HANGAR

Experimental Aircraft Association
Chapter 168
Dallas, Texas

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Season's Greetings

Flying At Aft CG

In Which a Professional Test Pilot Excites the Phugoid

By Chuck Berthe
From: The RVator, October '92, Part 1 of 2

Many years ago as a mechanical engineering student at the University of Oklahoma I attended a lecture in rather advanced mechanics (for me at least). The professor began by saying: "Now I'm going to teach you in twenty minutes what it took me twenty years to learn". He then proceeded to wax eloquent on the theory of planetary gears for somewhat in excess of twenty minutes after which time none of us had the slightest idea what he was talking about.

From that experience I learned that it is very difficult to translate insight achieved after twenty years of study to another mere mortal in just twenty minutes. Having said that, I will now attempt to teach you in some twenty paragraphs what it me "twenty years" to learn about flying at aft CG.

Dick VanGrunsven has been after me for some time to put some thoughts down concerning aft CG effects. Recently I had the experience of assisting a friend conduct aft center of gravity flight tests in his new RV-6. It seemed that this small flight test program could serve as a good vehicle to illustrate aft CG effects.

Before we get to the flying part it is necessary to lay some academic "ground work" in order to understand the flight procedures and results.

How The CG Location Affects Flying Qualities

Positive Static Stability

An airplane is normally designed to have the center of gravity forward of the center of lift. The center of lift is the result of all lift developed by the aerodynamic surfaces, the largest contribution normally coming from the wings; the other two major contributors are the fuselage and the horizontal tail. In order to trim the aircraft, the lift center is moved forward to match the center of gravity location by adjusting the elevator position. However, any change in lift generated by a gust, or other change in angle of attack, will act at the original lift center.

Weather Cocking Tendency (positive static stability)

Consequently, the aircraft acts as a weather vane. When deflected from its trim condition it will "weather cock" back to the trim condition. This is what we call "positive static stability". Dynamic stability is the manner in which the aircraft returns to the trim condition, i.e. does it return to trim rapidly and in a "dead beat" manner, or does it return slowly and overshoot the trim condition a number of times before settling out?

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Director's Meeting, November 12, 1992

The December Meeting will be on 12/1, this will be the annual X-mas party (covered dish) with optional gift exchange. The Chapter is providing ham, turkey and drinks. It was motioned and seconded to spend $25 to keep the room till 10 pm.

The December Fly-in will be held at Aero Country, the restaurant will be used instead of the trailer.

The January H.E. assembly will be at Gary Hansen's on 12/29.

The Young Eagles program was discussed. A coordinator is still needed.

The Kerrville Fly-in was discussed. Gary and Jerry will not attend the 11/14 meeting.

The '93 EAA Chapter insurance forms were reviewed. It was moved and seconded to have the Chapter take the $1M General Liability coverage for meetings and fly-ins.

The two Dave Hinkley ads in H.E. were discussed. He is way past due for one ad. Both ads will be run in Dec., they will be dropped after that. A "Past Due" bill will be sent.

The Aircraft Spruce Builders Conference was discussed. The various Forum volunteers were noted.

The November Meeting was discussed. We had 19 visitors, mostly as a result of the Builders Conference.

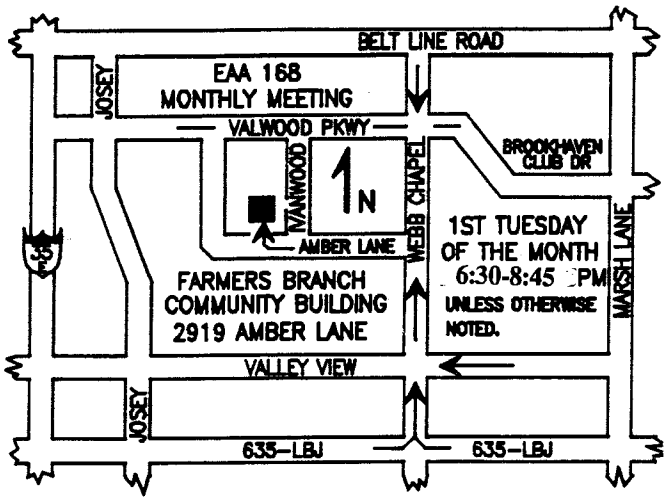
December Calendar

1 Regular Meeting (Christmas Party)
Farmers Branch Comm. Ctr. 6:00 pm - 8:45 pm

5 Fly-in

10 Director's Meeting
Farmers Branch Comm. Ctr. 7:00 pm - 8:45 pm

29 Hangar Echoes Assembly



H.E. Assembly

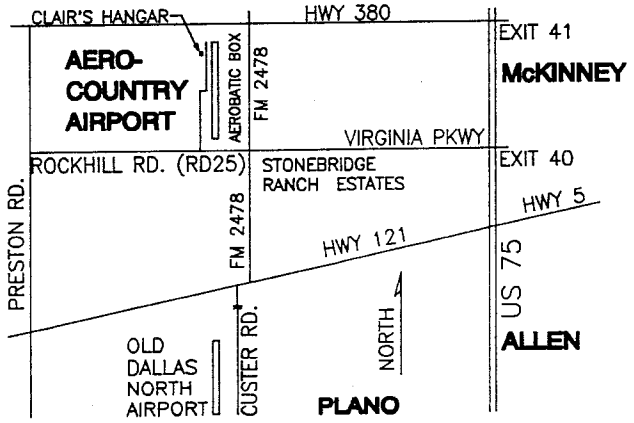
The January issue of Hangar Echoes will be assembled at Gary and Dina Hansen's house on December 29, 1992 starting at 7:00 pm. The address is;

2265 Reagan
Carrollton, 416-0099

December Fly-in

The December Fly-in will be on December 5th at Aero Country Airport. Our hosts will be Clair Button and Bill Wisley. Some aircraft parking will be available at Clair's hangar. Parking will also be available to the south near the restaurant. The Chapter 168 trailer will not be in attendance. We will use the airport restaurant for lunch. As usual, the Fly-in will run from 1000 to 1400.

If you want additional information, contact Clair at (214) 231-6070 or at the hangar (214) 347-2344.



From the President's Computer

Greetings to all! Time flies by, it's newsletter time again. Our airport meeting last month was at Addison, hosted by the Buce Hangar Crowd. We had a fine fly-in, Jerry Bidle and Red Marron cooked up some fine Hot Dogs, which the rest of us enjoyed. Thanks go out to Paul Johnson for getting the Chapter trailer to the Fly-in.

It's the end of the year, which is a good time to reflect over some of our events of the past year. We had, I believe, four first flights this year. Monroe McDonald has done a great job setting up our programs, providing us with interesting speakers. Our Fly-ins have been well attended and we have all enjoyed the camaraderie. Our Chapter handled Flight Line Operations at the Kerrville Fly-in and we were well represented at the recent Aircraft Builder's Conference. Sam Cooper stepped in to take on the role of editor of this newsletter, after Doug Vail relinquished the position. Don Lewis has kept the money and membership straight, along with Rance Rupp working on the mailing labels and membership rooster. Take a moment next time you see hard working members and complement them on their efforts. Not one of us can do it alone or go it alone, and I appreciate everybody's efforts on behalf of this Chapter and EAA. So Thanks from me to all the people who have helped throughout the year.

The Aircraft Builder's Conference was an outstanding success. It was hoped to have three hundred paying attendees, and five hundred and seventy five paid to attend. Aircraft Spruce and Kitplanes were pleasantly surprised. Folks traveled from as far away as Tennessee, Missouri, Kansas, Mexico, and the surrounding states for this event. Tom Scott and Crew hosted the Composite Forum, John Ivy and Crew handled the Woodworking Forum, and Sam Cooper and Ann Asberry worked the Sheet Metal Forum. A fine job was done by all, and the feedback the volunteers received was enthusiasm for Homebuilding and Flying! The Dream of building and flying your own airplane is still alive! Thanks go out to all the volunteers. (See kudos' elsewhere in this Newsletter)

Our monthly meeting this year is the annual Christmas party. The Chapter is buying Ham and Turkey, so bring a covered dish along and we'll have a fine dinner. See details elsewhere in this Newsletter. Merry Christmas to all!

See you at the meeting! Gary

P.S. Bring a gag gift and a friend along!

December Meeting

The December 1st Meeting will be the annual Chapter 168 Christmas party. The dinner will be covered dish, so bring in your favorite casseroles, side dishes, salads and vegetables. The Chapter will be providing ham, turkey and drinks. Spouses, significant others and offspring are welcome. We will be starting at about 6:00 p.m.

After the dinner there will be an optional White Elephant Gift Exchange. A White Elephant Gift is required for participation, but spectators will be welcome. We do ask that you bring something different than what you received last year.

Builders Conference

The Aircraft Spruce/Kitplanes Builders Conference held on Oct. 31 at Grand Prairie Airport was very well attended. There were about 575 paid attendees, with people coming from as far as Nebraska, Tennessee, and Mexico City, Mexico. The attendance was more than had been hoped for.

We would like to thank the following Chapter 168 volunteers who helped with some of the Forums. John Ivy organized the Wood Working Forum. He was assisted by Jerry Mrazek, Nick Nickle, Everett Thompson and Vern Williams. Tom Scott hosted a standing room only Composites Forum with several tables overflowing with tools and materials. Ann Asberry and Sam Cooper assisted with the Sheet Metal Forum. Finally, Gary Hansen pulled the Chapter trailer to the event and used it as a focal point to discuss the local EAA Chapters. To the volunteers, **Thank You** for donating your time and representing the Chapter.

Flying at Aft CG: cont'd

It turns out that the degree of static stability i.e. how far ahead of the lift center the center of gravity is, determines the character of the dynamic stability. The lower the level of static stability (the closer the center of gravity gets to the lift center), the slower the aircraft will return to the trim condition. We will see later how this can provide a clue as to approaching CG limits.

Two Dynamic Modes (positive static stability)

For an aircraft with positive static stability there are two dynamic modes of motion: the long period (or phugoid) mode, and the short period mode. The long period mode can be observed by raising the nose from the trim condition for a time sufficient to allow a change in altitude and airspeed. When the pitch controller is released the nose will slowly lower to below the trim condition and as the trim speed is reached the nose will rise and overshoot the trim condition and repeat the process a number of times until the motion finally damps out. This long period mode requires approximately one minute for each cycle and is generally lightly damped and will overshoot five to fifteen times before it finally settles out. This mode is the reason we can't simply trim once on a cross country flight and forget about it. Any gust or bump encountered sufficient to change the attitude, the altitude, or the airspeed, even slightly, will excite the mode and the oscillations will occur. We normally stop these excursions by re-trimming, and this will suffice until the next gust appears.

The short period mode has a period of only one to six seconds and is normally so well damped in light aircraft that it is not noticed as an oscillatory mode, but more as a measure of the degree of "quickness" available for making small changes in nose position. The short period mode was not considered of design consequence until after World War II when aircraft began going higher and faster. It could well be a design factor for the newer homebuilt designs that cruise above 300 mph and altitudes above 20,000 feet.

As the static stability is reduced, or the center of gravity is moved aft toward the neutral point, the frequency of these dynamic modes will

reduce. That is, the aircraft will become more sluggish and slower to respond to control inputs. At the same time the forces required to move the nose will become lighter.

What the Pitch Controller Controls (positive static stability)

When positive static stability is present the longitudinal controller (stick or wheel/column) controls **angle of attack**. When the pilot applies a force on the controller the airplane will respond with a change in angle of attack proportional to the force applied. This can be observed by applying a change in trim (this is equivalent to steady control application). The result will be that the airplane will settle down at a new angle of attack (or new airspeed, when in unaccelerated flight). An advantage of this "angle of attack command system" is that the force required to maintain the new angle of attack is proportional to the change in angle of attack and consequently proportional to the change of speed from trim. This is called speed stability and it is very important in providing the pilot a tactile indication of deviation from trim speed.

The fact that the pilot controls angle of attack with pitch forces is quite important during landing flare. Angle of attack is proportional to sink rate in the landing flare; consequently the pilot can change sink rate by changing force on the stick. If the sink rate is too high we apply more back pressure. If the sink rate is too low and we are floating we simply reduce some of the back pressure to increase the sink rate, and then re-flare. We will see later that with aft center of gravity positions stick force will no longer provide an indication of sink rate.

Neutral Static Stability

Neutral static stability occurs when the center of gravity is located directly over the center of lift. This could be caused by design, aircraft damage, or center of gravity location due to improper loading. In the case of light aircraft, the cause is generally due to improper loading.

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Flying at Aft CG: cont'd

Dynamic Modes (neutral static stability)

At neutral static stability there are no phugoid or short period modes. There are now four dynamic modes, but the one that dominates is a neutral stable first order mode (no oscillations, no overshoots) in pitch rate.

In addition, the pitch forces required for attitude changes will be further reduced from those of the previous cases.

What the Pitch Controller Controls (neutral static stability)

In the case of neutral static stability the pitch controller controls **pitch rate** (a "rate command system"). Back pressure on the controller will cause a pitch rate proportional to the pressure applied. When the control input is released, the pitch rate will go to zero, the nose will stop moving and remain at the resulting pitch attitude. This is very similar to what we expect an aircraft to do normally in roll. A normal airplane is neutrally stable in roll. A roll controller input results in a roll rate proportional to the input, and when the input is released, the wings will maintain the resulting angle of bank. In the case of roll this is exactly what is desired. However in the case of the pitch axis it can get us into trouble.

Now controller force only tells us how fast the nose is pitching. It tells us nothing about speed. When we release pressure on the controller the nose will stop pitching, but will remain where we left it regardless of speed. The good news is that the nose will remain right where you put it. The bad news is that the nose will remain right where you put it. Without close monitoring of power and airspeed, this could result in problems (like inadvertent stalls or airframe over speeds). In the landing flare, controller force no longer gives us an indication of height control. Normally we over flare slightly and then gradually modulate back pressure to achieve a near zero sink rate for touchdown. With this "rate command system" when we release back pressure to reduce the flare the nose will remain in the nose high flared position and the aircraft will float. Forward force on the controller will be required in order to

make the aircraft settle, and another flare iteration is required. While you are sorting this out unused, and now unusable, runway is flying by. Neutral static stability landings can be made safely by learning the proper technique, **if** you fully understand the problems, however, the pilot work load will always be increased.

Negative Static Stability

When the center of gravity is located behind the center of lift the result is negative static stability. As with the previous cases, this can be due to a number of causes, but generally is caused by aft loading.

Weather Cocking Tendency (negative static stability)

In this situation the weather cocking tendency is negative, that is the aircraft will attempt to swap ends. It's like throwing an arrow feather end first. The rapidity of the swapping of ends is dependent on the level of instability. This is determined by just how far aft of the lift center the center of gravity is located. As we will discuss later, it is possible to fly an aircraft with negative longitudinal static stability **if**, the end swapping requires as long as a number of seconds to take place, and **if** there is adequate control power. To land an aircraft in this condition can be quite difficult to impossible.

Dynamic Modes (negative static stability)

There are now three dynamic modes. The first two are generally of little consequence. The one that gets the pilot's attention is a first order divergent mode. This means that when the pilot makes a pitch input, the nose will accelerate to a faster and faster pitch rate until the pilot removes the input. Then things get a little better, the nose will now cease to accelerate, but only continue to diverge at the highest pitch rate attained while the pilot input was being held. As if things aren't bad enough, the pitch forces will be quite light. It will take very little force on the controller to achieve a pitch attitude and pitch rate that could be unrecoverable.

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Flying at Aft CG: cont'd

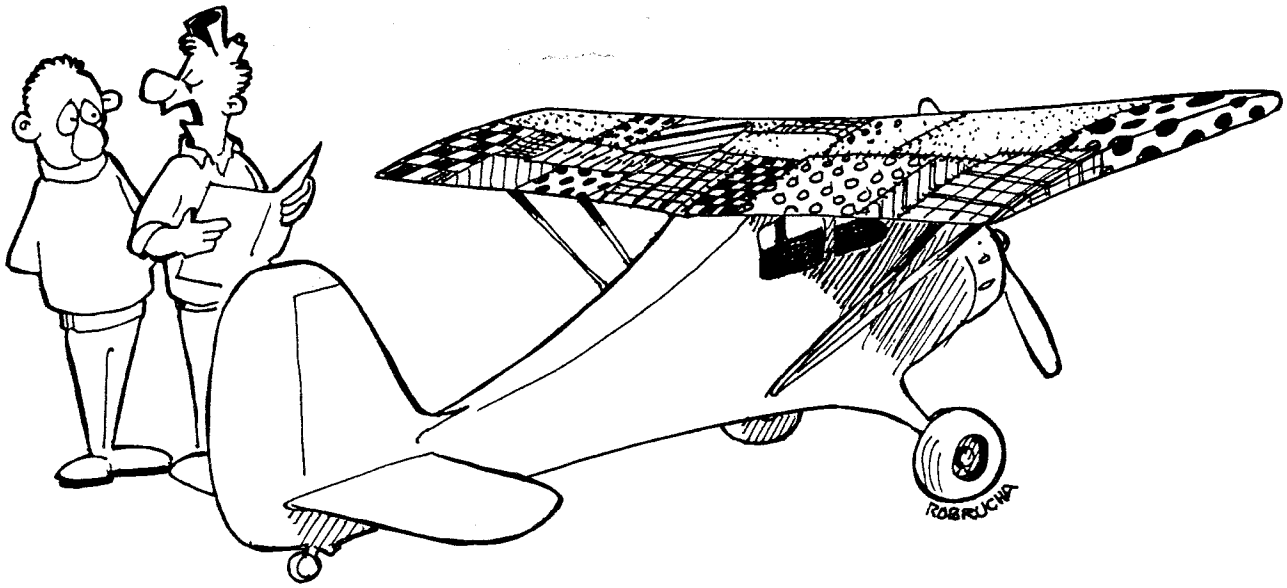
This divergent mode is the main reason that designers, regulating agencies, flight instructors, check pilots, flight engineers, and pilots with a professional attitude, are very interested in center of gravity location. Your airplane can be loaded in such a way that it will be impossible to control. Staying within the designer's center of gravity limitations assures that your aircraft will be controllable.

What the Pitch Controller Controls (negative static stability)

In the case of negative static stability the pitch controller controls **pitch acceleration**. As mentioned above, if the pilot applies a back force on the controller the nose will pitch up at an ever increasing rate until the force is removed and then it will continue to pitch up at the highest pitch rate achieved during the input. It is obvious that in this situation the pilot is not going to leave control inputs in for very long if control is to be maintained. Consequently, control can only be achieved by making small pulsing inputs in both directions. An input to raise the nose must be countered by an equal input in the opposite direction. This must then be followed by a period of no input in order to judge the resulting nose position and pitch rate. The pilot must continually repeat this pulsing, and sampling technique in order to maintain control.

The light pitch forces add to the complexity of controlling an unstable aircraft. If the center of gravity is too far aft, excessive pitch rates can be achieved in a very short time. The pitch rates can become so great that the elevator will not have enough control power to effect a recovery. If these conditions are not recognized prior to take off a short, but eventful, flight will result.

To be continued next month.



I THINK IT IS WHAT IS KNOWN AS A "CLASSIC RASWING"!

Op-Ed

The opinions expressed here are solely those of the author and do not represent the Experimental Aircraft Association of Chapter 168.

By John Clary, a.k.a. Igor's Master

What makes a ground-bound aviator different from the other earthworms?

Are those who fly or aspire to flight different from those who are content to remain on the ground, or is it strictly a matter of degree along some scale of loftiness. Does John Madden go at one end of the scale, with those like Charley Hillard and Clint McHenry at the other end? Or, to paraphrase F. Scott Fitzgerald, are those who fly different from the rest of us?

I believe there is a passion that separates those that want to fly from those who have to fly and those who won't fly. I want to fly, I want it with every fiber of my being. My wife flies when she has to and I have cousins that have never been on an airplane and couldn't be forced to do so at gun point. My wife and cousins are otherwise very nice, normal people with no other discernible psychological problems. My children are not that enthused about aviation either, which may mean that it isn't an inherited trait.

There are, however, many families where every member is involved in some manner with aviation on a daily or very frequent basis. This seems to indicate that if not inherited the trait may be infectious, so we could help our cause along by spreading it around. An old poster I read said very much the same thing, "Enthusiasm is infectious, spread it around."

One way we could help our cause is to invite primary school children to field trips to general aviation airports, where they could see and touch real airplanes owned by real people. I myself may have caught the bug at an early age when my father was stationed at Pensacola FL, within sight of the training center and where I could see aviation take place 6 days a week.

Another method may be having people promoting flying at the various "Career Days" that take place at high schools and junior highs around the area. Emphasize that flying is something that anyone in good health can do, with proper training, and that it isn't limited to the Chuck Yeagers and Neil Armstrongs of the world. Also make note that there are as many jobs on the ground to support aviation as there are in the air, and that a career in aviation can be as emotionally rewarding as any.

Without trashing anyone else's profession or hobby, I think aviation is one of the truly contributory occupations we have available, unlike others that take much but offer little in return.

This is Igor's Master, returning to the laboratory. Happy flying, to those of you who can.