A REPORT ON THE LEGARE T-TAIL MODIFICATION FOR THE Q2
February 25, 1983

[Editors Note: this is a transcription of my original report done as a QAC dealer in 1983. These tests were done on the GU canard before the introduction of the LS-1 canard. My later testing with the LS-1 canard showed the T-tail to be unnecessary with the new canard. These tests were also conducted well before anyone thought of installing vortex generators on the GU canard; therefore, the results and conclusions may not apply with them installed. G. Michael Huffman 816-838-6235, mikehuffman@kc.rr.com, March 20, 2006]

I. BACKGROUND INFORMATION

Late in 1982, while accumulating approximately fifty hours of flight time on my Q2 N22QS, I noticed that the airplane exhibited several oddities in its flight characteristics, including:

1. The oft-mentioned pitch-down tendencies in rain or with other flow-disturbing medium on the canard leading edge.

2. A decided tendency of the aircraft to vary its pitch attitude (with no control inputs) at landing approach speeds in gusting or turbulent conditions. This tendency made it difficult to fly approaches at the normal approach speed of 85 miles per hour whenever turbulence was present; it was only by maintaining 100 mph IAS or above that the aircraft felt comfortable under such conditions

3. Change is the elevator hinge moment at landing approach speeds in turbulence. When I would hit the bottom of a "bump," the control stick would try to move forward of its own accord.

4. A definite lack of elevator effectiveness beyond approximately 10 degrees of down elevator deflection. Additional deflection produced only more drag without an appreciable increase in angle of attack.

It was noticed that all the aforementioned oddities concern the pitch control and pitch stability of the aircraft; i.e., they all concern the canard.

Quickie Aircraft Corporation had introduced the aileron reflexer (in part) to be able to offset the decrease in lift on the canard when flying in rain. This was done by "reflexing" both ailerons upward to provide an equivalent decrease in lift on the wing, thus balancing ghe aircraft. My Q2 had always been equipped with the reflexer and I had found it to be extremely handy. I found, for example, that more reflex was required to keep the tail down on landing when there was an accumulation of bugs on the canard leading edge. However, the reflexer was not the cure for all the problems on my aircraft. In the two instances where I encountered rain, the reflexer did not provide enough control to offset the pitch-down tendency.

For these reasons, I decided to investigate the possibility of adding a horizontal stabilizer to the aircraft. Aerodynamic theory would say that the addition of a horizontal tail should increase the pitch stability in at least three ways. First, the presence of the tail should stabilize the aircraft in much the same way that feathers stabilize the flight of a n arrow. This would hold true even if the horizontal tail were non-adjustable in incidence angle. Second, by making the incidence angle adjustable, the center of gravit of the aircraft could be allowed to move forward (most Q2s seem to come out on the nose-heavy side anyway) and be balanced by a down load on the tail (any aircraft is more statically stable the further forward the CG is located). And third, by increasing the down load further, the canard could be unloaded somewhat. This unloading should manifest itself by the elevator assuming a higher (trailing-edge-up) position for trimmed flight. Thus, the first ten degrees of down elevator travel could be saved for maneuvering rather than used for trimming. The horizontal tail would also seem to offer help in the rain flight characteristics by providing a balancing down load to offset the loss of canard lift. Another fortuitous benefit could be that the tail might provide increased steering effectiveness by increasing the down load on the tailwheel during landing.

All during this time of considering a horizontal tail configuration, I went back to a similar configuration I had seen on Gary LeGare's Q2 at Mojave months earlier.

And it turned out that Gary was making plans and kits available. So, rather than designing my own, I decided to install Gary's modification.

This report describes the results I obtained by installing the LeGare T-tail modification on my Q2. Comments concerning the plans and the installation are presented along with results from ground and flight testing. It should be emphasized that these results are valid only for my specific aircraft and should not be generally assumed to apply to all Q2s. This report is not meant to be as and should not be construed to indicated an endorsement or recommendation of the modification.

II. PLANS AND INSTALLATION

LeGare offers both a set of plans and a kit for the T-tail mod. At the time I started my T-tail modification, the prefabricated parts of the kit were not available, so I built my own from the plans. Since no dimensions are given for the prefabricated parts, I conferred with LeGare by phone and obtained the necessary dimensions.

Because I did not purchase the kit and have not subsequently seen one, I cannot comment on the kit itself. With regard to the plans, the text included is very detailed and provides a good step-by-step procedure. However, a few minor problems with the plans were noted and deserve comment:

a. In making the cutout in the vertical stabilizer foam for the mechanism, Gary says to cut "approximately halfway through" the foam. Apparently my vertical stabilizer is thinner than his since my cutout had to be almost the full depth of the stabilizer thickness in order to clear all the mechanism.

b. The pulley guard for the AN210-1A pulley shown on Appendix sheet 6 needs to have a third "prong" to prevent the cable from coming off the pulley between the two tangent points.

c. The description of the manner in which the T-tail cables connect to the aircraft elevator trim system is inadequate. For instance, most builders make the tailcone of the aircraft removable, yet no instructions are give to allow the cables to be easily disconnected and reconnected when removing the tail. I installed turnbuckle assemblies in the baggage compartment which are accessible from the front through the seatback bulkhead. When these turnbuckles are disconnected, the cable slack allow the tail to be raised, forming a gap at the bottom through which I can disconnect a couple of links similar to those on the rudder cables. Also, no instructions are given for tensioning the T-tail cables, a factor of some importance, as will be discussed in Section III below. Nor were any instructions given for providing a pitch trim indicator to let the pilot know what position the trim wheel is set for.

d. In my opinion, pop rivets are inadequate for attaching the cover plate on the tail. For one thing, inspections of the mechanism would require drilling oout the rivets, which would likely damage the thin four-ply vertical stabilizer laminate. Also, I do not trust the pop rivets to stay secure under the effects of airloads through the thin laminate. I installed #6-32 nutplates under the laminate and attached the cover plate with screws.

e. A few drawing errors exist on the Appendix sheets. On Sheet 5 and Sheet 7 the .62 diameter TM1 part is shown large in diameter than the .75 aluminum tube, causing some possible confusion as to where one stops and the other starts. And on Sheet 4, the AN960-10 washers called out on each side of the cable thimbles should be AN970-3 to keep the thimbles from sliding off the AN3-10 bolt.

Regarding the installation of the mod on my Q2, everything proceeded according to the plans except that the job required about thirty hours to complete rather than the six hours advertised.

III. FLIGHT AND GROUND TESTING

Since installing the T-tail on my Q2, I have accumulated approximately twenty hours of flight time. This section reports the results of testing during that time.

General System Testing

One of the first things I noticed after installing the tail was that, on the ground, when a light load (perhaps two pounds) was applied to the trailing edge of the T-tail airfoil, the airfoil would change incidence angle, backdriving the trim system and rotating the trim wheel. If I increased the cable tensions, and system friction to the point that the airfoil would not move under a reasonable load, the trim wheel could not be turned. On my first flight, immediately after takeoff, the trim wheel began moving of its own accord toward further airplane-nose-up trim and a pronounced pitch-up occurred. I grabbed the trim wheel and held it in position with my left hand and flew the airplane with my right hand. After getting some altitude, I experimented with the trim setting and found that if it was set for nose-down trim, it would tend to go further nose-down and, if nose-up, further nose-up.

I temporarily solved the problem on my airplane by installing a cockpit-adjustable friction lock on the trim wheel and by increasing the mechanical advantage of the trim wheel windlass (that's technical talk for the "rope-winder-upper gizmo"). However, I believe this situation presents potential problems with controllability of the aircraft which should be corrected. If the trim position were to suddenly change low to the ground, a pitch change could occur which might not be able to be corrected with the elevator quick enough to avoid trouble. FAR 23 require that trim systems for certificated airplanes to be inherently non-reversible (i.e., like a worm gear drive) so that airloads or failure of the actuating mechanism will not produce trim changes.

Another effect noticed when simulated airloads were placed on the T-tail airfoil was that, even with relatively high cable tensions, a fairly large amount of movement of the T-tail (5 degrees or so) was produced due to cable stretch and other deflections in the system. In general, deflections in tab systems should be kept to a minimum to minimize the possibility of flutter.

One way to accomplish an improvement in this situation would be to move the pivot point of the torque tube closer to the center of pressure of the airfoil. The T-tail airfoil appears to be very similar to the NACA 0009 airfoil, whose center of pressure occurs approximately at the 22-25% chord position, depending on angle of attack. However, the T-tail pivot point is located at 31% chord, which would produce the hinge moment direction observed. If the pivot point where moved to the 21% chord position, slightly ahead of the center of pressure, the hinge moments would be reduced by a factor of three and reversed in direction. Thus, any backdriving would tend to neutralize the trim setting rather than amplifying it.

It is my understanding the LeGare has recognized some of these problems and changes will be forthcoming.

Flight Test Program

After a few initial test flights to work the bugs out of the system, a flight test program was undertaken to answer some specific questions:

1. Does the system provide adequate pitch trim authority to replace the standard trim system and/or the aileron reflexer?

2. Does the system improve the pitch stability of the aircraft?

3. What is the effect of the system on minimum controllable airspeed and on maximum airspeed?

4. Does the system decrease pitch-down problems when flying in rain?

5. Can the system be overpowered by the elevator?

6. Does the extra pitch authority provided by the system endanger the stall-proof design characteristic of the aircraft?

7. Is the system flutter-free?

8. Does the system increase tailwheel steering authority during landing?

Before beginning the flight test program, several things were done to the aircraft:

a. An accurate weight and balance was re-performed, going so far as to weigh the aircraft with known weights in the fuel tanks, pilot seat, and baggage compartment so that accurate calculations of the moment arms of those locations could be determined, rather than relying on the Q2 Pilot Manual for loading graphs.

b. Wing and canard incidence angle measurements were made; here it was found that the main wing incidence angle is correct, but that the canard incidence angle degreases as one moves from BL 48.8 outboard.

c. Landing gear geometry was rechecked to look for tire toe-in or camber problems (none were found).

d. The left elevator was fitted with a deflection template visible from the cockpit in flight.

e. A fitting was mounted on the control stick for measuring stick forces.

f. A G-meter was installed.

This section reports on the results obtained thus far. Incidentally, each of the results presented has been re-verified several times except as noted.

Pitch Trim Authority. The T-tail was found to be quite powerful in providing pitch trim. For instance, at a middle CG condition and at a constant elevator position (9 degrees trailing edge up), a pitch trim setting of 0 degrees T-tail incidence angle produces a trim speed of approximately 160 mph IAS, while a setting of only 3-5 degrees (airplane-nose-up) produces a trim speed of 105 mph.

As the airplane slows down below 100 mph, correspondingly greater amounts of trim are required. Landing approaches at 85 mph seem to work best at about 20 degrees airplane-nose-up trim. Trim settings beyond 25 degrees either way cause not further change in pitch attitude; in fact, in smooth air, I could sometimes detect a stall occurring in the T-tail at about 25 degrees. If I held a constant elevator position and began feeding in trim the pitch attitude would increase up to about the 25 degree trim setting and then would suddenly decrease somewhat, and then become relatively constant up to the 45 degree limits of travel. These same effects were noted in both trim directions.

These results are consistent with the lift curve of the NACA 0009 airfoil: for low Reynolds number, it rises linearly from zero to about 12 degrees, then flattens out to about 18 degrees, the undergoes a rather mild decrease (“stall”) from there to about 30 degrees. By adding the aircraft angle of attack to these figures (about 9 degrees at 90 mph), we come fairly close to the 25-degree trim position at which the tail stall was observed.

With this is mind, I can see no reason for allowing T-tail travel in excess of 30 degrees either way; between 30 degrees and the 45 degrees currently specified, the lift force actually decreases.

Longtitudinal Stability Tests. The T-tail on my aircraft is set up to be easily removed and reinstalled. Thus it was that I was able to conduct testing with and without the tail, on the same day under the same ambient conditions. On February 18, stick-free longitudinal stability tests were performed with the aircraft ballasted to the center of the CG envelope, both with and without the tail, and at both ends of the airspeed range. The tests were conducted by first establishing a trim speed, and then letting go and observing the airspeed changes. Ideally, the airspeed should exhibit the so-called phugoid characteristic, oscillating above and below the trim speed, with each oscillation becoming smaller in amplitude so that, within about three or four cycles, the trim speed is reestablished. If this behavior occurs, the airplane can be said to have good, positive static and dynamic stability, in the "long-period" sense.

The results of the stability tests are plotted in Figure 1. They show that, in all cases, with or without the tail, positive static and dynamic stability does exist. In the case of the high-speed run without the tail, the stability could best be described as sluggish, with a considerable increase in speed beyond the 170 mph stick-release speed and a very flat peak at 180+ mph before the nose slowly began to rise back toward the trim speed. This behavior is probably produced by the so-called "tuck" tendencies, even though in my airplane the tuck did no go so far as to result in an unstable condition statically. The addition of the T-tail markedly changes the character of the high-speed stability to a well-damped phugoid characterized by low accelerations and a period of about 35 seconds.

At low speed without the tail, a definite phugoid was exhibited but, as can be seen from the graph, the damping was considerably less than at high speed. Oddly enough, the addition of the tail seemed to decrease the damping even further. No logical explanation can be postulated for this behavior; perhaps the air turbulence happened to be greater during the flight with the T-tail installed.

On February 19, the above tests were repeated at gross weight and most-aft CG, and a 50 pounds over gross and most-aft CG. Although no detailed data was taken during those runs, the qualitative character of the results was identical to the tests at mid-CG. The only testing done outside the CG envelope was one very cursory test conducted without the tail at a gross weight of 1096 pounds and a CG 48.3" aft of datum. Under those conditions, the aircraft is definitely statically unstable at both ends of the airspeed range.

One aspect of longitudinal stability which is not apparent from the long-period data of Figure 1 is the short-period effect of the tail during landing approaches in turbulence. As mentioned earlier, my airplane changes pitch attitude quite markedly in such conditions without the T-tail, whereas with the T-tail, the pitch changes are very much diminished, to the point that an 85 mph approach speed can be maintained comfortably, even in gusty conditions. If for no other reason, this result makes the T-tail worthwhile.

The T-tail does not seem to affect the elevator hinge moment variations in turbulence (and would not be expected to). I am still searching for the source of these variations. One possibility is air leaks through the elevator/canard gap. I have sealed those gaps but have not flown the aircraft as yet with them sealed. *[Ed: later testing with sealed gaps seemed to reduce rather than enhance elevator effectiveness and did not markedly improve hinge moment variations.]*

Regarding elevator stick force gradients, my elevator centering springs are such that a spring force (exclusive of airloads) of approximately 23 pounds is required to move the elevator from the 5 degree trailing-edge-up center position to the 17 degree trailing-edge-down stop. Testing of stick forces in flight showed that elevator hinge moments caused by airloads are relatively light, with a maximum total force of about 33 pounds being observed in all stick force tests. Of that 33 pounds, approximately 23 pounds was due to spring forces. Thus, the normal "pounds of stick force per G" terminology loses meaning since, if one rolls the into a tight turn and pulls the stick back to establish a constant G-force turn, as the airplane slow down (quite rapidly in a Q2), further aft movement of the stick is required to keep the G-force constant. Hower, further aft movement requires overcoming more of the spring force. The issue is further confused by the fact that, beyond about 10 degrees of down elevator deflection, no appreciable further lift is generated—only more drag (and more spring force on the control stick). The maximum G-load I was able to produce was about 3.5 Gs, by beginning a turn at approximately 160 mph and pulling the stick back as rapidly as seemed prudent.

Effect on Minimum Controllable and Maximum Airspeeds. To sum up the results of several tests, the addition of the T-tail produced no discernable differences in either the minimum controllable airspeed or the maximum straight-and-level airspeed.

Effect on Stall-Proof Characteristics. No formal testing has as yet been done in this area, but will be done. The testing will involve placing the trim wheel in the maximum nose-up position and then bringing the stick back to see if a true stall can be produced. *[Ed: these additional tests were never performed.]*

Effect on Elevator Controllability. The tests have shown that controlled flight can be maintained by overpowereing the T-tail with the elevator, regardless of airspeed or T-tail incidence up to 45 degree travel either way.

Flutter Testing. While no formal flutter testing of the T-tail has been performed, the airplane has been flow for short periods of time at 190 mph IAS with no evidence of flutter.

Effect on Tailwheel Steering Authority. Without the T-tail, my airplane seems to lack tailwheel steering authority. On landing in crosswind conditions, gusts tend to weathervane the aircraft into the wind and upon making rudder corrections, the tail wheel can be heard and felt skidding on the concrete for perhaps a second or two until it “takes hold” and begins correcting the yawed condition. It was expected that the T-tail would markedly increase steering effectiveness by providing a down load on the tailwheel. However, such an effect has not been observed; the steering effectiveness on landing seems to be about the same, with or without the T-tail.

Effects of Flying in Rain. I had one opportunity to make takeoffs and landing in the rain with the T-tial. The rain was what I would classify as “light to moderate”; the windshield was wel all over and new droplets were falling on any given square inch about once every second or so. The aircraft happened to be loaded about on the forward edge of the CG envelope. The takeoff was made with the T-tail in the 20-degree airplane-nose-up position. As takeoff speed was approaching, I began feeding in airplane-nose-up elevator movement, but it was not until I reached approximate the 10-12 degree down position that I finally broke ground. At that point, I was exerting a pull of perhaps 20 pounds on the stick. As I turned crosswind and downwind, I experimented with the stick position and with the T-tail incidence to see if I could slow the airplane to a reasonable approach speed. Additional T-tail incidence did not seem to help much (as would be expected from the previous test results), but additional backpressure did produce a gliding speed of about 95 mph. By the time I was ready to land, my arm was becoming tired of holding the steady back pressure. I flew the airplane onto the runway at about 85-90 mph, but the tailwheel did not want to come down. I cannot be sure whether I had all the available elevator travel in or whether my arm was too tired to pull any harder. Since there was a light gusty crosswind, I weathervaned and recovered twice before deciding to go around, narrowly missing a runway light. The second landing attempt was successful, though probably by accident. (Without hesitation I came to the decision that it was time to put the airplane in the hangar and clean out my shorts.)

These results do not agree with LeGare’s experience with the T-tail. He has flown demonstration flights in the rain without apparent difficulty. So where is the difference? One possibility is in the previously-mentioned “washout” in incidence angle on the outboard portions of my canard. Another possibility is that, even though the T-tail plans specify to leave the standard elevator springs in place, LeGare has replaced his springs with very light ones so that, at the large elevator deflections necessary to fly in the rain, he would not have to exert the same amount of arm-tiring back pressure and thus might be more successful at controlling the airplane. One of my next tests will be to investigate the flight characteristics with lighter springs. *[Ed: these additional tests were never performed.]*

IV. CONCLUSIONS AND RECOMMENDATIONS

Considering all the above results and also considering the more subjective general feelings I developed during the testing, the bottom line is that the T-tail is a valuable addition to my aircraft. Although it may be difficult to realize by looking a the data, the T-tail gives the airplane a better and more crisp feeling in pitch throughout the flight envelope. With more testing, the T-tail may allow the CG range to be widened; also, with changes to the elevator centering springs, elevator gap seals, etc, the T-tail may allow more comfortable flight in rain. These additional tests will be performed and reported on later. *[Ed: these additional tests were never performed.]*

One recommendation is in order: if a builder is planning on making changes to the installation, he should proceed very carefully. Small changes in trim system design have been known to cause flutter or loss of control.

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