Canard Composite Strength / Structures

Or, as Tim Fisher would say, "Composite Strong"

Marc J. Zeitlin

June 2nd, 2018

2:30 PM

Columbia Airport Campground Mess Hall

What Will I Talk About?

- ***Who Am I?***
- ***How Does Composite Construction Work?***
  - ***Concept***
  - ***Example: Main Spar***
  - ***Example: Canard***
- *Design Limits of Canard Composite Aircraft*
  - *Design Margin – Limit Load vs. Ultimate Load*
  - *Varieze / Long-EZ*
  - *COZY III / COZY MKIV*
- *Static Structural Testing*
  - *RAF Varieze Structural Load Testing*
  - *Our Varieze N262DB Structural Load Testing*
  - *Keith Murphy's Varieze Main Spar Load Testing*
  - *Jochen Fuglsang-Petersen's COZY III Structural Load Testing (Germany)*
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  - *Dave Knox's Long-EZ Main Spar Shear Web Wrinkling (non-fatal)*
- *Van's Aircraft - Design Margin Usage*
- *Questions and Answer – until done (ANY topic)*

Who The Heck Am I?

- Biography / Resume'
  - http://www.mdzeitlin.com/Marc/bio.html
  - https://www.burnsideaerospace.com/resume/
- Built Quickie Q2
- Built COZY MKIV #386, N83MZ – ~1430 flying hours
- Started / Administer Unofficial COZY Builders Web Page and COZY Mailing List (~720 members)
- As **Burnside Aerospace**, provide engineering consulting and canard A&P services (Pre-Buy, Pre-Sale, Condition Inspection, Builder Assist, Modifications, Upgrades, etc.)

- I provide **UNOFFICIAL** technical support for **COZY** aircraft to all canard builders, flyers and prospective builders

How Does Composite Construction Work?

- Use strong/stiff materials on outside
- Use lighweight materials on inside
- Optimize weight

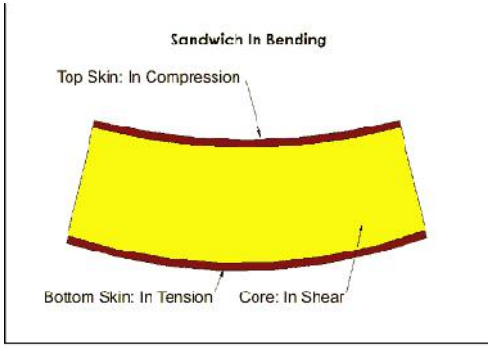


Figure 1

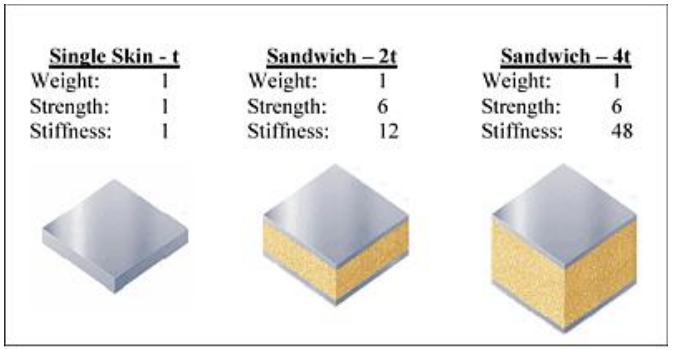


Figure 2

From "boatdesign.net"

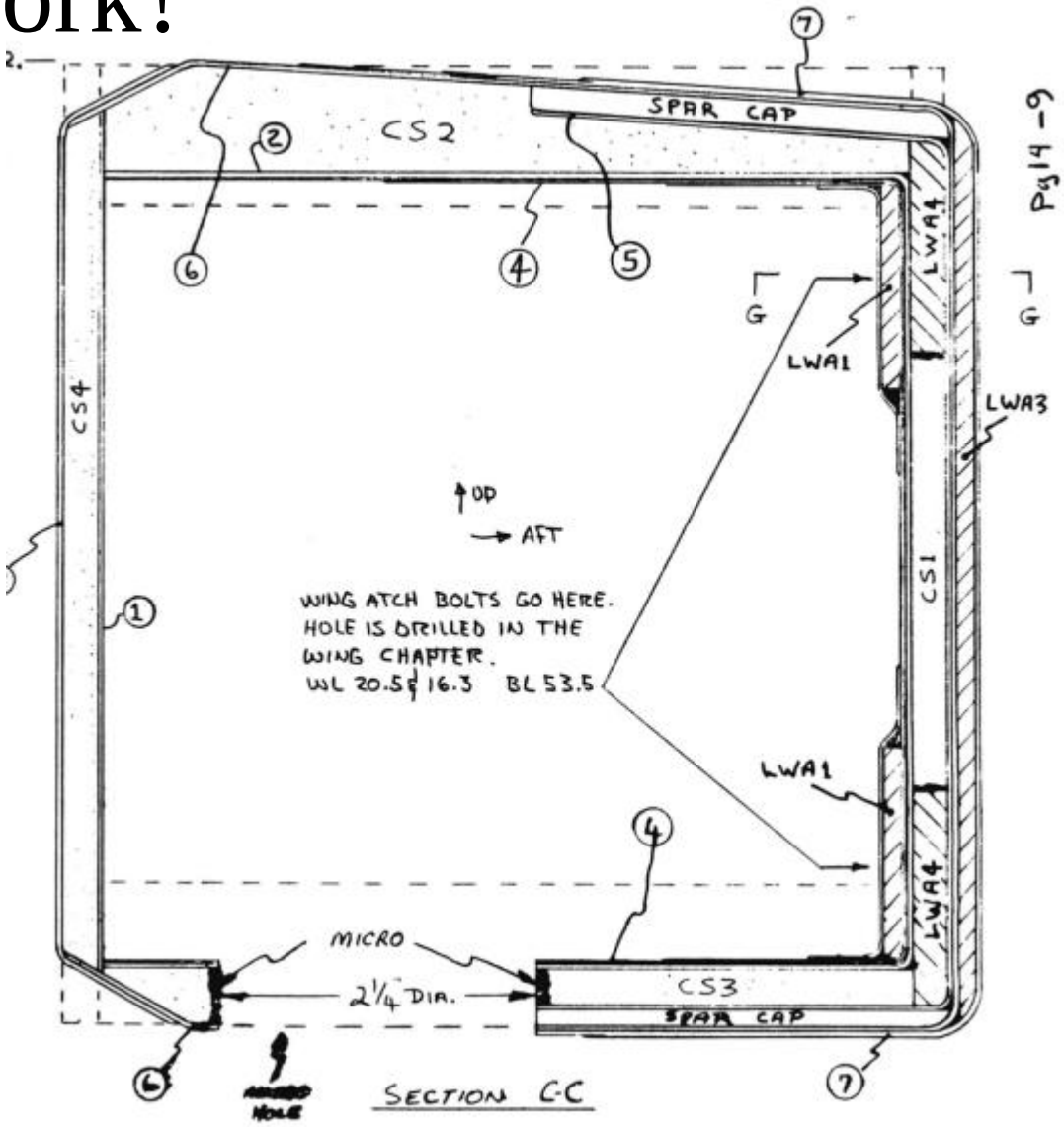
- Structure is Fiberglass
- Core is foam (multiple types)
- Matrix is epoxy (some aircraft use Polyester or Vinylester Resin)

- No molds required – all parts fabricated on flat table or simple jigs
- Wings, winglets and canard "hot-wired" from foam with templates to form core shape

From Dave and Lynn Schilder

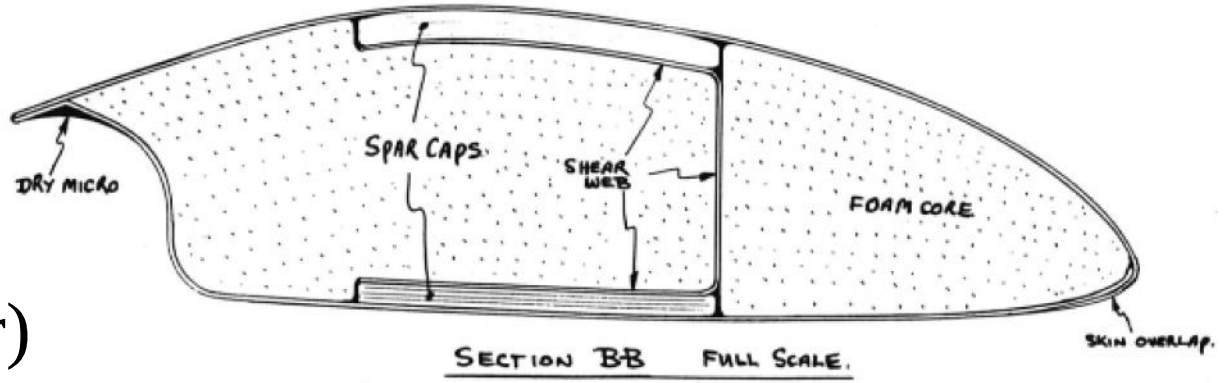
How Does Composite Construction Work?

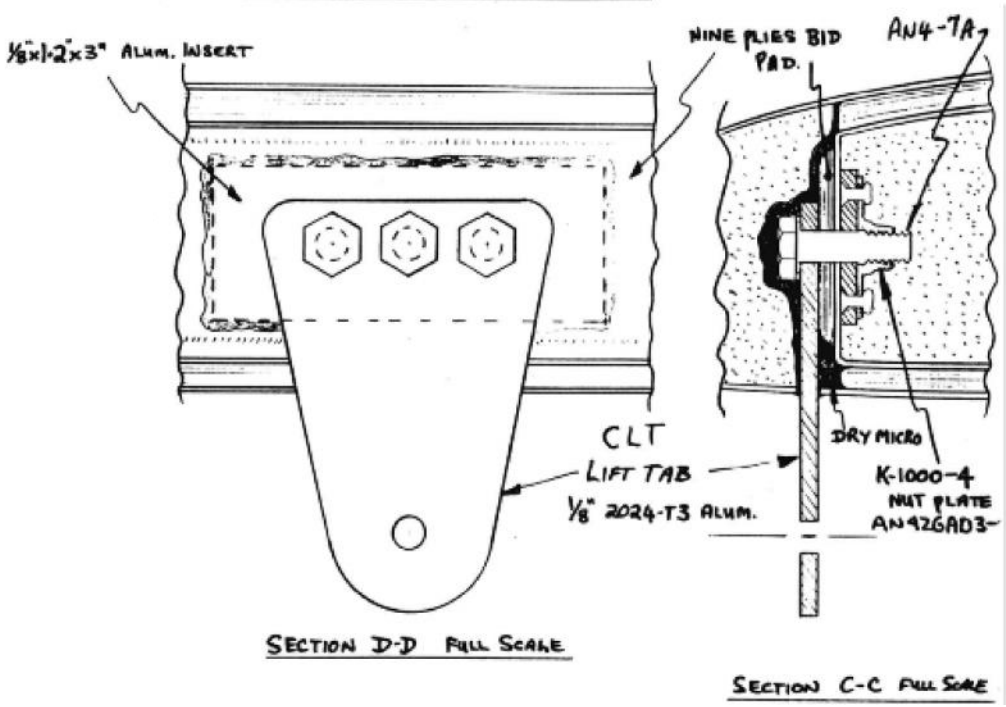
- Main Spar (Long-EZ, COZY, etc.)
  - Caps (UNI)
  - Shear Web (BID)
  - Hard Points (AL)
  - Torsion Box Closeout
- Optimal usage of fiber directionality



How Does Composite Construction Work?

- Canard
  (GU, but Roncz is structurally similar)
  - Caps
  - Shear Web
  - Hardpoint
  - Skin Torsion Box
  - Optimal usage of directionality





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Design Limits of Canard Composite Aircraft

- Design Margin Derivation
  - Aircraft designed for “Load Cases” at appropriate “G” loading
  - Wing Lift (positive/negative “G”, including gusts, etc.)
  - Flutter (stiffness driven)
  - Asymmetric Lift
  - Nose Slap Down on Landing
  - Swept Wing Twisting
  - Drag / Anti-drag
  - Landing Loads at MGW
  - Heavy structure attachments
  - Etc.

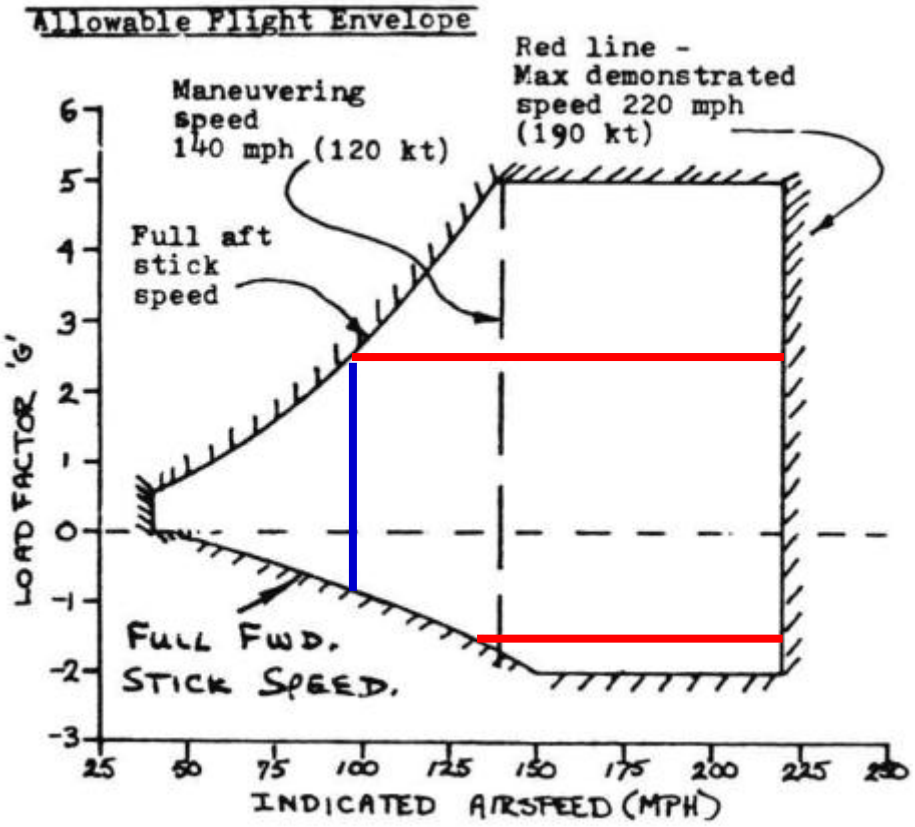
Design Limits of Canard Composite Aircraft

- Limit Load
  - Maximum Design Loads aircraft ever expected to see – i.e.:
    - 5G @ 1325 lb. MGW for Long-EZ
    - 5G @ 1050 lb. MGW for Varieze
    - 3.8G @ 1500 lb. MGW for COZY III
    - 3.8G @ 2050 lb. MGW for COZY MKIV
    - 10 fps descent rate for landing gear attachments
    - Etc. – tens or hundreds of load cases could exist, depending upon complexity of aircraft and use model
  - Structure expected to withstand these limits with **NO** damage whatsoever, continuously or for appropriate number of cycles
  - Between Limit and Ultimate load, no catastrophic failure is allowed, however permanent deformation of structure is acceptable (with structure retirement afterwards)

- Ultimate Load
  - Load at which structure is allowed to fail
  - In perfect world, entire airplane would disintegrate into dust after 3 seconds at UL – in real world, one thing (maybe two) fail upon reaching UL
  - **USUALLY** (in metal planes) Ultimate Load is 1.5 X Limit Load (where 1.5 is the “Safety Factor”, but other multipliers can be used based on confidence levels / design goals)
  - A common SF for composite structures is 2.0
  - Most of RAF derived structures are designed with a higher (and unknown) Safety Factor to account for MFG unknowns and builder skill set variability

Design Limits of Canard Composite Aircraft

- Varieze / Long-EZ
  - Identical Flight Envelope “G” limits as designed
- Varieze
  - 1050 lb. MGW
  - 1100 lb. limited to +4G / -1G
  - Many fly heavier…
  - Red Lines – Latest flight envelope based on Wing Attach Fitting Corrosion issues: +2.5G / -1.5G)
  - Blue line – new Va (maneuvering speed
- Long-EZ
  - 1325 lb. MGW
  - 1420 lb. MGW (takeoff ONLY) under special circumstances – limited to +3.8G / -1G
  - Many fly heavier…



Design Limits of Canard Composite Aircraft

- COZY III / COZY MKIV
  - Identical Flight Envelope “G” limits as designed
- COZY III
  - 1500 lb. MGW
  - 1600 lb. MGW Takeoff Only under certain conditions
  - Many fly heavier…
- COZY MKIV
  - 2050 lb. MGW
  - No special dispensation for higher weights, but…
  - Many fly heavier…

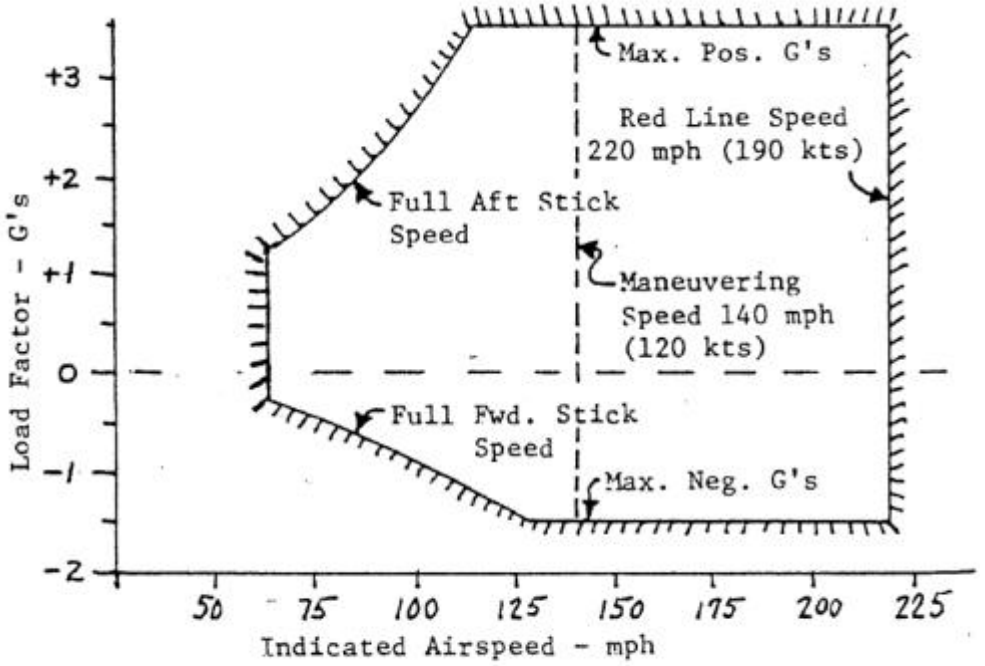


Figure 4: Allowable Flight Envelope

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Static Structural Testing

- RAF Varieze Structural Load Testing
  - Ernie Joiner donated 21 year old Varieze to RAF for destructive testing
  - Canard
    - Failed at 8.3G (SF = 1.66) – earlier than expected – design had higher SF
    - Broke flush with fuselage sides, both sides
    - Other canards have broken at upward of 12G (SF = 2.4)
    - Long-EZ – same GU canard – may not have 1.5 or 2.0 SF based on higher MGW
    - Recommend maximum 3.5G VE/LE limit based on canard failure level
  - Main Wing
    - Failed at 7G (SF = 1.4) – far earlier than expected
    - Unknown reason for low failure level

Static Structural Testing

- RAF Varieze Structural Load Testing
  - Winglet
    - Outboard – Failed at design UL
    - Inboard – Would not fail at more than 2X design UL

- NOTE EXTREME VARIANCE IN FAILURE LEVELS IN RELATION TO DESIGN POINTS

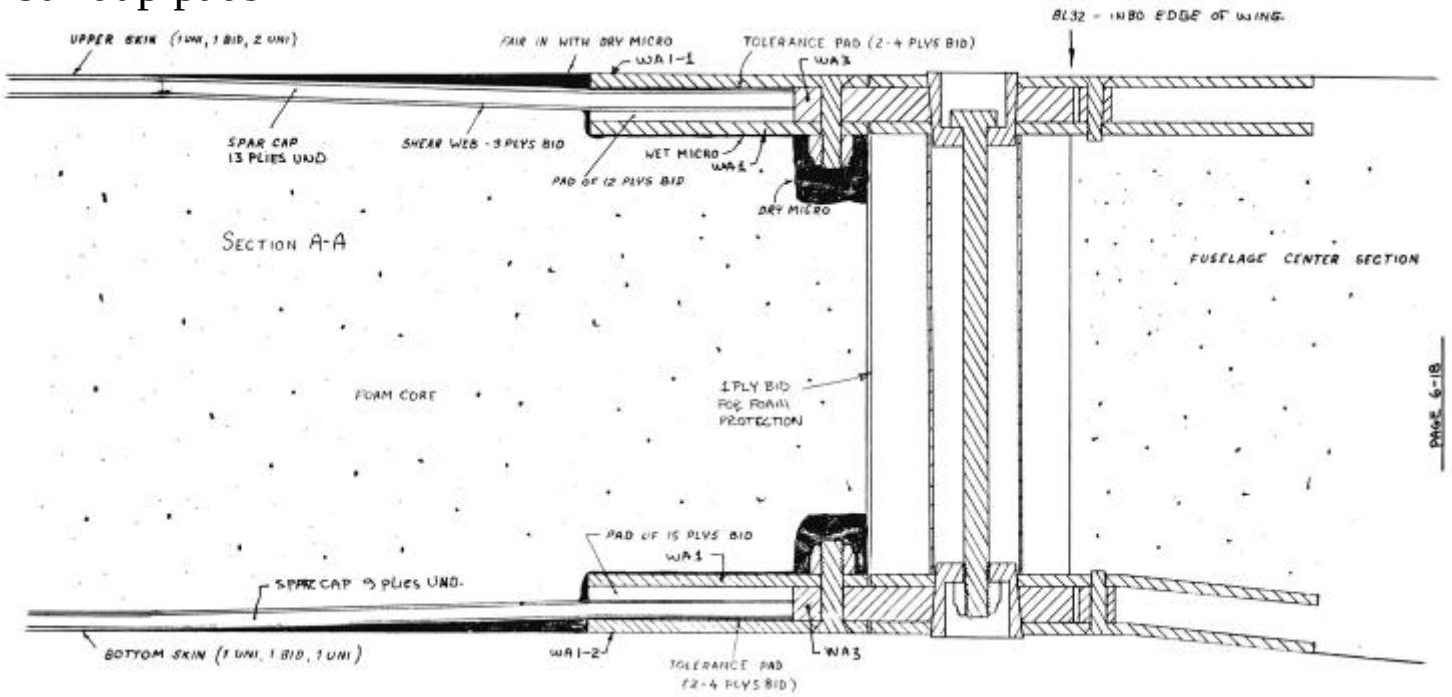
- http://cozybuilders.org/Canard_Pusher/RAF_LE-Structural-Test.pdf

Static Structural Testing

- Our N262DB Varieze Testing
  - Canard: No failure up to 7.5G
  - Main Wing: Failed at ~7G (SF = 1.4) far below expectations
  - Wing spar failure – pullout from AL attach fittings

Static Structural Testing

- Keith Murphy “Varieze” Main Spar Testing
  - Heavily modifed LE with steel tube fuselage and modified main spar attach scheme
  - Purchased Main Spar from unknown builder
  - Wanted to static test to Limit Load (5G) to proof unknown main spar
  - Main Spar failed at 2.4 – 2.6G (SF ~ 0.5). Obviously, any safety factor under 1.5 is unacceptable, and under 1…
  - Compression side of Main Spar failed due to “kink” in cap layups and missing buildup pads



Static Structural Testing

- Fuglesang COZY III S/N 99
  - Required to static test whole aircraft by German authorities
  - Loaded canard / wing / winglet together at maximum incidence AOA angle – 10 deg. Nose up
  - Maximum inward load applied to winglets with winch
  - Failure Level – no failure – loaded to 5G Max. at 1600 lb. MGW for 3 seconds
  - No deformation of the structure noted after release of loading

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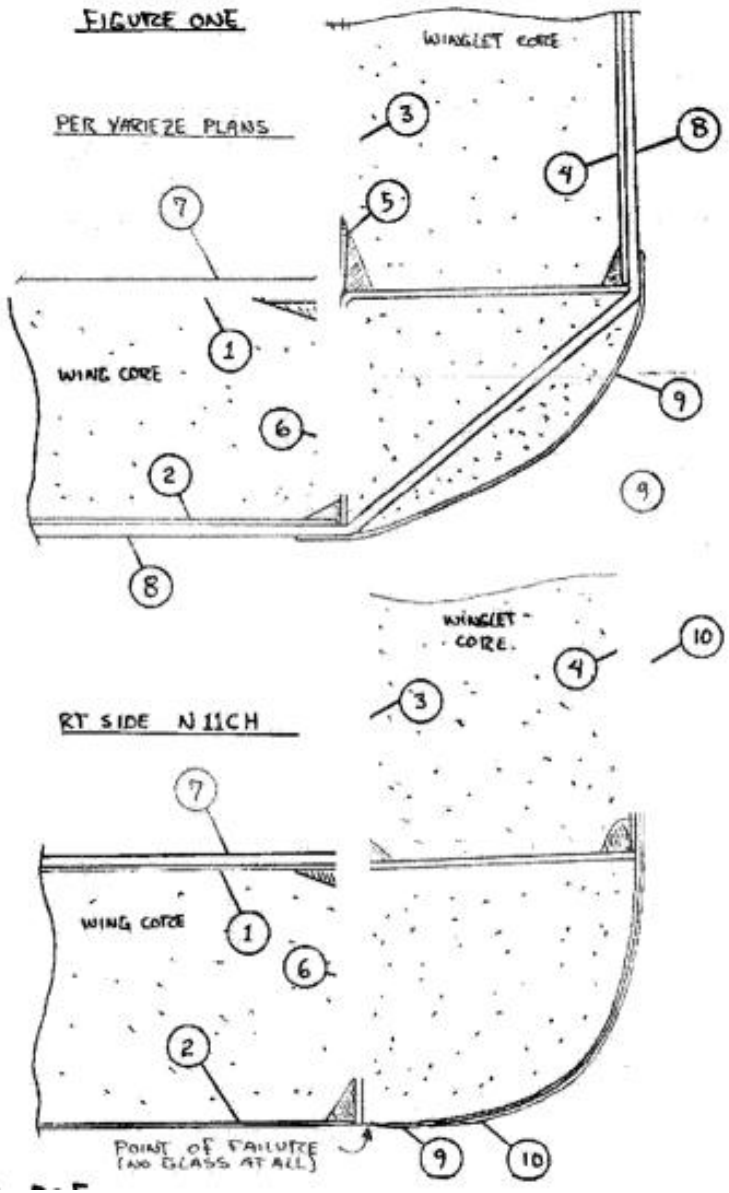
In-Flight Structural Testing

- In flight structural testing without static testing is generally contraindicated for what should be fairly obvious reasons

- Varieze N11CH Winglet Attach Layup
  - July, 1982 in-flight right winglet departure – over 200 mph low altitude pass
  - See CP #33, Page 5 for full write-up
  - Missing layups resisting inward lifting force of canard
  - Strength no more than 1/20 of expected value with correct structure
  - Fatal crash – builder error



In-Flight Structural Testing

- Tim Sullivan Long-EZ N7999H Winglet Attach Structure
  - Major winglet in/out oscillations above 130 KIAS – 6” to 12” at the tip
  - Landed safely – no injuries
  - Attributed to wrong materials in “knuckle” joint, poor fabrication techniques and dust devil imposed loads
  - Still took over 1000 hours, 21 years and a tornado (excessive outward loading) to cause failure
- http://www.cozybuilders.org/N7999H_Accident_Eval/

In-Flight Structural Testing

- Dave Knox Long-EZ N309SH
  Main Spar Shear Web
  - Wrinkles in Shear Web of Right Side of Main Spar
  - ~600 hours on plane
  - Has pulled 5.1G – 5.2G momentarily
  - Unknown builder
  - Unknown failure time – discovered during disassembly for check after 6 years of storage
  - Cause:
    - Maybe wrong shear web layup orientation (0/90 rather than +/- 45)
    - maybe too few plies
    - maybe wrong material used (UNI/Triax/Biax?)
    - haven’t disassembled for evaluation yet

Aircraft Design Margin Usage

- "Unfortunately in science what you **believe** is irrelevant" – Bill Husa (aircraft designer – since deceased)

- August, 2011 **Sport Aviation** article by **Dick VanGrunsven** (designer of all RV aircraft) addresses overweight/overpowered aircraft as well as other modifications – specifically in response to an award winning RV-10 written up in Sport Aviation!
- A couple of quotes from Dick:

  - …Any "penciled in" gross weight increase is just wishful thinking. **The laws of physics are not repealed by wishful thinking.**

  - **WHO OWNS THE MARGIN?**
    It seems common practice among homebuilders to second-guess the factory engineers, particularly regarding gross weight increases. Because of all of the added features, empty weight creep erodes the aircraft's useful load. The simple solution for the homebuilder is to "pencil in" a new gross weight limit. "It's only 100 pounds (3.7 percent) more; how much effect can that possibly have?" Imagine this example: You are on a mid-size airliner with a gross weight of 270,000 pounds. Just before leaving the gate, the captain comes on the PA system and says: "We've overbooked more than usual today, so we're going to assume that the factory engineers over-designed this airplane and allowed an abundant safety margin. We're going to take off at 280,000 pounds instead. So move over, there are 50 more passengers coming on board." Run the numbers; it's the same over-weight ratio as simply penciling in an additional 100 pounds to the gross weight of an RV-10.

    Along with gross weight increases, some builders take the same liberties with horsepower increases and speed increases, betting their lives on the assumption that the airplane is designed with a huge margin of safety—it is really far stronger than it needs to be. This is not really true. **Certificated aircraft, and well-designed kit aircraft, are designed to withstand limit loads at specified maximum weights. During testing, they are subjected to ultimate loads, which are higher than design limit loads by a specified margin. Yes, there is a margin between the design and ultimate strengths. But that margin belongs to the engineer. He owns the margin. It is his insurance against the things he doesn't know or can't plan for, and the pilot's insurance against human error, material variations, and the ravages of time.** Wise pilots respect this design safety philosophy and leave this insurance policy in effect by operating strictly within established limits.

- Emphasis in **red** **MINE**…

Questions? (& Answers)

- Whattaya Got?

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- Websites: http://www.cozybuilders.org
  http://www.burnside-aerospace.com