SERVICE BULLETIN 113

I. DESCRIPTION

A. SUBJECT

Center of Gravity Location and Longitudinal Stability and Control for Glasair II-S TD Aircraft

B. APPLICATION:

Glasair II-S TD Aircraft Through Serial Number 2184

C. PROBLEM DESCRIPTION:

Weight and balance data from our prototype 180 hp II-S RG and from two customer-built 200 hp Glasair II-S aircraft, all with constant speed propellers, indicates that the actual completed weight of the aft section of the fuselage is greater than anticipated. This aft empty weight c.g. location limits the weight of baggage and, in some instances, passengers that can be carried without exceeding the aft c.g. limit. Our calculations show that a lightly equipped Glasair II-S TD fitted with a fixed pitch propeller would have a flight c.g. aft of the specified limit when l oaded with a 170 lb pilot, a 170 lb passenger, 80 lb of baggage, and minimum fuel (8 gal in the header tank). A similar II-S TD, with accessories such as an autopilot pitch servo, electric trim, and multiple avionics antennas in the aft fuselage, would have a flight c.g. even farther aft.

NOTE: See Section E, Weight and Balance Calculations, in Part I of this service bulletin for definitions of terms and for the c.g. limit specifications.

D. STABILITY AND CONTROL DISCUSSION

Every aircraft is subject to limitations concerning the longitudinal position of its center of gravity. The flight c.g. must fail within certain forward and aft limits to ensure that the aircraft is stable and controllable during flight. These limits are set by the designer and are functions of such variables as the wing airfoil, the size of the tail feathers, the length of the tail moment am (distance from the wing to the horizontal stabilizer), etc.

1. DISCUSSION OF STABILITY

Stability can be characterized as positive, neutral, or negative. When a system is positively stable, it will tend to return to its initial condition if displaced from that condition. An example of this is a ball bearing resting at the bottom of a bowl; if displaced from this position and released, it will return (after a series of oscillations) to its original position. A system that is neutrally stable will tend to stay in its new condition if a change is made. This is like a ball bearing resting on a level table top, if the bearing is displaced from its original position it will remain at the new position. A negatively stable system will diverge from its original condition when displaced. This is like a ball bearing balanced on top of an inverted bowl, if given a slight nudge, the bearing will diverge from its initial position and not return.

2. INITIAL ESTIMATE OF II-S AFT C.G. LIMIT

The aft c.g. limit for the Glasair I and the Glasair II was set at 28.5% of mean aerodynamic chord (MAC). The aerodynamicist we consulted to analyze the Glasair 11-S set the aft c.g. limit for the II-S at 33% MAC. Feedback concerning the first customer-built II-S aircraft have indicated that this limit is too far aft.

3. FLIGHT TEST AND STABILITY ANALYSIS

With the goal of -ore effectively using the full c.g. range of the Glasair H-S configuration, we recently hired a new independent consultant to perform a new stability and control evaluation of the Glasair II-S aircraft and to re-examine the aft c.g. limit. As part of the stability evaluation, a flight test program was undertaken to measure the airplane's stick-fixed neutral point, which is a measurement commonly used to set the aft c.g. limit. If the flight c.g. is located at the stick-fixed neutral point, the airplane will be neutrally stable in flight; with the c.g. forward or aft of the neutral point, the airplane will be positively or negatively stable, respectively. To ensure that the aircraft is positively stable in flight, we feel that it is desirable to provide a reasonable margin between the aft c.g. limit and the stick-fixed neutral point measured by our flight test program**. Consequently, we have set the aft c.g. limit at 31% MAC for all Glasair II-S aircraft**, provided the new larger elevator (described later) is installed.

Setting the aft c.g. at a particular limit does not mean that the airplane will suddenly become dangerously -controllable if loaded a tiny fraction of an inch aft of the limit. The stability changes gradually as the position of the c.g. moves aft. With the c.g. aft of the specified limit, however, the airplane could be beyond the pilot's ability to control when confronted with adverse circumstances such as strong turbulence or instrument meteorological conditions with a failed vacuum system. Therefore, the Glasair II-S Owner's Manuals will contain the following statement:

WARNING: The Glasair II-S TD must not be operated with the flight cg. aft of 31% MAC.

E. WEIGHT AND BALANCE CALCULATIONS

Before describing specific solutions, here is a detailed discussion of weight and balance calculations.

1. GENERAL DATA

Definitions

Datum is an imaginary vertical plane from which all horizontal distances are measured for balance purposes.

NOTE:The datum is located 58.0" forward of the cowling attach flange joggle (aft edge of the engine cowling). See FIGURE (I).

Station is defined as the distance in inches from the reference datum.

Arm is the horizontal distance from the reference datum to the center of gravity of an item.
Moment is the weight of an item multiplied by its arm.

Center of Gravity (c.g.) is defined as the sum of the moments divided by the total weight.

MAC (mean aerodynamic chord) is defined as the value that, when multiplied by the span, results in the wing area.

FAA Estimate for Weight of Aircraft Occupants

For weight and balance calculations, the FAA assumes an average weight of 170 lb for the pilot and passengers.

NOTE: For your own weight and balance calculations, use the actual weights of the pilot and passengers who will normally be aboard the airplane.

FAA Minimum Fuel Allowance

EA-AC 43-13 defines minimum fuel for balance purposes as no more than the quantity of fuel necessary for one-half hour of operation at rated maximum continuous power; this is the maximum amount of fuel that can be used in weight and balance computations when low fuel may adversely affect the most critical balance configuration.

The flight c.g. for the Glasair U-S moves aft as fuel is burned from either the main or the header tank, so low fuel does affect the most critical balance configuration. Consequently, we use eight gallons of fuel (48 lb), carried in the header tank, as the minimum fuel for weight and balance calculations.

NOTE: To check the e.g. limits, EA-AC 43-13 requires loading the minimum fuel in the most adverse location, which for the Glasair II-S is in the main tank. We always use the header tank as an emergency reserve, however, and use the fuel in the main tank first, so minimum fuel for our c.g. calculations is carried in the header tar&

Glasair II-S TD Specifications

Mean Aerodynamic Chord (MAC):……………………………………………………………44.5"
Station of Wing Leading Edge at MAC: ……………………………………………………76.20
(for II-S kits through serial number 2177)

Flight c.g. Limits:
(for II-S kits through serial number 2177)
Forward…………………………………………………………………Station 82.21 (13.5% MAC)
Aft………………………………………………………………………..Station 90.00 (31.0% MAC)

NOTE: Use the following formula to calculate aircraft c.g. with respect to the MAC:

$$\text{Aircraft c.g. (\%MAC)} = \frac{(\text{c.g. Station} - 76.20) \times 100}{44.5}$$

Various Moment Arms: (Glasair II-S TD)
Oil (1.9 lb./qt.)………………………………………………………………………………. Station 44.00
Fuel--Main Tank (6.0 lb/gal)………………………………………………………………… Station 82.35
Fuel--Header Tank (6.0 lb/gal)……………………………………………………………… Station 65.75

Fuel--Wing Tips (6.0 lb/gal)……………………………………………………………………Station 87.33
Firewall…………………………………………………………………………………… Station 60.00
Baggage……………………………………………………………………………………Station 124.00
Passengers………………………………………………………………………………… Station 108.00
Instrument Panel…………………………………………………………………………….. Station 85.00
Main Gear Axles…………………………………………………………………………….. Station 74.00
Tail Wheel Axle……………………………………………………………………………… Station 232.75
Wing Tip Extensions………………………………………………………………………….Station 93.00
Cowling Split Line (Attach Flange Joggle)……………………………………………………Station 58.00

NOTE: The positions of the main and nose gear axles will be slightly different for each individual Glasair II-S TD. The builder must determine these dimensions, using the procedures described in the following section.

2. EMPTY WEIGHT C.G. CALCULATION

The empty weight e.g. of each individual aircraft must be determined before any additional c.g. calculations can be made.

First, with the wings level (wing tips at same height) and with waterline 100 level longitudinally, use a plumb bob to mark the location of the cowling attach flange joggle (the aft edge of the cowling) onto the floor.

NOTE: Refer to pages D-43 and D-44 in the Fuselage Assembly section of the Instruction Manuals for a description of the procedures used to lay out and mark waterline 100.

Measure 58.0" forward from the cowling attach flange joggle, and mark a line at this point perpendicular to the longitudinal centerline of the airplane. This line represents the intersection of a plane in space with the floor. This plane is defined as the reference datum (station 0.00) from which all moment arms are measured,

Measure the distances marked “X” and “Y” in FIGURE (1) from the datum line to the centers of the main gear and tail wheel axles. These distances represent the stations of the landing gear. For our example Glasair II-S TD, distance "X" is 74.00" and distance "Y" is 232.75".

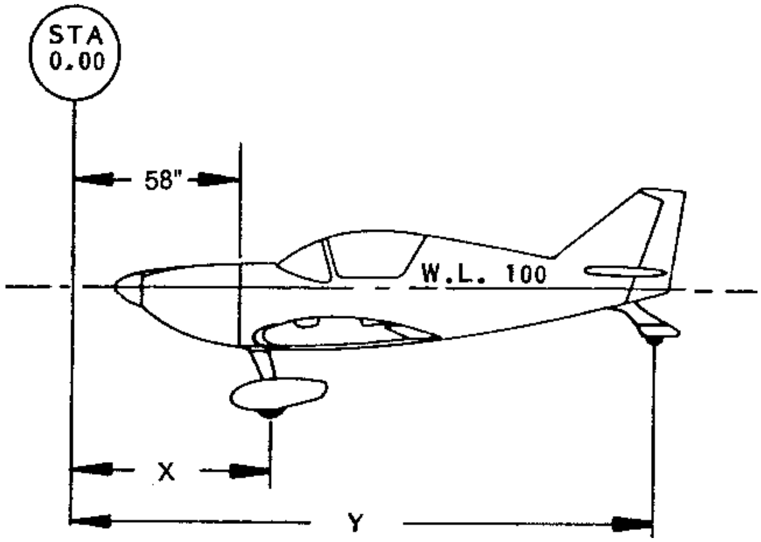

FIGURE (1)

Now weigh the airplane, without fuel, but with oil and other operating fluids, using three scales, one under each of the wheels. The main gear scales should be capable of handling about 600 pounds each. While weighing the airplane, block up either the main wheels or the tail wheel so that waterline 100 and the wings are level. Be sure to subtract the weight of any blocks or wheel chocks used on the scales. The empty weight of our example Glasair II-S TD is 1263 pounds with a 160 hp engine and a Sensenich fixed-pitch metal propeller.

Use the data just collected to determine the empty weight c.g. as shown in the following example.

Sample Empty Weight c.g. Calculation

The following empty weight c.g. calculation is for a Glasair II-S TD equipped with a 160 hp engine and a Sensenich fixed-pitch metal propeller. The weights are estimates based on data from the first customer-built Glasair II-S FT.

ITEM	WEIGHT	STATION	MOMENT
Tail Wheel	95	232.75	22111
Left Main Gear	577	74.00	42698
Right Main Gear	591	74.00	43734
TOTAL	1263		108543

c.g. = $\frac{108543}{1263}$ = Station 85.94

c.g. (%MAC) = $\frac{(85.94 - 76.20) \times 100}{44.5}$ = 21.89% MAC

NOTE: The weights will vary with each individual airplane, depending upon many variables.

3. FLIGHT C.G. CALCULATIONS

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To calculate the flight c.g. tabulate the weights, stations, and moments, as shown in the following example. Add the weights and moments, and divide the total moment by the total weight to obtain the center of gravity.

WARNING: In most situations, the c.g. moves aft as fuel is burned from either the header tank or the main tank. Calculate the flight c.g. using the quantity of fuel expected to be remaining at the end of the flight. The flight should be planned so as to have at least six gallons of reserve fuel (approximately 30 minutes) remaining at the end of the flight.

Sample Aft C.G. Limit Check

This calculation is based on the empty weight and empty weight c.g. of our example Glasair II-S TD. Conditions: Minimum fuel (8 gal in header tank), no fuel in main tank, 8 qt. oil (included in empty weight), 340 lb total of pilot and passenger, 80 lb baggage. This could be considered a worst case condition, approaching or exceeding the aft c.g. limit.

ITEM	WEIGHT	STATION	MOMENT
Empty Airplane	1263	8594	108542
Pilot and Passenger	340	108.00	36720
Fuel (Am. Tank)	48	65.75	3156
Fuel (Main Tank)	0	82.35	0
Baggage	80	124.00	9920
TOTAL	1731.0		158338

$$\text{c.g.} = \frac{158338}{1731} = \text{Station } 91.47$$

$$\text{c.g. } (\%MAC) = \frac{(91.47 - 76.20) \times 100}{44.5} = 34.31\% \text{ MAC}$$

The c.g. exceeds the aft limit in this condition.

II. SOLUTIONS

Since the aft empty weight c.g. location of some Glasair II-S TDs my not permit loading the airplane with heavy occupants and baggage and flying with low fuel without exceeding the aft c.g. limit, this section will describe some solutions to provide a more effective use of the full c.g. range of the Glasair II-S aircraft.

A. LARGER ELEVATOR

Our calculations indicate that enlarging the elevator area by 32% will result in a 6.6% aftward shift of the stick-fixed neutral point. Even if this is an optimistic estimate, we should expect to realize at least a 4% aftward shift of the neutral point, which is still significant. Enlarging the elevator will also provide increased elevator authority, which will benefit the low speed handling characteristics of aircraft equipped with slotted flaps. Moreover, the stability enhancement provided by an enlarged elevator will be especially desirable for airplanes with the wing tip extensions since the extended Lips destabilize the airplane in pitch. A final benefit of enlarging the elevator is to increase the stick feel by requiring more stick force per G; with this change, the elevator control will feel more balanced with respect to the aileron control.

As soon as a flutter analysis is complete, we will install the enlarged elevator on our prototype II-S RG and perform flight testing to verify that the new surface provides the benefit that aerodynamic theory suggests it should. Since the potential benefit of this modification is so large for the amount of work involved, we predict that it will be mandatory for all Glasair II-S aircraft, if the flutter analysis and flight testing do not reveal any insurmountable problems.

If we decide to incorporate the large elevator modification, we will re-tool our elevator mold to add 2.0" to the elevator trailing edge and 16" to the elevator span. In addition, we will supply instructions describing how to fill the gap between the tip of the existing stabilizer and the new elevator's counterweight arm, which will move outboard. By using a new vacuum bagging process, there will be a decrease in the weight per unit area of the elevator panels, which will be offset by the area increase plus the additional counterweight needed for the extended trailing edge. As such, we estimate that the larger elevator and the extended stabilizer will add only a few pounds to the tail.

B. MOVING THE WING AFT

Depending on the results obtained from flight testing the larger empennage, we expect to require moving the wing aft 1.5" on all Glasair II-S aircraft. This change will shift the empty weight c.g. forward by about 2.5% of MAC. For builders who have not yet started the Final Assembly section of the Instruction Manuals, this change will not be as significant as for other builders who are already working on final assembly. In fact, if you have not already fabricated the wing root fairings, moving the wing aft will require only about 30 to 40 hours of additional construction time for items 1 and 2 on the following list, as verified by our own shop personnel on a local customer's airplane. Items 3 through 6 would require little or no additional construction time if construction has not progressed to that point. If the components described in items 3 through 6 have already been fabricated and installed, we estimate that an additional 20 hours of modification work will be required. For completed aircraft, we will not be able to estimate the total time involved until we tackle the modification ourselves.

Moving the wing aft will require:

1. for kits through serial number 2177, enlarging the wing attach hard points in the fuselage sides and in the center belly panel section;
2. for kits through serial number 2177, cutting away the unidirectional longerons over the wing cutout in the fuselage side panels and laminating new ones at the new wing location;

3. possibly relocating the elevator bellcrank pivot so that the elevator pushrod does not rub where it passes through the wing rear spar shearweb;
4. possibly moving the trim system pulleys to optimize cable routing;
5. reconfiguring the lower instrument panel center section since it most move aft with the wing to clear the fuel gauge standpipe;
6. angling the lower edge of the seat back to meet the relocated aft edge of the seat pan, since the seat back will stay in its present position. This area can be fitted with upholstery or even shaped for lumbar support.

After flight testing the larger elevator, we plan to move the wing aft on our II-S RG prototype, and will then be able to draft the retrofit instructions. In the meantime, we suggest that you concentrate your construction work on areas other than the wing attachment and the wing root fairing work.

NOTE: With the wing moved aft, use the following specifications to calculate the flight c.g.;

Station of Wing Leading Edge at MAC: ………………………………………………………77.70

Flight c.g. Limits:

Forward………………………………………………………… Station 83.71 (13.5% MAC)

Aft……………………………………………………………….. Station 91.50 (31.0% MAC)

We recognize that moving the wing aft is a significant design change and win lengthen building time to complete the aircraft. We feel, however, that the potential improvements provided by this change will make the extra building time worthwhile. All Glasair II-S fuselages manufactured after 4/02/92 (serial number 2178 and later) have the unidirectional longerons, the wing attach hard points, and the wing cutout scribe lines located 1-1 /2" farther aft. For kits produced before 4/2/92, we will be publishing instructions for any necessary modifications, such as moving the wing cutout longerons, and the Instruction Manuals win be revised to reflect the new wing position,

C. MINIMIZING WEIGHT IN THE AFT FUSELAGE

General Considerations

We recommend that builders do everything possible to keep weight from building up in the aft put of the airframe. Keep any laminates in the tail cone area as light as possible without compromising their strength by making them too dry. Some builders have the feeling that, if three laminates are good, then four are better; these people attempt to "beef up" the structure by applying additional laminates in some locations. As anyone who has seen our prototype Glasairs perform in air shows can attest, however, the stock Glasair airframe is incredibly strong. Additional laminates, or larger laminates than specified, are not necessary.

If you have a choice of locating a component or an accessory in the tail cone or forward of the wing, choose the forward location if at all possible; if the tail cone location is your only option, install the component as far forward as possible. Do not modify the aircraft by installing any auxiliary fuel storage aft of the main wing spar.

Internal Tail Structure Weight Reduction

The number of laminates on the aft fuselage bulkheads and the forward and aft vertical fin shearwebs can be reduced. This will save a total of about 1.5 lb in the aft fuselage. The laminate schedules originally specified for these components in the Glasair II-S Instruction Manuals were the same as for the Glasair III. (Our decision to make the two airplanes the same in this respect was based on a desire to standardize our instruction Manuals, the illustrations, technical support, etc.)

<u>NOTE</u>: The revised laminate schedules for the internal tail structure are detailed in instruction Manual Revisions F and S-C, which were published on April 1, 1992. If you have already completed these components, it is impractical to remove them and redo the work.

Finishing and Painting

Try to minimize the amount of body putty and other fillers used in the aft fuselage area when preparing for paint. Use Q-cell mixture instead of body putty as much as possible. On the leading edge of the stabilizer especially, use just enough material to fill any gaps and smooth the weave of the cloth; do not build up the leading edge contour.

Every coat of primer and paint applied to the airframe moves the c.g. aft became most of the airframe arm is behind the aft c.g. limit. So, when painting, avoid building up excessive thicknesses of primer and paint. Choose polyurethane paint for the final finish as this paint achieves coverage with a very thin film.

D. TEMPORARY SOLUTIONS FOR FINISHED AIRCRAFT

If your airplane is currently flying, here are a few temporary solutions to incorporate until the required modifications can be made. Although, individually, none of the following solutions makes a large difference, every improvement provides some benefit and, added together, they are significant.

<u>WARNING</u>: Keep in mind that we expect that an aft limit of 31 % MAC will be acceptable <u>with</u> the larger empennage. Flight at 31 % without the larger empennage is possible, but not optimum, as pitch control is more sensitive. We suggest that you may want to temporarily set your own aft c.g. limit ahead of 31 %, based on your ability to safely handle the aircraft, until the previously described modifications are completed

1. HEADER TANK

Keep the header tank full on flights with two passengers and baggage. The weight of fuel in the header tank under normal operating conditions will help keep the c.g. forward. This is the procedure used for our factory II-S RG prototype; the header tank is always fail and is used only as a reserve or for an emergency. Placard the airplane with wording such as: "Header Tank--Emergency Reserve Only." This should always be done, regardless of what other solutions are selected.

<u>NOTE</u>: Since fuel can become stale over time, use the header tank fuel periodically (while flying with a light load or full main tank fuel to make sure the c.g. is within limits) and replace it with fresh fuel. Replace the fuel in the header tank at least every three to four months.

2. TEMPORARY VARIABLE LOAD PLACARDS

Perform calculations to determine how much baggage can be carried for different weights of pilot and passenger while maintaining the flight c.g. within the specified range when flying with minimum fuel. Post this data on a placard or a loading chart that is always carried in the airplane. A placard based on flight c.g. calculations for our example II-S TD (160 hp engine, Sensenich fixed-pitch metal propeller) would look like this:

AIRCRAFT LOADING WITH MINIMUM FUEL
(8 gal in header tank, main tank empty)

Pilot and Passenger	Baggage
198 lb	80 lb
230 lb	63 lb
260 lb	48 lb
290 lb	31 lb
320 lb	15 lb
350 lb	0 lb

NOTE: The placard for any particular Glasair II-S will be different from our example, depending on the empty weight and the position of the empty weight c.g.

3. TEMPORARY RANGE REDUCTION

Assuming a fuel bum of 9 gal/hour, the Glasair II-S can remain airborne for about 5.3 hours with no reserves. Few people like to sit in an airplane for that long. Typical legs on our cross-country flights, for example, are in the range of 3 to 3.5 hours. If you are willing to limit the duration of your cross-country legs to 3 hours, the additional fuel remaining at the end of the flight will enable you to carry more baggage than would otherwise be possible while maintaining the c.g. within limits, as the following flight c.g. calculation illustrates.

AIRCRAFT LOADING WITH REDUCED RANGE
(8 gal in header tank, 13 gal remaining in main tank)

Pilot and Passenger	Baggage
231 lb	80 lb
260 lb	65 lb
290 lb	49 lb
320 lb	33 lb
350 lb	17 lb
382 lb	0 lb

NOTE: Again, the placard for a different Glasair II-S will be different from the above example.

E. C.G. LOCATIONS FOR DIFFERENT AIRCRAFT CONFIGURATIONS

The following table shows the empty weight and flight c.g. locations for Glasair II-S TD aircraft fitted with various engines and propellers. The numbers for the flight c.g. were all calculated at the critical load configuration (aft c.g.): FAA average pilot and passenger (170 lb each), 80 lb of baggage (the specified maximum for the Glasair II-S), and minimum fuel (8 gal in the header tank). All the examples were calculated using our example II-S TD as a basis.

NOTE: As mentioned previously, use the actual weights of the pilot and passenger who will be flying in your airplane to calculate the flight c.g.

NOTE: The Sensenich propeller mentioned in the table is a fixed-pitch, metal propeller designed for we with the Lycoming 160 hp engine on homebuilt airplanes in the Glasair's performance range. Sensenich has expressed interest in developing a similar propeller for we with the 180 hp engine, but indicates that development will take an additional 12 to 18 months.

NOTE: Wooden propellers are not recommended for the Glasair II-S TD.

GLASAIR II-S TD C.G. LOCATIONS
(% of MAC)

CONFIGURATION	EMPTY WEIGHT C.G.	CRITICAL LOAD FLIGHT C.G.
160 HP ENGINE, SENSENICH METAL PROP		
Standard Wing Position	21.89	34.31
Wing moved 1.5" Aft	19.29	31.51*
160 HP ENGINE, CONSTANT SPEED PROP		
Standard Wing Position	20.03	32.80
Wing moved 1.5" Aft	17.31	29.90
180 HP ENGINE, CONSTANT SPEED PROP		
Standard Wing Position	18.97	31.93
Wing moved 1.5" Aft	16.24	29.04

*Even though this example is currently beyond the aft c.g. limit (31 % of MAC), it may possibly be judged acceptable if the aftward movement of the stick-fixed neutral stability point is large enough, as verified by flight testing and evaluation of the larger empennage.

F. IFR FLYING

Glasair owners who will fly in IMC should first evaluate their ability to control the airplane under adverse conditions. This should be done under the hood with a safety pilot in VFR conditions and at normal cruise altitude. Try to find some turbulence, such as strong thermal conditions. The safety pilot should simulate equipment failures and introduce distractions for the pilot, the pilot should not use the autopilot. This flight should be conducted at the aft c.g. limit, i.e. the worst case stability situation.

Under these conditions, the pilot should evaluate his or her ability to meet the instrument practical flight test standards, dealing with all of the circumstances that may be encountered in an IFR flight. The pilot should note the degree of difficulty in performing these maneuvers for evaluating whether or not to undertake any particular IFR flight in the future, given all of the other circumstances bearing on the flight.