THE DAVID GALL WHEEL ALIGNMENT

(FOR Q-2 AND Q-200 EXPERIMENTAL AIRCRAFT)

DISCLAIMER

The following presents a series of related thoughts on a topic. It is not sufficiently well organized to constitute an article, nor is it even structured adequately to be called an essay. It is not crafted so as to persuade or inform, merely to record my thoughts and convey the basis for that thinking. I have no training or background as an engineer, formal or informal, and no experience with the designs I discuss except that I have read every issue of QuickTalk/Q-Talk, every issue of the QAC newsletter, the complete Quickie and Q-2 plans, and various other articles that have appeared in Sport Aviation and elsewhere. I have not built an airplane, but I own a Quickie kit that has almost no work done yet. Anyone who incorporates ideas presented herein or in any way alters their intentions or behavior as a result of the ideas presented herein does so at their own risk and by continuing to read beyond this paragraph does implicitly absolve me of any liability or responsibility for any outcome of such actions, desirable or otherwise. I intend to incorporate such ideas as are presented here in my own efforts to build airplanes, therefore this constitutes nothing more than my own personal notes, shared with others for the sole purpose of informing them of my intentions and reasoning. None of the ideas presented here are new or proprietary; rather, the exposure to this particular audience may be new. No attempt is made to overcome the inertia this group has developed as a result of their indoctrination in certain other techniques claimed to benefit in the same manner as these ideas. In other words: don't argue with me, I'm not trying to persuade you; and don't sue me, my net worth is negative!

That said, . . .

BACKGROUND QUOTES

From Nov./Dec. 1985 QuickTalk issue #24, p. 10:

"From Mike Dwyer #2841

> *"My new canard was measured for flex mounted in a complete airframe, no engine or fuel. Placing 130 lbs. on the wing flexed it 0.6" and 250 lbs. flexed it 1.2". I estimate that with fuel, people, engine etc. it will flex 3" downward. Tires accounted for about 29% of the flex."*

From Nov./Dec. 1987 Q-Talk issue #6, p. 7:

"Q-2 TIPS"

> *"Bob Malechek here in Dallas has been exercising his analytical mind and tinkering ability to try to figure out and overcome some of his Q-200's mysterious handling qualities. He's beginning to feel his plane handles now more like a trike than a taildragger (and it's not a Tri-gear). Some thoughts on tires: Bob built his pants to fit the McCreary 5.00x5's but switched to Lamb's saving 3" diameter and 4 lbs. He noticed the McCreary's have a rounded tread contact with the ground whereas the Lamb was flatter. More stable? He found the Lamb was balanced better than the McC. With the diameter decrease, he moved his axles 1.25" forward of the LS-1 plans callout. While he was at it, he put a normal load in the cockpit and then set his wheel to contact the ground vertically (no camber) and straight down the runway (no toe). After 12 landings, he believes something among these changes was significantly better. With his soft tailwheel and 70+ hrs. in the bird now, he may need to install a small TV to keep from falling asleep after touchdown. More from Malechek as testing continues."*

From Mar./Apr. 1988 Q-Talk issue #8, p. 10:

"Dear Jim:

> *"My Q-200 taxied squirrley [sic]. Ran off the runway twice slowly uncontrolled. When I changed the axles to steel I noticed that with full weight on the wheels that you no longer were looking 2" forward of the opposite axle IAW QAC plans. I was looking at the ground due to the down flex of the canard. I cross haired the inside of the axle hole with thread, marked a X 2" forward of the opposite axle hole, noted an approximate center for the new outside hole. Then floxed shut the outside axle holes using duct tape to hold the flox in place during curing. (Thanx Fred Wemmering QBA Nov/Dec 87). Then drilled a very small hole where I estimated the center of the new hole should be, re-checked the sight picture, drilled a bigger hole, checked sight picture, and finally drilled a 5/8" hole that had a perfect sight picture for 1° toe out on each wheel. No change was needed on the inside hole, brake calipers, or wheel pants. The new hole center is about 1/2" down from the center of the old hole. My taxi tests now are great even with a ten knot cross wind. Final note: I also had a very small variation in toe out prior to this adjustment.*
>
> *"Dave Naumann - Enterprise Alabama"*

SUMMARY

Okay, get out your calculator. I'm not going to drag you through a long dissertation about the ground directional stability of the Quickie/Dragonfly/Q-2/Q-200 series of designs, or try to convince you that all the fixes aimed at this problem have missed the mark by addressing controllability (control authority) rather than stability (a different but related issue). Nor will I dignify arguments about the criticality of "ground angle of attack" save to say that all the effort spent on that issue is wasted. I won't abide the argument to build strictly according to plans, either.

I will state flatly that there's ample evidence in the pages of QuickTalk/Q-Talk (no single-data-point hyperbole here) to indicate that stock plans-built airplanes have ground directional stability problems; that the majority of fixes proposed over the years, although incorporated by many with often positive and repeatable results, have not directly addressed the problem; and that a few fixes have had legitimate success in correcting the problem, but have been largely overlooked and lost in the hoopla surrounding the promotion of certain other "factory" recommendations, specifically, the T-tail, reflexor, and "ground angle of attack" campaigns.

The correct fix for the ground directional instability of these airplanes, I believe, is to give them a front-end alignment, just as you'd give your car a front-end alignment if it began heading for the weeds un-commanded. Some minor adjustments to the tailwheel can also contribute positively, which I'll cover, but the primary culprit is the main wheel alignment. If built according to the plans the alignment is plain, flat wrong.

Notice that I've said nothing about aerodynamics. No incidence change, reflexor setting, enlarged rudder or tacked-on T-tail will ever compensate for a wheel alignment problem. Frankly, I find it a bit perplexing that the designers of these planes would even think to look for aerodynamic fixes for such an obviously wheel-related problem. No one, to my knowledge, has ever complained about an overt lack of directional stability or control authority in the air; in fact, the Q-birds have been highly praised over the years by numerous writers for having good control harmony and response. If that changes when the airplane is in contact with the ground, why would anyone not go directly to the point of ground contact as the most likely culprit?

CAMBER

Granted, there's been much discussion over the years about wheel alignment on Q-birds. For the most part it has centered on toe-in vs. toe-out, with toe-out emerging as the apparent winner. However, there's more to wheel alignment than just toe. Equally important is camber, a tiny little word you'll find mentioned in the second quotation above about Bob Malechek's airplane. Unfortunately, Bob has at least two more reports in subsequent issues wherein he correctly credits his toe-out and tailwheel mods as significant contributors to his improved handling, but he fails to also mention camber. Perhaps he did not recognize the significance of this factor in correcting his airplane's directional instability.

On the subject of camber, from "Race Car Vehicle Dynamics" by Milliken and Milliken, published by SAE International, p. 46:

> *"In accordance with SAE terminology.... The camber is positive if the wheel leans outward at the top relative to the vehicle, or negative if it leans inward.*
>
> *"In racing circles, tilt of a wheel is universally referred to as 'camber', with the sign conventions following SAE as above. The effect of camber on the tire forces and moments actually depends on the angle between the tire and a perpendicular to the ground—as opposed to the angle between the tire and a chassis reference....*
>
> *"In general, a cambered rolling pneumatic-tired wheel produces a lateral force in the direction of the tilt. When this force occurs at zero slip angle, it is referred to as 'camber thrust'."*

Under the heading of 'Alignment' on page 726 of the same book appears the following:

> *"Camber angle to the road surface is one of the fundamental variables that determine tire performance....*
>
> *"Camber also works like steer: When a tire is cambered it tends to pull the car in the same direction in which the top of the tire is leaning. A simple way to think about this is camber-steer force equivalence.... For bias-ply tires... 1.0° of camber is equivalent to about 0.2° of steer (5:1). From this simple rule of thumb, it can be seen that static negative camber will require toe-out to keep the wheels from fighting each other."*

Keep that last reference firmly in mind as you build your Q-bird, and as you consider the remainder of this treatise.

ALIGNMENT

Also appearing under 'Alignment':

> *"The amount of static toe on the front will depend on other suspension parameters such as... ride and roll steer, compliance steer..., and camber (both static and dynamic with ride and roll motion). Minimum static toe is desirable to reduce rolling resistance and unnecessary tire heating/wear that will be caused by the tires working against each other."*

Wait a minute: what's this "ride and roll steer, compliance steer" stuff? Well that's the change in steering angle, camber, and toe as a result of the geometry of the axle as the suspension moves through its range of travel. Of note to us is the fact that the camber and toe can be affected absent the steering links of a steerable axle. On the Q-birds the flexibility of the canard in both bending and twist conspire to aggravate the built-in inboard (negative) camber (of a plans-built plane) and to initiate inboard toe as the load on each wheel increases. What does all this mean? Consider for a moment....

FORCE ANALYSIS - INSTABILITY

Our baseline airplane will be a stock, plans-built Q-200. When this plane rolls down the runway, the built-in inboard camber and almost neutral toe allow the main gear tires to generate forces, each inboard toward the center of the airplane, that oppose one another. Another tire characteristic described in the literature is that of generated forces being generally proportional to the load on the tire, so the forces on the left and right gears balance.

Now consider a crosswind gust from the left: the airplane is "heeled" over to the right slightly due to the new side forces on it. This increases the load on the right main tire and decreases the load on the left main tire. The changed loads allow the canard to flex differently, bending and twisting more on the right and relaxing on the left. The right main tire generates more inboard force due to the increased load on it, but more, the inboard camber and toe are increased due to canard flex, amplifying the effect. At the left canard tip the opposite conditions prevail, and the reduced inboard forces of the left main tire are further attenuated by the geometry moving toward a more 0-0 camber-toe setting. The additive resultant of the two front tires' forces is a strong force to the left, just as though the airplane had been equipped with steering and the driver had turned the wheel to the left.

But wait, there's more! This force to the left acts just like steering, so the plane starts to head for the weeds to the left. This is called a turn, and, as any turn, it generates centrifugal force. Since the turn is to the left, the centrifugal force acts to the right, but more importantly, it acts through the Center of Gravity (CG) of the airplane which is somewhere above the surface of the runway. The tires' resultant force acts at the runway surface to the left and the centrifugal force acts at the CG to the right; the resultant rolling couple tends to roll or "heel" the airplane to the right -- in this case, further to the right than the initiating crosswind had already heeled it. So the airplane's response to the initial disturbance is such as to amplify the initial disturbance; this is a textbook definition of instability.

CONTROL RESPONSE - REVERSAL

Hold on, now, we're almost done with this part, but first we've got to consider the pilot's role in all this. After all, it's not the machine but the man/machine entity which must be stable to be useful. When the crosswind first hits, the plane veers to the left. What is the pilot's reaction? How about a good bootful of right rudder, that ought to do it. The Q-bird's tailwheel swings to the right -- wait! Which way does the Q-bird's tail go when this happens? To the left, of course. We can go out to the hangar and see this without even opening the canopy. Good.

After the tailwheel is displaced to the right, the tailwheel, impotent though its reputation may be, does generate some force to the left... acting at the surface of the runway... below the CG... creating a rolling couple to the right... ARRGHH!! Our tiny tailwheel, in attempting to alleviate the veer to the left, has actually exacerbated the situation and further propelled us to certain doom! (If you don't see that, re-read the two preceding paragraphs.) Naturally, being pilots, we're going to apply even more right rudder with even more deleterious results. It's no wonder the tailwheel has a reputation for being ineffective and "skidding" just when we need it most.

As a side note, consider the effect of the ailerons on the front-end geometry of these planes as I've described here and you'll have an understanding of how the mysterious "reverse aileron steering" works. By all accounts, this phenomenon is quite positive and reliable, if initially slightly awkward, but, oddly, Mike Dwyer and others with corrected front-end geometry report that the effect is not nearly as pronounced as others would have them believe. Hmmm. Class project: explain why that is.

EXAMPLES

Okay. I think that's enough analysis.

Quoted above are three QBA reports which should not be ignored. At the Sun-N-Fun QBA forum this year (1997) Mike Dwyer stood and announced proudly and convincingly that his Q-bird is probably built closer to the plans than anybody's, even Gene Sheehan's, which I do not dispute. He reported over 870 hours of operation, and strongly advocated following the plans. With his quote from 1985 (above) in mind, I asked him about the stance of his landing gear at gross weight. He confirmed that he had adjusted his main gear for zero camber at gross weight. I think from now on I'll consider Mr. Dwyer's airplane to be the baseline against which all others should be measured, pending his consent, as there is no factory standard against which to compare.

Between Dwyer, Malechek, and Naumann, we have three Q-birds reporting significantly better than stock ground handling. No mention of "ground angle-of-attack," reflexors, T-tails, or bigger rudders. Malechek says he moved his axles forward 1.25 inches and has a "soft" tailwheel; in other reports to Q-Talk he also mentions tailwheel centering springs. These, too, contribute to directional stability and control authority, but the meager control authority of the tailwheel will never rival the power of the destabilizing forces that the main wheels can generate when misaligned as they are if built in accordance with the plans.

CRITICAL SPEED

Page 174 of "Race Car Vehicle Dynamics" introduces Significant Speeds:

> *"...Maurice Olley was the first to discover the critical speed beyond which some vehicles become divergently unstable."*

Continuing on page 177:

> *"At the 'critical speed' the car becomes divergent, that is, a small steering input results in very large (theoretically infinite) responses in terms of path curvature, yawing velocity, lateral acceleration, or vehicle slip angle."*

Hmmm. Sounds like a ground loop to me. The text goes on to describe situations requiring no steering input such as a crosswind or bump causing a small disturbance to the car's path that also result in divergence. In light of my explanation of a few paragraphs back, I think there is no need to further analyze the Q-bird landing gear for potential causes of divergence; there are ample reports in the pages of QuickTalk/Q-Talk which will attest to the speed-related nature of the airplanes' instability, even including the admonition to new pilots to practice taxiing slowly at first, then at ever-increasing speeds until they are comfortable. This amounts to little more than training the on-board computer to act as an active stability-augmentation system! Repetition makes the task secondary so that the flight test task can become primary.

The speed-related nature of some of the reported accidents may not at first be apparent to the casual peruser of back issues. Consider, though, that the speed in question is not airspeed, but ground speed.

Suddenly, what may have been a mysterious occurrence on a calm day becomes an anomaly in that the familiar home-drome airport normally has a ten-knot wind down the runway. On the day of the accident, even if the pilot made a liftoff or touchdown at lower than normal airspeed, that may have been a higher than normal ground speed nonetheless! Or, consider the first arrival of the experienced Q-bird pilot at an airport of an elevation higher than he's used to. Although all other conditions may be identical to those of familiar haunts, including the indicated airspeed at touchdown, nevertheless, the increased density altitude causes a higher than normal ground speed at touchdown which may put the airplane in its divergently unstable zone: wipeout! The simple combination of a hot summer day and no wind may be enough to send the liftoff speed past the critical speed, exposing a pilot who thought he was familiar with his craft to a wicked side of it he'd never imagined. Even a different CG location can cause the airplane to require a slightly higher liftoff speed. The truly insidious nature of the beast may come to light, however, at the most embarrassing of times: the first passenger ride! Assuming an FAA standard 170 lb. passenger, that's roughly a 20 percent weight increase above what the airplane has been operating at. This will translate into a 10 percent increase in liftoff and touchdown airspeeds, which may further translate depending on the usual prevailing winds into a proportionately larger percentage increase in operating groundspeeds....

Unfortunately, I can't say definitively what the critical speed is for a plane built in strict accordance with the plans, but from reports in QuickTalk/Q-Talk I'd hazard a guess that the 45 to 50 mph indicated airspeed range is close, but without correlating wind information or direct ground speed readouts it's really quite pointless to name a speed. What is important is that the critical speed quite obviously falls below the minimum liftoff speed at least some of the time.

More importantly, however, it establishes that the Q-birds follow the classical mechanics of ground vehicle dynamics. There is no malicious black magic at work in these planes, and they ought to be correctable through application of sound, rational, scientific principles. Witness the three reporters above, the critical speed of these planes ought to be changeable quite easily through application of a front-end alignment.

APPLICATION

"Race Car Vehicle Dynamics," page 24:

> *"The peak of the [tire lateral thrust] curve may remain at a constant value or fall off slowly as indicated [chart]. In dry conditions, race tires generally reach their peak lateral force at slip angles in the vicinity of 3°-7°. On a wet surface the peak will in general be lower, and the fall-off in lateral force after the peak will be more rapid."*

What does this tell us? It tells us that those who advocate 2° of toe out to tame the Q-birds are using up the available tire lateral force range to a significant degree just to make the airplane reasonably docile, indicating that the tiger whose tail they've grabbed is a strong one, indeed. It also tells us that, since peak tire lateral thrust is similar to the load carried by that tire, the lateral forces are large causing great heat and wear on the tires. A quick estimate for a 1000 lb. Q-200 might be that each main tire is carrying 450 lbs. while the tailwheel carries 100 lbs. Extrapolating, the tire lateral forces during straight rolling at speed may be as much as 300 lbs. But wait, that 300 lbs. is not occurring on those airplanes with toe out for the toe out somewhat alleviates the inboard loads built in to those airplanes when they were stock; rather, the stock airplanes built strictly to the plans without camber or toe out mods are experiencing high inboard lateral thrust loads on the main gear.

Significantly, the main gear lateral thrust loads substantially exceed the thrust that the tailwheel can generate, and, as has already been shown, brisk application of steering inputs to the tailwheel can actually adversely increase the lateral thrust of the main tires. Is it any wonder, then, that the tailwheel gets described as ineffective?

NUMBERS

Okay, back to the calculator. Using Mr. Dwyer's numbers from the quote at the opening of this harangue, it becomes readily apparent that the spring rate of the canard is about one-half inch per hundred pounds. Pretty convenient! So, with a 1000 lb. gross weight we can estimate that 900 lbs. are carried by the canard resulting in about four-and-a-half inches of canard sag. Since the span is 200 inches and both wing tips respond equally to the loading, we can figure the angle of deflection using the sag over the semispan: Arctan(4.5" / 100") = 2.58°. So the wing bends under gross weight load in such a way that the anhedral is reduced by 2 x 2.58° = 5.16° or about five degrees. Structures texts tell us that a uniform beam loaded at its ends will exhibit a tip deflection twice the overall deflection, in other words, our main gear tires will lean inboard about five degrees each, maybe a little more since the canard is a tapered beam, not uniform.

As a check, Mr. Naumann (quoted above) reports that his "new hole center is about 1/2" down from the center of the old hole." Given the stock axle length of 7.25 inches, the hole offset for 5° of tip deflection works out to 7.25" x sin 5° = .63 inches, within tolerance, I believe, of the referenced 'about 1/2"'. Further, note that Mr. Naumann retained 1° of toe out (under load) which compensates for insufficient camber of about 1/5° ("camber-steer force equivalence" quoted above from Race Car Vehicle Dynamics) yielding 7.25" x sin 4.8° = .60 inch. Finally, Mr. Naumann does not relate the weight he used other than to say "full weight" and there's always the inevitable builder tolerances to consider. Using his 1/2 inch number and the axle length of 7.25 inches gives arctan(.5" / 7.25") = 3.95°, so we agree within one degree as to the amount of built in "bad" camber that the plans give us if we follow them.

I'm going to continue using the 5° number for several reasons, not least of which is that many builders are now flying using a 1100 lb. gross weight. Also, my goal is not to just reduce the instability inherently built into these planes, but to go past neutral and into the positive stability area. I want a plane that doesn't just accept benignly, but one that counteracts actively the effects of bumps and gusts and such. I want a no-workload ride. Too, there are dynamic effects encountered in crosswinds and tailwheel steering inputs and bumps and aileron inputs, etc., which will serve to flex the canard more than just the gross weight condition; I want a camber margin on the "good" side of neutral that can absorb these small excursions. And, to reduce tire wear, I want this all without having to resort to outboard camber as Mr. Naumann did. (Did I mention that 'crowning' of the runway also has a negative effect on the angular relationship between the tire and the pavement surface?)

Using 5° as the final tip deflection and the amount of inboard camber that a stock, plans built Q-bird needs to have removed, there are things that can be done in construction of the airplane to effectively "pre-load" this spring that is the canard. Working backward, again, with Mr. Naumann's numbers, and using the technique called for in the plans of sighting across to the other wheel pant to establish the toe and camber, we find that the aiming point for the sight picture must be 192" x sin 3.95° = 13.2 inches(!) up from the opposite wheel pant's axle hole. Using the 5° that I advocate yields 192" x sin 5° = 16.75 inches. Wow. That's a bit more than the 5.5 inches I've seen advocated elsewhere, but I have always questioned the genesis of that number as nothing more than a number pulled from a hat. However, 16.75 inches up from the axle hole would be a challenging place on which to sight, so perhaps during construction a stick could be bondo'd to the wing center section and a point about 9 inches up from the plane of the axles used as the aiming point. Be careful, too, that in construction 'up' is closer to the surface of the earth since the canard is built inverted.

Just for fun let's see what Mr. Naumann's “looking 2 inches forward of the opposite axle IAW QAC plans” gives for a built in toe out preload. Arctan(2" / 192") = .6°. The geometry of the canard under load allows some of this toe out to be lost, though I don't have data on how much twist deflection the tip experiences. Assuming that .5° of toe out remains under load and applying the 5:1 camber-steer equivalence gives about 2.5° of camber that may have been compensated for by the factory. Well, it's a start.

So, what can be done for new construction airplanes? Mount the wheel pants with 5° outboard camber and retain the plans-specified toe out setting, I say. For existing planes there may not be enough room in the wheel pant to adjust camber sufficiently; For these, I recommend either cutting away and remounting the wheel pants or choosing a smaller replacement tire (and wheel?) to permit the necessary camber adjustment. At the very least, follow a procedure similar to that described by Mr. Naumann to re-align the main gear axles. Be sure to do the procedure at gross weight and to allow the main gear to spread laterally under load so that the full extent of the canard sag may be developed before any new axle holes are drilled.

It's that simple.

TAILWHEEL

I also promised to address some tailwheel considerations. Unfortunately, the data available on tailwheels is not nearly so robust as that available on groundloops. Let me explain.

Certain individuals will rightly advise making no changes to the airplane until having flown it as a "factory stock" item, else where is your baseline for measuring change? Well, I only know of two airplanes that are otherwise stock yet have the front-end alignment correct: Dwyer's and Naumann's (and I'm not really sure that Naumann's qualifies as otherwise stock). However, I can't abide the argument to build stock first, especially when that argument is coupled with the inevitable comment about having only a single data point as a basis on which to initiate modifications. I believe that the names Gene Sheehan and Gary LeGare constitute single data points, yet when they advocated T-tails and Reflexors and "Ground-angle-of-attack" tweaking, everybody jumped on those bandwagons. So, there aren't that many airplanes out there to look at that don't also have a reflexor or such, thus muddying the database on which to judge the effectiveness of tailwheel mods.

Now, there are also those who will argue that I base my front-end alignment argument on a 'single' data point, that of the three builders reports quoted at the head of this diatribe and especially Mr. Dwyer's airplane. Not so. I have myriad data points telling me what does NOT work scattered throughout the pages of QuickTalk/Q-Talk, namely, all the accident reports of stock airplanes that just don't behave, and all the back-and-forth tweaking of the T-tails, reflexor settings, and ever more precise callouts for the bogus "Ground-angle-of-attack" setting that never seems to have been right, in retrospect, after the accident. In short, although I may only have one or two data points on which to stake my claim, I have an entire herd of dead lemmings at the bottom of the "cliff of truth" to attest to the inadequacy or outright failure of all those other single-data-point fixes.

Also, not one external reference has ever been presented (to my knowledge) to lend either theoretical or experimental support to the arguments in favor of the current crop of mods; in fact, there are no arguments in support of increasing the load on the tailwheel, only the contention that

1) it skids, and
2) there isn't much load on it.

I believe that I've adequately described above the dynamics of the tailwheel "skid" and it is worth noting that in the above-described scenario any increase in load on the tailwheel only increases the force with which the tailwheel can generate the roll moment that exacerbates the already diverging behavior of the airplane. In short, increasing the load on the tailwheel makes the tailwheel more prone to "skid" and decreases the range of usable rudder pedal force and rate of application that can be used before rudder application becomes the precipitating event that initiates a ground loop. So long as such behavior persists it is moot to try to qualify the differences between tailwheel setups. Also note that the behavior attributed to tailwheel "skid" actually requires an effective tailwheel, whereas if the tailwheel were truly skidding it would be unable to generate the forces that ultimately put the airplane into the weeds.

This is not to say that certain tailwheel changes can't be said to be helpful. Indeed, the addition of centering springs (as opposed to the in-circuit springs normally used on tailwheel installations to absorb shock) can be shown to be beneficial in both the directionally unstable stock configuration and in the corrected front-end alignment situation that I advocate. In the stock situation the centering springs, as would a locking tailwheel, oppose the rapid yawing of the airplane necessary to ground loop (within the traction limits of the tailwheel), while not generating the adverse roll moment that a rapid or forceful corrective pilot input generates. The springs also oppose pilot inputs, giving more control feel while attenuating the force or speed of control inputs that may otherwise have caused or amplified divergence.

Finally, centering springs respond immediately to any deviation of the airplane's heading from its track whereas pilots have reaction times; the centering springs can apply a smaller corrective force sooner than a pilot can, further reducing the risk of creating adverse rolling moments. All of these effects are also beneficial to airplanes with corrected front end geometry. The question then becomes one of necessity: are centering springs necessary once the front end geometry is corrected?

Similar arguments could be made regarding the solid rubber tailwheel supplied in the kit vs. pneumatic tires, but I'll withhold judgment until I've examined a Q-bird built according to "corrected" plans, with adequate precompensation built into the canard to assure that the toe out and, particularly, the camber are both positive when the airplane is loaded to gross weight. I believe, without any justifiable evidence, that the stock tailwheel is adequate to the task, but I may learn otherwise (I hope not the hard way).

FINAL SUMMARY

Well, I've probably lost and/or angered somebody with these words. That is not my intent, but is, perhaps, inevitable. I've not edited or rewritten to convince or persuade, only to record. I've shared this with the intent of reporting my own, personal conclusions on this topic, and am open to reasoned, thoughtful rebuttal, but I'm pretty well convinced that I'm not exactly preaching to the choir, either. This is not an exhaustive analysis nor is it a flight test report so is subject to revision, but I believe that it is essentially grounded in the theories of ground vehicle dynamics as presented in the referenced text, which is more than I can say for any 'analysis' presented so far in advocacy of T-tails, reflexors, or "ground angle-of-attack." I recognize that my writing style leaves much to be desired, and to those for whom this became just so much gobbledygook, I apologize.

Just make sure your camber and toe are both positive at gross weight, and enjoy your Q-bird for what it should be!

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