer 4000) and install it on a Genoma² fuselage. This works pretty well specially for the circling ability. Of course, the minimum wing load is increased.

What is the influence of the wing load in circling ability in a thermal?

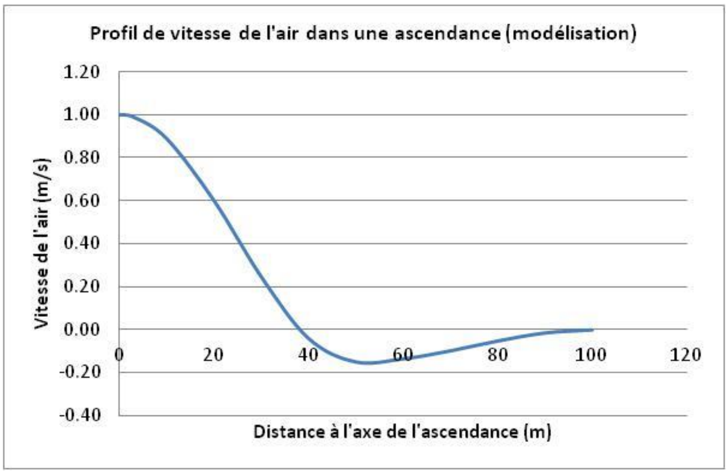
To appreciate this topic, we need to define the circling radius formula:

$$Rvirage = 1.63 * \frac{Ch}{Cz * \sin(incl)}$$

Where "Rvirage" is the circling radius in m.

“incl” is the bank angle radius in radian.

A thermal is a sort of tube where the air is going up at the center and going down all around. We can make a rough estimation of a thermal using some cosines formulas (a function used for lots of physical phenomena). See the small complement at the end of this article for more technical details.



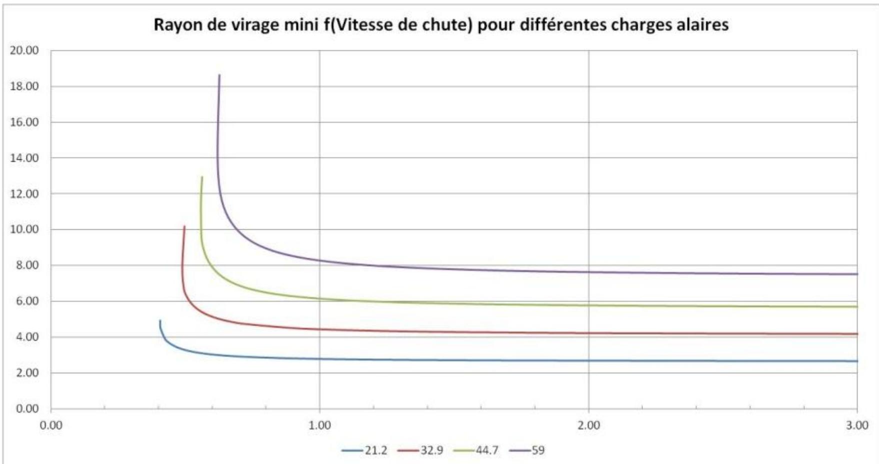
We then see that there is a certain interest to circle in the center of the thermal. For the moment, we all agree on that, don’t we?

The minimum circling radius is then to be obtained. But the more the plane circle tight, the more it sinks…

Is there a sort of optimum?

Let make additional graphics presenting the sinking rate and the circling radius:

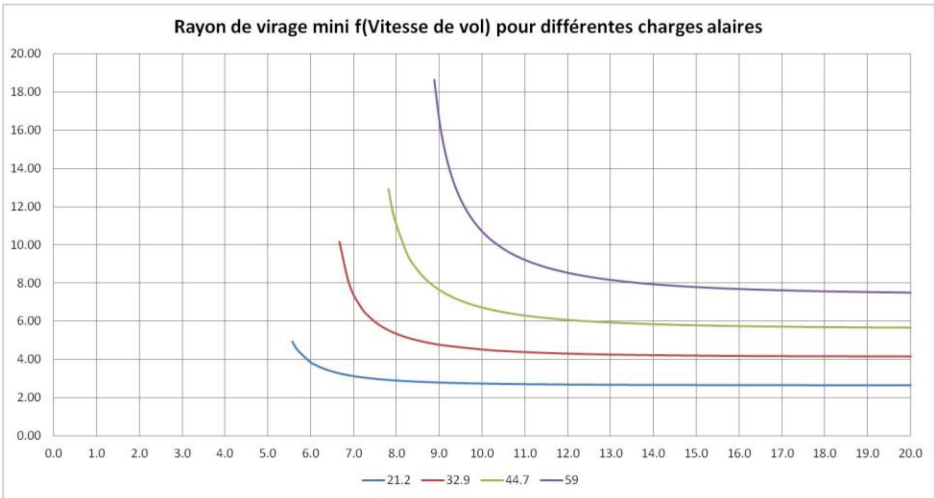
Circling radius for a defined sinking rate when circling. All is expressed for



different wing load.

As we can see, the circling radius is not decreasing so much over a defined sinking rate.

And if we trace the circling radius as a function of the speed, we found the same type of graphic.



Circling radius for a defined flying speed when circling. All is expressed for different wing load.

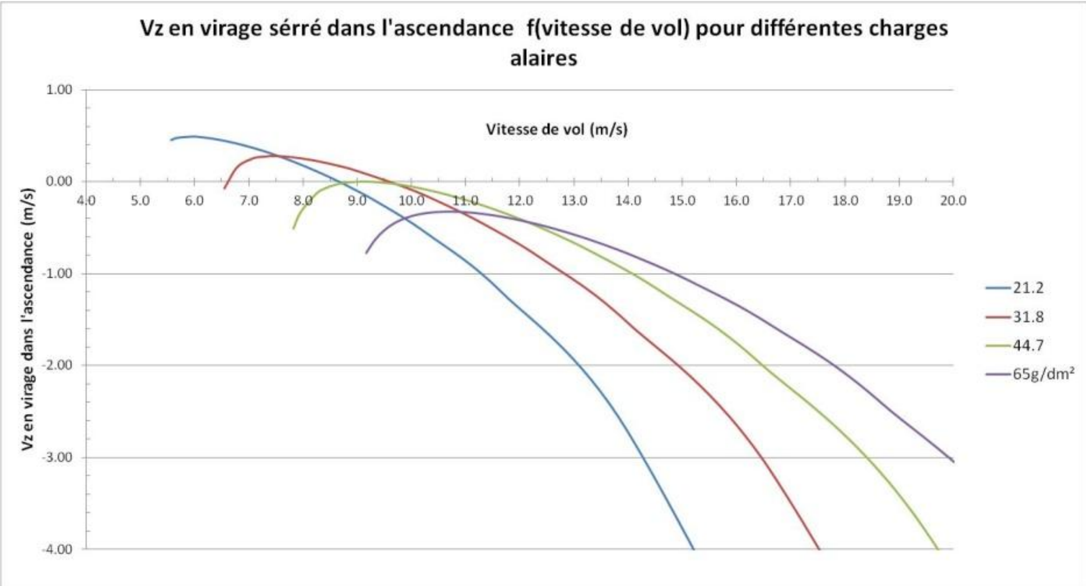
This means that there is no requirement to go too past to have a tight circling radius.

There is then an optimum speed to circle tight and to optimize the lifting rate in a thermal. This speed is at a flying point just over the best gliding ratio speed. Something about V+0.5m/s to 1m/s.

Ok! We have a part of the things. Let now integrate the wing load in this…

Then we see that we really have to be careful. If 150g has a very small effect on the sinking rate (about 2cm/s), in a small thermal, this difference may appears something about 4cm/s differences. This is then no more neglectable.

A light plane may take a small thermal where a heavy one may sink in it and where another one may stay at iso-altitude.



Example of a plane circling in the same thermal when more or less ballasted. It may take the lift of sink…

As a consequence, our TD planes must be as light as possible to take the smallest lift encountered and as heavy as possible to return from down to the wind.

A compromise must be reached. Which one?

Go back to the category rules

First of all, we need to analyze the TD category you want to fly.

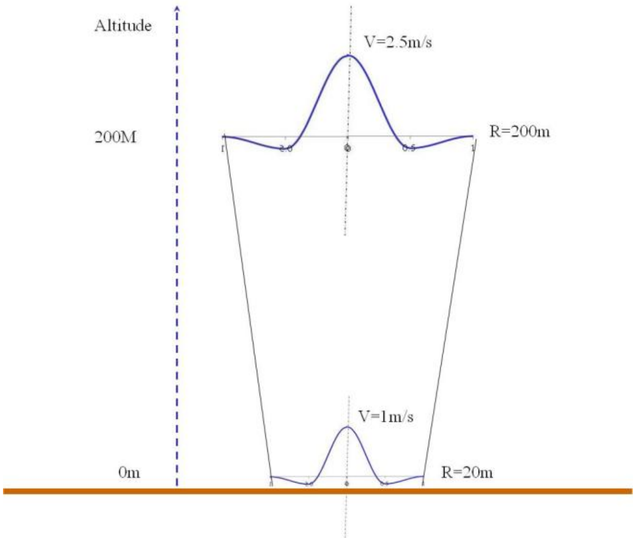
A F5J plane has 30 seconds to find the lift and a real advantage to take it at the lowest altitude as possible. You can see that in some fly-off, the motor is regularly cut at an altitude of 10m directly in the lift! Here the thermals are very narrow and light. Planes must be as light as possible.

The F3J planes will launch at the highest speed as possible in order to reduce the launch phase and to reach the highest altitude possible. They normally reach an altitude of 100m and over. Here the thermals are more strong and large! But planes have then to transit to catch the thermal. So transition is far much important for this category. And planes must be heavier up to a certain point.

We then foresee that there is not a unique way to ballast, but several ones that depend upon categories.

A wing load for a define thermal

To take the lift, the plane must have an accurate wing load that allows it to increase altitude in an optimum way. So let define what "a standard thermal" is.



I leave in an "oceanic western Europe" area where wind is most of the time between 5 and 9m/s and thermals quiet smooth. Planes get in altitude at a speed that is usually between 0.4 and 1m/s.

When wind is low, thermals can be catch between 10 and 50m altitude if the plane is able to circle inside a 10 to 20 m radius. With high wind we normally have to reach 200m and over, but the plane has to circle in 80m radius.

Most of the time the catching altitude is 100 to 150m and circling radius is about 40m.

That's then what I call a standard lift.

If the thermal is narrow and not very strong as it is closed to the ground, the plane must be as light as possible. In a lift near the ground or at 50m altitude, the plane must circle tight. A wing load of 10 to 20g/dm² is the way to do it. You see what type of a F5J plane we must have…

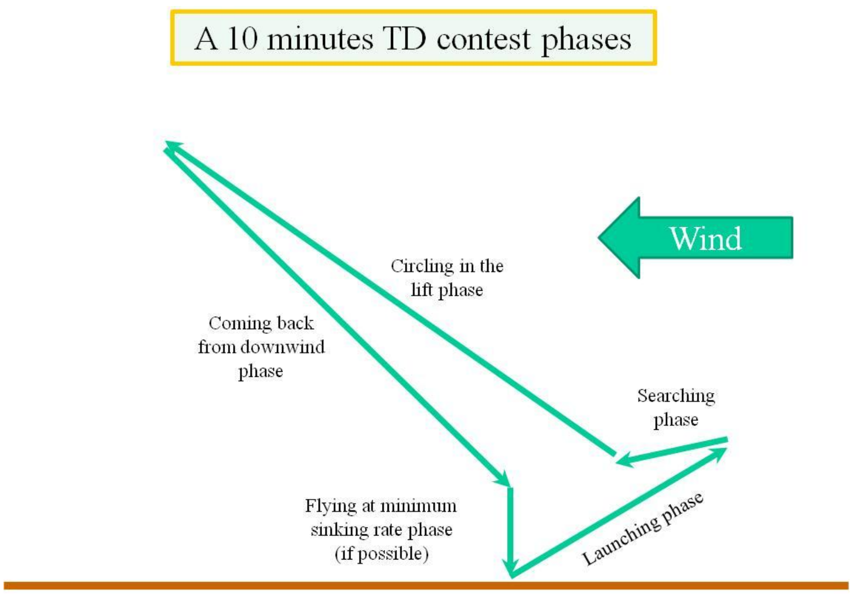
At 100m of altitude, the plane can circle in a bigger volume. And a wing load of 30g/dm² or even a bit more is quiet standard.

Over 200m altitude, the plane has to be in a 80m circle radius. Any type of plane can do it. Circling is then no more an issue. The issue is to transit. You can then see what type of F3J or F3B plane we can have.

The "Go in the lift and Return home" policy

A compromise between circling ability and high transition speed ability has to be reached.

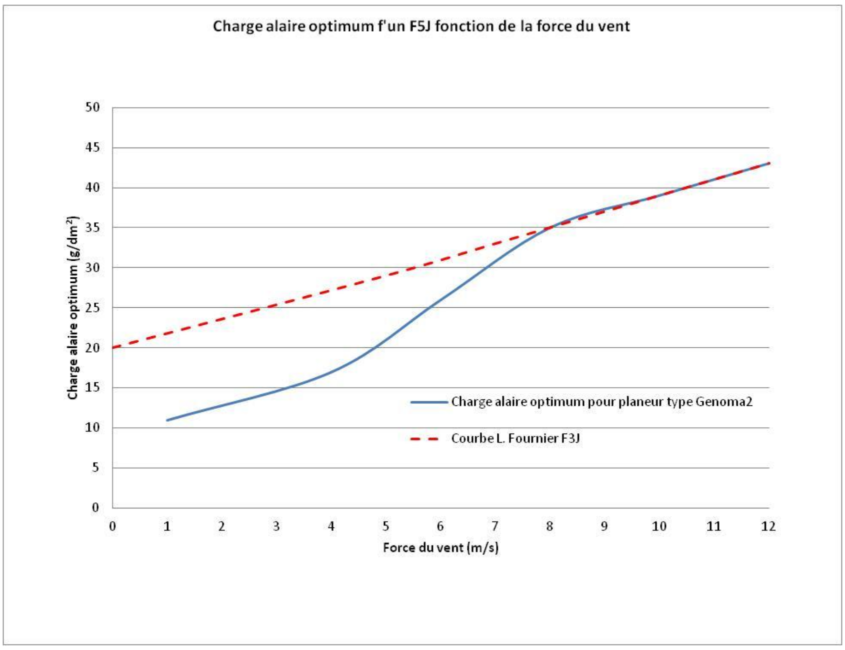
Planes should not only be able to take the lift or to transit from downwind. They must take the lift and return home to land. This is what we can call the "go in the lift and return home" policy. It must be launched at a defined altitude and position (generally upwind). Then plane has to transit to get the lift, get altitude following the thermal downwind. At a precise time, the plane should come back for landing. The flight is a success if the pilot has remaining altitude and time over the field to end the flight and prepare the landing phase accurately.



To succeed a TD flight, plane need to reach altitude, find a thermal, take it for as long as required to finish a 10 min flight, return home for landing with an altitude margin. For high wind, this requires to go very far downwind (up to 2 km) and reach a very high altitude (6 to 700m).

We then can compute this, mixing all formulas available to predict the best wing load we have to adopt. It is a bit complex, but it works…

We then obtain the following graph made for the Genoma² (F5J rules) and for the Supra (F3J rules):



For a wind lower than 5m/s, a F5J plane that is launched inside the lift should be at a wing load lower than 20g/dm². Plane should then be “as light as possible”. I do not believe that a 4m wing span plane can be lighter than 11g/dm². 15 to 17g/dm² is still very difficult to obtain for a F5J plane. That’s why I limit the curve to this “still unrealistic” F5J wing load. But who knows…

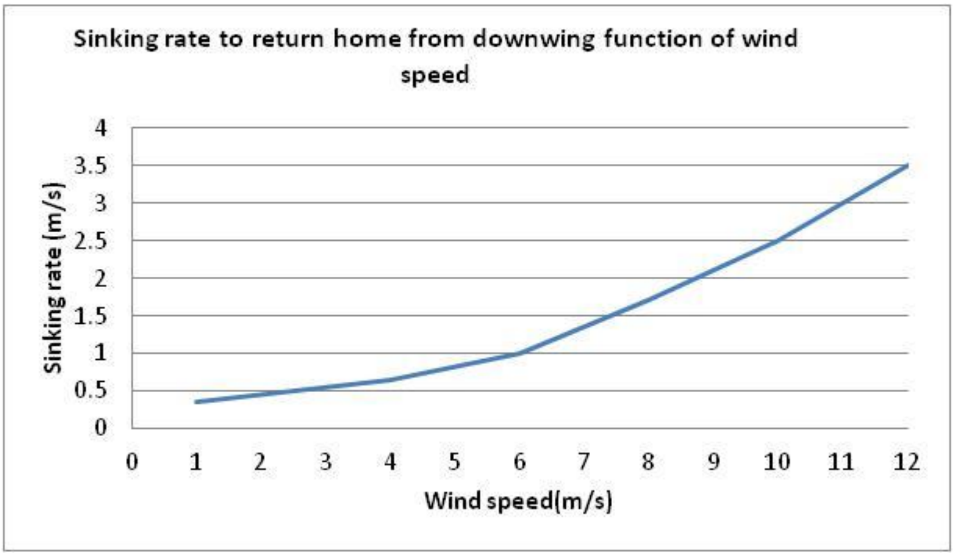
You can understand why producers are creating such light planes. Of course, if the pilot is not able to launch inside the lift, plane should be capable to a better transition ability and then to have a higher wing load. It may then be ballasted as a F3J plane or close to. The more the plane will pass time to search the thermal, the more it will have to be ballasted.

For a wind between 5 and 8m/s, a light F5J plane could not return home from downwind with an acceptable sinking rate. Here, the transition speed is more and more important and requires weight. F5J and F3J categories becomes closer.

Over 8m/s of wind, a plane that would like to make the 10 minutes flight should take only heavy thermals (the ones that provide a 1.5 to 2.5 m/s climbing rate and even more). Circling is no more so important. Here, the really thing is to return from far from downwind. F5J and F3J planes follow the same curves.

Of course, all such data are to be taken as a basis. Things can change a bit from one plane to another… But this is what I think is a start of a rational.

If you try to predict the sinking rate a plane should adopt to return from downwind with the predicted optimized wing load, then man can see that the more the wind is strong and the more the plane has to sink. If with very low wind a plane can fly and return home a a reasonable speed and sinking rate, in a high wind, the pilot really has to "push on the stick" (for an up to 15 deg dive in "calm condition").

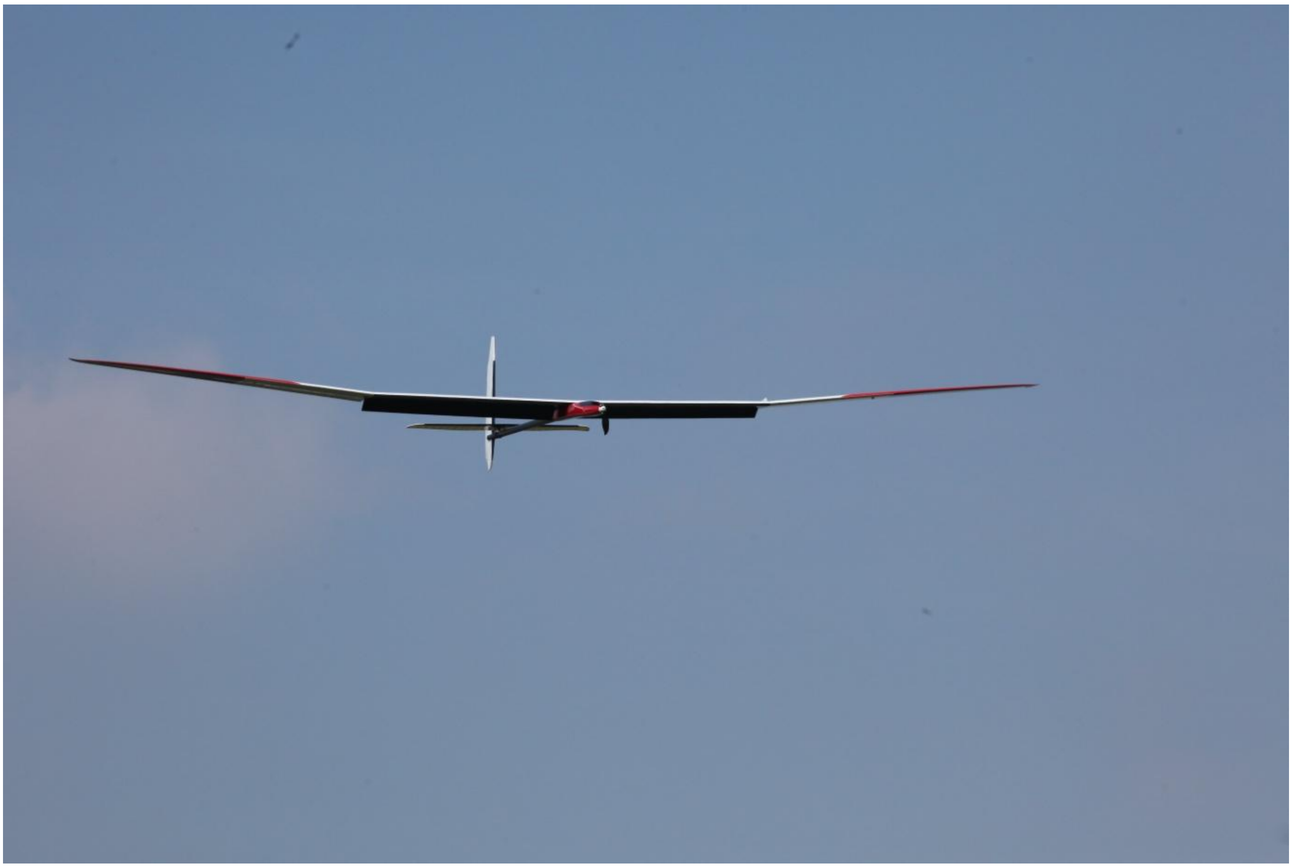


If a plane can return home flying "as usual" in a light wind condition, in strong wind, the plane must "dive". That's not easy to do and need lots of practices in in such heavy conditions.

I try to see if such ballasting result is something that can be correlated to the reality.

F3J category is quiet mature and we can say that the curve provided is something that makes sense. At least for the Supra.

F5J is a younger category and limited experiences are available. However, some Eastern Europe countries are more experienced than we are in France. They fly unballasted. But wind condition is totally different from the oceanic Western Europe ones. Wind is generally lower than 7m/s. So… not so bad isn't it?



After a successful flight, the landing phase. Do not forget it. An accurate ballasting policy is important but not sufficient…

Conclusion

Ballasting for a TD competition requires quiet a complex rational to be established.

No need to reach the maximum authorized FAI wing load of 75g/dm² for the maximum wind speed of 12m/s. something about 45g/dm² is enough.

There is not a single way to ballast and each category should conduct to its own way.

Ballasting has to integrate the following factors:

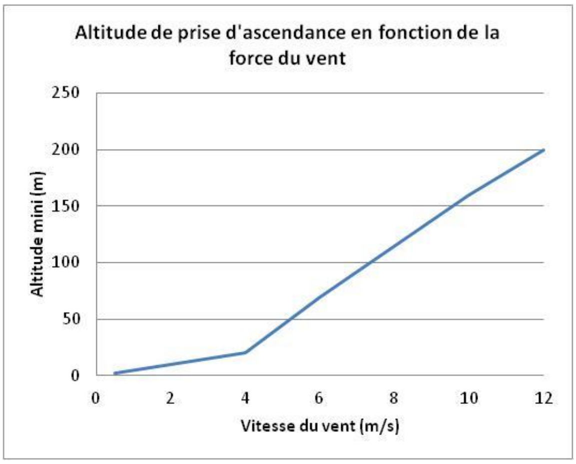
- Wind force

- Thermal characteristic (minimum altitude to take it, radius, force)
- Launching rules of the category
- Thermal searching phase duration
- Lift slipping speed
- Launching distance upwind and associated launching altitude
- …

Ballasting may be similar for some categories like F3J and F5J for heavy wind condition where transition phase becomes more important than circling tight one.

For light condition, F3J and F5J Launching categories rules provide different answers for ballasting. A F5J plane will be as light as possible providing that the pilot reaches the thermal during the launching phase. A F3J plane will be more ballasted in order to reach, in an optimum manner, the thermal the pilot know it is.

Finally, one may try to state the “standard” minimum altitude to take a lift as a function of wind (as a very rough estimation of course). And of course, if it is not the reality, you may say that this is my fault!

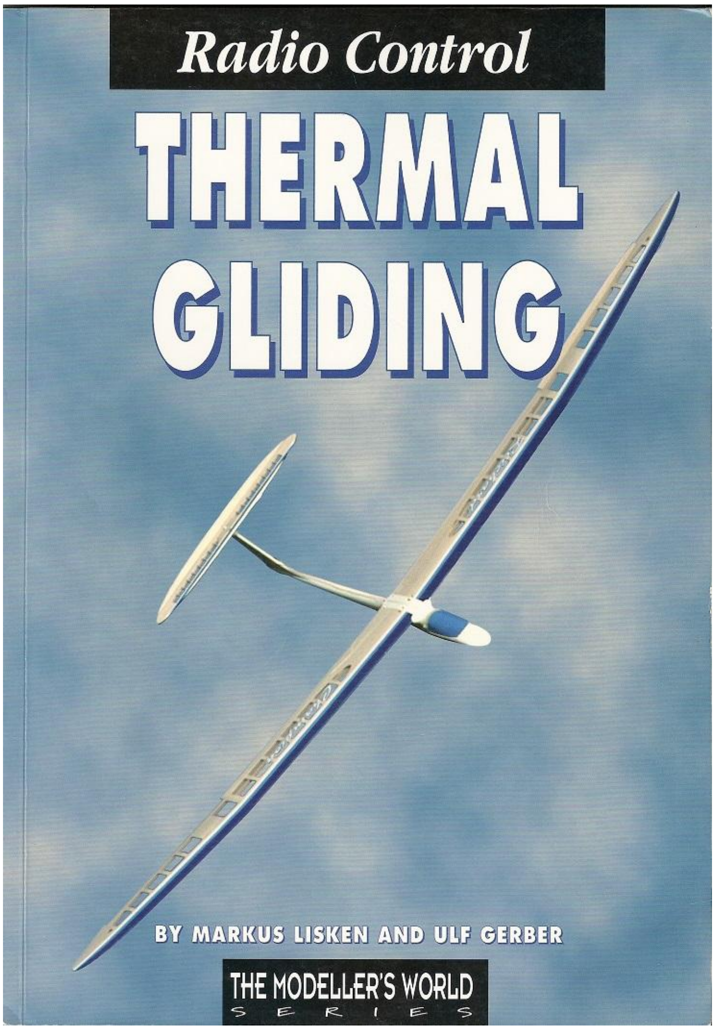


In F5J more than in any other category, the minimum altitude a plane can take a lift is very important. A rough estimation is provided here. This has to be tailored by lots of things such as humidity, pressure, temperature, ground aspects… and also the pilot and plane ability to circle tight. If this doesn’t work, just say that this estimation is rubbish or that it is the Author’s fault…

So, at your flight, steady, Ballast!

Supplement : How to model a thermal

I read a book called “radio controlled thermal gliding” that explains the method presented hereafter. Note that this book has many other interests.



I recommend the readers to buy it as I did if it is still possible:

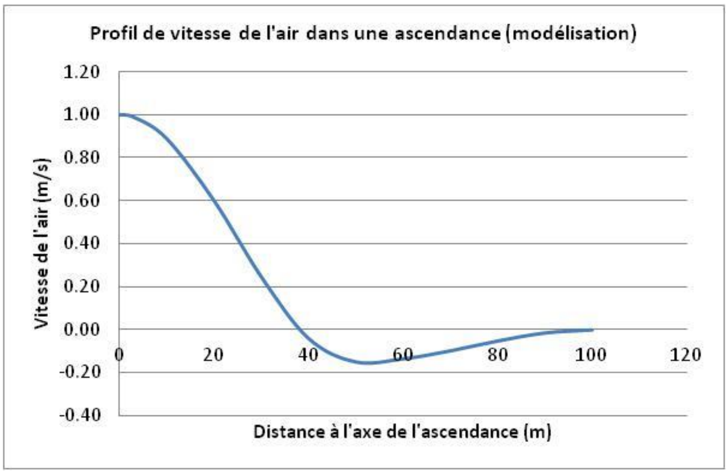
Let consider that a thermal, as for lots of physical other phenomena, it can be represented with “cosines” functions. Let take one for the lift and one for the sink.

The core of the lift is climbing, and the external area is sinking.

Because of Nature doesn’t like “holes” and “strong variation” (any variation are “smooth), we can state:

- That there is as much air that climbs that air that sinks.

- That in the center, the air has a maximum speed with a regular variation at the center
- That at the external side, the air is calm (no sink and no lift)
- There is continuity between the 2 phenomena (sink and lift)



Modeling a thermal is something that is quiet useful. Of course this is only a simplified model and reality is a bit more complex. But for a first order of magnitude, this is not so stupid.

Let then take a representation of the lifting air (you then can do the same rational for the sinking air) with the following formula:

Vasc=A0+A1*cos(A2*r).

"A0", "A1" and "A2" are coefficient to de defined, "Vasc" the air speed and "r" is the radius.

Of course we all want to have a radius in meter and an air speed in m/s.

So, for a radius between 0 and 0.5R, with R the total radius of the phenomena, the formula is then the following:

$$Vasc = A0 * Vmax + A1 * Vmax * \cos(A2 * r/R)$$

Where Vmax is the maximum velocity of the lift (in the core).

For r>0.5*R, we also have:

$$Vasc = B0 * Vmax + B1 * Vmax * \cos(B2 * r/R)$$

All the external conditions here presented allow computing the 6 coefficients:

A0	0.4256	B0	-0.0743
A1	0.5743	B1	0.0743
A2	6.28318531	B2	6.28318531

This may appear a bit complicated but with a small excel sheet, you can trace a very nice graphic and make lots of further calculation…

One can ask the question about representativity of such model. I then try to see the lift of a plane circling in the thermal and the sinking rate when escaping from the lift. My measures show me that most of the time and for a standard 3 to 4m plane and standard thermaling conditions, the lifting speed and sinking one are more or less equals. Then, for a standard lift that provides 1m/s climbing rate circling, I verified that the sinking rate is also more or less the same value… So…

And as we say in France “faute de grives, on mange les merles”!