Aging Aircraft Concerns on Comanche Airplanes

ICS National Convention

Tacoma, WA

15 August 2007

Hans Neubert

Pages 1 through 56

Current Fleet Problems

- Landing Gear Collapse
- Torque Tube Corrosion
- Cracking in Torque Tube Horns
- Limited Availability of Parts

Landing Gear Incident Data

- www.faa.gov/data_statistics/accident_incident/preliminary_data/
- Data for all GA events by “Gear Up Landing” & “Gear Collapse” collected for nearly 5 years
- Data for all Comanche events by “Gear Up Landing” & “Gear Collapse” retained as subset on Excel spreadsheet
- Approximately 2 per day for all GA
- Approximately 2 per month for all Comanche’s

All Landing Gear Data – 1 Jan 02/27 Oct 07

By _____
Job No. _____

LANDING GEAR UP & COLLAPSES
JAN 1, 2002 → PRESENT

Sht 1 of _____
Date 2002

1 JAN	511FB	BE55	NOSEWHEEL COLLAPSED AFTER LNG, CROSS CITY, FL
1 JAN	5301R	C172	NOSEGEAR COLLASED ON LNG., ST. PETERSBG, FL
1 JAN	7084P	PA-24	LOST ELEC. PWR, LNG. GEAR UP, FT. SMITH, AR
3 JAN	1045U	PA-34	NOSE GEAR COLLAPSED ON LNG, TACOMA, WA
3 JAN	761JW	C-210	LANDED GEAR UP, KANSAS CITY, MO
5 JAN	2603W	M020	FLY BY PWR, UNSAFE GEAR, GEAR COLLAPSE, MEDFORD, OR
5 JAN	231WG	M020	NOSE GEAR COLLAPSE ON LNG, DALLAS, TX
9 JAN	538AJ	EXP-BERKUT	NOSE GEAR COLLAPSED ON T/O ROLL, PALO ALTO, CA
10 JAN	166P	BE33	GEAR PROB. IN FLIGHT, NOSE GEAR COLLAPSE, PADUCAH, KY
10 JAN	287BW	C182	GEAR COLLAPSE ON LNG, FT. WAYNE, IN
10 JAN	3671H	M020	GEAR COLLAPSE ON LNG, GREENVILLE, SC
10 JAN	7559V	C177	A/C LANDED GEAR UP, LIVERMORE, CA
11 JAN	201HB	M020	MAINT. FLIGHT, PROBS W/GEAR, GEAR COLLAPSE, PRESCOTT, AZ
12 JAN	4PF	C337	MAIN GEAR STUCK, NOSEGEAR DOWN LNG, SLC, UT
13 JAN	5511P	PA24	GEAR WOULD NOT EXTEND, GEAR UP LNG, PROSSER, WA
13 JAN	6280V	C172	TOUCH & GO'S, LNG. GEAR UP, SOUTHERN PINES, NC
14 JAN	8485P	AC50	AEROCOMMANDER NOSE GEAR PROB, GEAR COLLAPSE, MESA, AZ
12 JAN	9602B	C172	GEAR UP LNG AFTER FUEL BURN-OFF, SANTA ANA, CA
12 JAN	9657T	C210	GEAR UP LNG, BATTLE CREEK, MI
15 JAN	941MA	MU2	AIR CARGO A/C LANDED GEAR-UP, HEBRON, KY

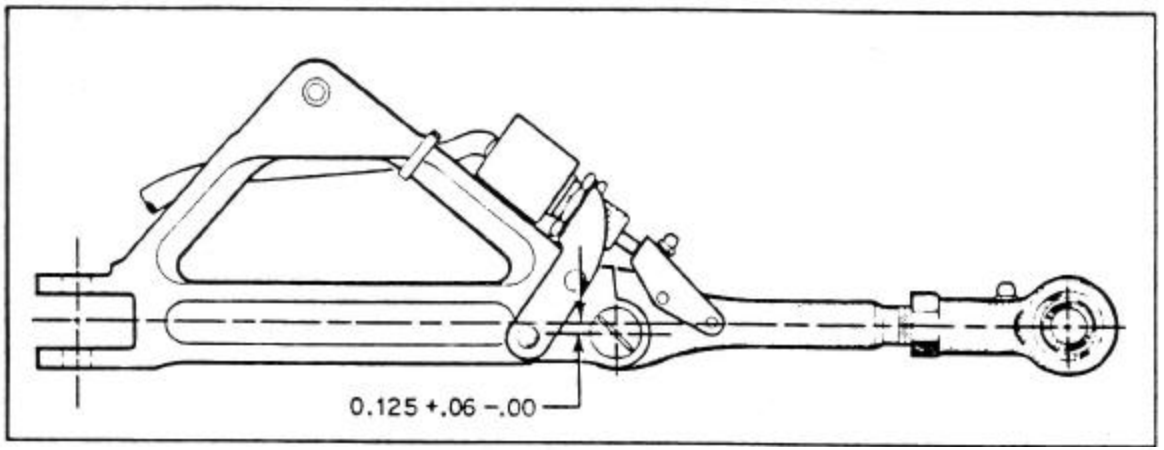
Comanche Specific Gear Related Problems

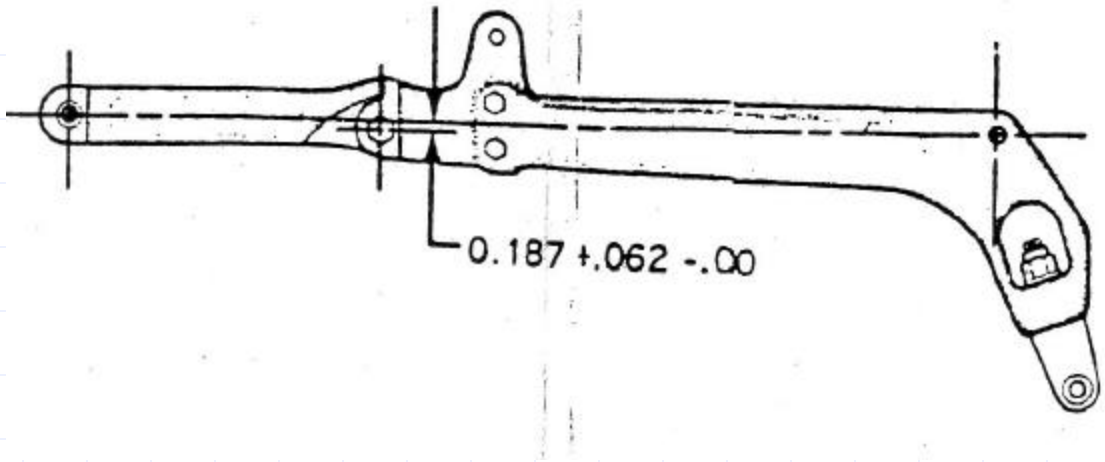
Comanche Specific Gear Related Problems			
Date	**N Number**	**Model**	**Brief Description**
1/1/2002	7084P	PA-24	Lost Elec. Pwr, Gear Up Lng, Ft. Smith, AR
1/13/2002	5511P	PA-24	Gear would not extend, Gear Up Lng, Prosser, WA
1/19/2002	7176P	PA-24	Smell smoke, Manual Extend, Collapse, Moab, UT
2/9/2002	7807P	PA-24	Gear Dwn, No Light, Collapse, Pell City, AL
2/24/2002	6202P	PA-24	Practicing Approaches, Gear Up Lng, Georgetown, KY
2/23/2002	9055P	PA-24	Collapse on Landing, Atlantic City, NJ
2/28/2002	6610P	PA-24	Gear Up Lng, Gulf Shores, AL
3/16/2002	6518P	PA-24	Gear Up Lng, Glendale, AZ
4/7/2002	9140P	PA-24	Gear @ 45°, Gear Collapse, Portland, ME
4/14/2002	6909P	PA-24	Nosegear Collapse, San Angelo, TX
4/17/2002	7818Y	PA-30	Gear Colllapse, Enterprise, AL
4/21/2002	7401P	PA-24	Veered right, Right MLG collapse, Prescott, AZ
4/29/2002	7366P	PA-24	Eng. Problems, Gear collapse, Colo. Springs, CO
4/29/2002	7961P	PA-24	Gear Up Lng, Pipestone, MN
5/6/2002	7953P	PA-24	Right MLG Collapse, Rome, GA
5/7/2002	7224P	PA-24	Gear Collapse, Lumberton, NC
5/26/2002	250LJ	PA-24	Right MLG hit on T/O, Gear Collapse, Waupaca, WI
6/21/2002	8974Y	PA-30	Elec. Failure, Gear Up Lng, Watsonville, CA
6/30/2002	6027P	PA-24	Right MLG Collapse, Pueblo, CO
7/4/2002	400BK	PA-24	Would not extend, Gear Up Lng, Ft. Worth, TX
7/15/2002	767WP	PA-24	Nosegear Collapse, Sedona, AZ
7/20/2002	5227P	PA-24	Hard Lng, Damage to Nosegear & wings, Pt. Clinton, OH
7/26/2002	5639P	PA-24	Gear Collapse, Muskogee, OK
8/14/2002	144TL	PA-24	Nosegear Collapse, Minneapolis, MN
8/19/2002	9030P	PA-24	Gear Collapse, New Bedford, MA
9/7/2002	7817Y	PA-30	Left wheel came off, Winder, GA
10/19/2002	7875P	PA-24	Elec. Failure, Gear Up Lng, Millinocket, ME
10/20/2002	2VQ	PA-30	Left MLG did not lock, gear collapse, Manassas, VA
11/7/2002	7349Y	PA-30	Elec. Failure, Gear Collapse, Panama City, FL
11/13/2002	7390P	PA-24	Gear Up Lng,. Front Range, CO
11/13/2002	8382P	PA-24	Gear Up Lng, Borrego Springs, CA
12/14/2002	5582P	PA-24	Gear Collapse, Fayetteville, NC
12/15/2002	948SB	PA-30	Malfunction, Lng on road, Jackson, MI
1/4/2003	6404P	PA-24	Gear Up Lng, Mertle Beach, SC
1/12/2003	6080P	PA-24	Gear Up Lng, Honolulu, HI
1/14/2003	8619Y	PA-30	Elec. Failure, Gear Up Lng, Martinsburg, PA
2/19/2003	5065P	PA-24	Gear Up Lng, Toms River, NJ
2/13/2003	7818Y	PA-30	Gear Collapse, Enterprise, AL
3/7/2003	543AS	PA-24	Gear Collapse, Ft. Myers, FL
3/15/2003	842PS	PA-24	Eng. Probs, Gear Up Lng, Williams, AZ
3/16/2003	6518P	PA-24	Gear Up Lng, Glendale, AZ **(that's twice-see 3-16-02)**

Landing Gear Collapse Causes

- Maintenance Neglect
  - Worn out parts – Insufficient lubrication
  - Misadjusted switches – fatigued wires
  - Excessive friction in gear cables and bearings
  - High amperage draw on motor and solenoids
  - Improper rigging and cable preload
  - Main gear pivot fitting & nose gear clevis failure
- Vagueness in Service Manual
  - Preload on cables not well written

Landing Gear Overcenter Positions





Adjustment of Down Limit Switches

- Service Manual (Twin) Paragraph 7-44 d, Items 3 & 4
  - 3. Disconnect the retraction transmission by pulling up on the release lever and manually retracting the landing gear using the emergency extension lever.
  - 4. At the point where the green light goes out, apply reward pressure on the nose gear and inward pressure on the main gear. The gear should not unlock.

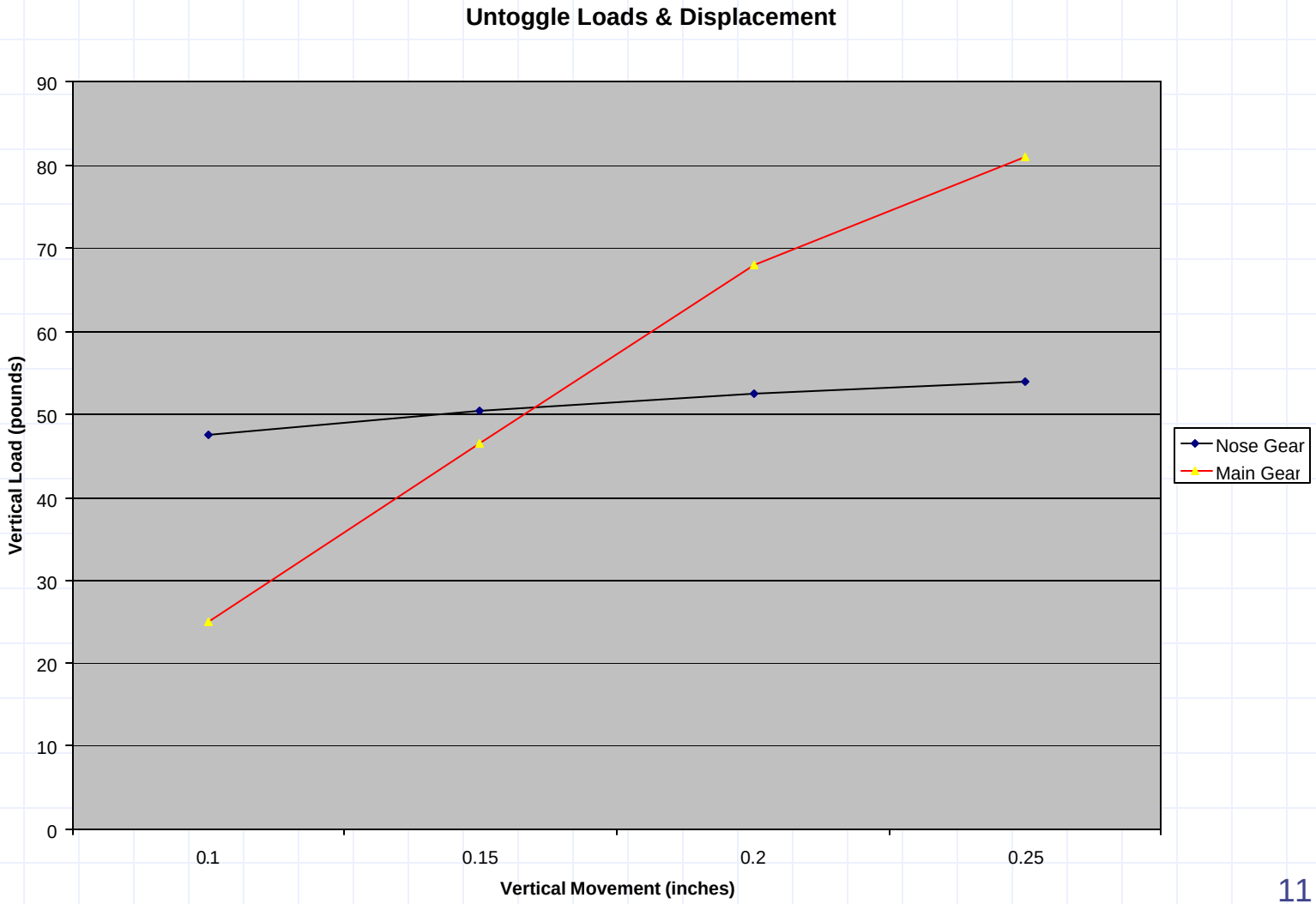
Evaluation of Gear Down Pressure

- Simple set-up using bathroom scale, jack, long stick, and dial indicator
- Push up at pivot point
- Measure load and displacement
- Transmission is disconnected
- Plot up results

Test of Over-Center Force and Movement

Transmission disconnected

Results of Tests



Summary of Gear Collapse Suggestions

- Maintenance, Maintenance, Maintenance
- Replace circuit breaker and solenoid at next annual
- Check cable (conduit) preload
- Minimize gear cycles in short time period
- Lubricate ALL zerk fittings (remove excess)
- Check log book for 1000 hr AD gear compliance

Torque Tube Background Data

- Corrosion has been observed between the torque tube and the attaching bolts
  - Piper Service Letters 667A and 772
  - Advisory Directive 74-13-10 issued by FAA
- Inspection requires replacement of existing attaching stabilator bolts with corrosion resistant bolts
  - Replacement of bolts with CRES bolts is terminating action of the AD

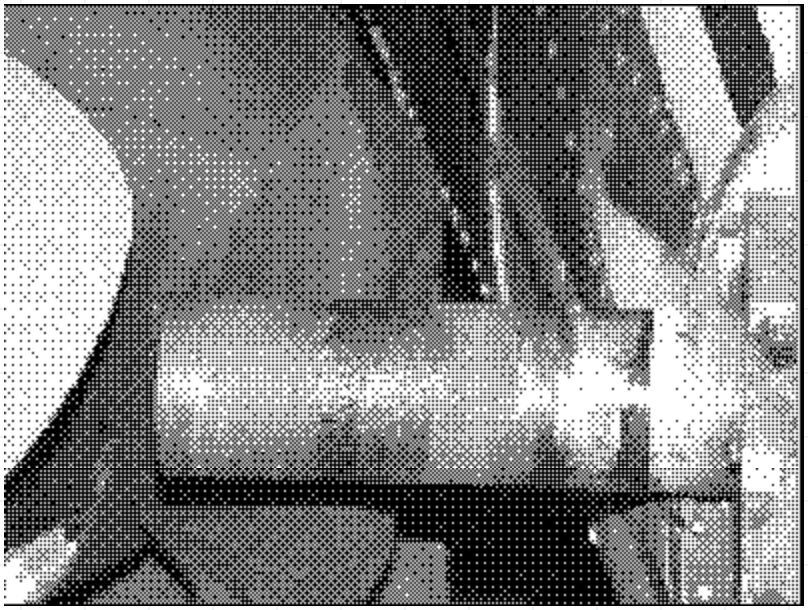
ICS Action Plan

- Fearing that a potentially devastating AD could result from the SAIB, ICS action included:
  - Testimonial letters responding to SAIB from 9 recognized Comanche specialty repair facilities
  - Initiated owners survey of inspection results on both the Delphi and ICS site
  - Received from Altus an unserviceable torque tube assembly for structural load testing

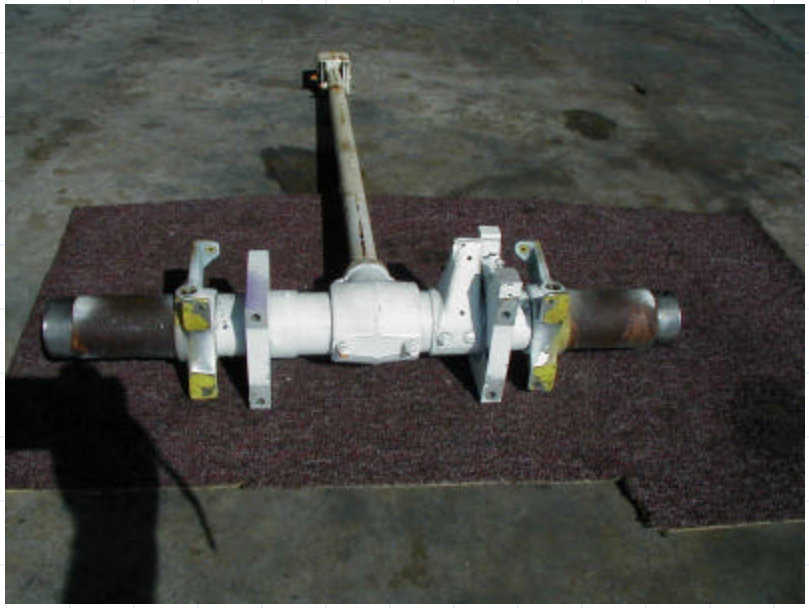
Testimonial Letter Summary

FACILITY	REPRESENTATIVE	FINDINGS OF CORROSION
Webco Aircraft	Bob Weber	"I have reviewed SAIB #CE-04-08 and have never encountered anything remotely similar to what these pictures show"
Aircraft Engineering, Inc.	Bill Turley	"In some instances, some corrosion found, but never to the extent displayed in the SAIB"
Iliff Aircraft Repair & Service	Charles Iliff	"We have never found any serious amount of corrosion"
Johnston Aircraft Service	Dave Johnston	"We have never seen, experienced or heard of the amount of corrosion shown in the pictures accompanying the SAIB"
Clifton Aero	Tim Talley	"We have not found on our inspections, the severe rust pits [shown in the SAIB] on the O.D. of the stabilator torque tube"
Penn-Air Inc.	Dan Claycomb	"We find corrosion, but none that could be considered unairworthy"
Liebfried Aviation Inc.	Andy Liebfried	"The difficulty in a re-occurring inspection is that disassembly will provide more damage at the hands of inexperienced technicians than a quality process and treatment for the tube on a one time or long term inspection basis"
Swift Aviation Services	August Mazzella	"We have never discovered as extensive corrosion as depicted and feel that, as repetitive an inspection would be unnecessary and may cause more damage to the area, outweighing the benefit"
Squire Aircraft, Inc.	Bob Squire	"While doing an annual inspection I always check all components of the empennage and I have not found any evidence of corrosion on the torque tube as pictured in SAIB CE-04-08

Samples of Torque Tube Corrosion



Samples of Torque Tube Corrosion

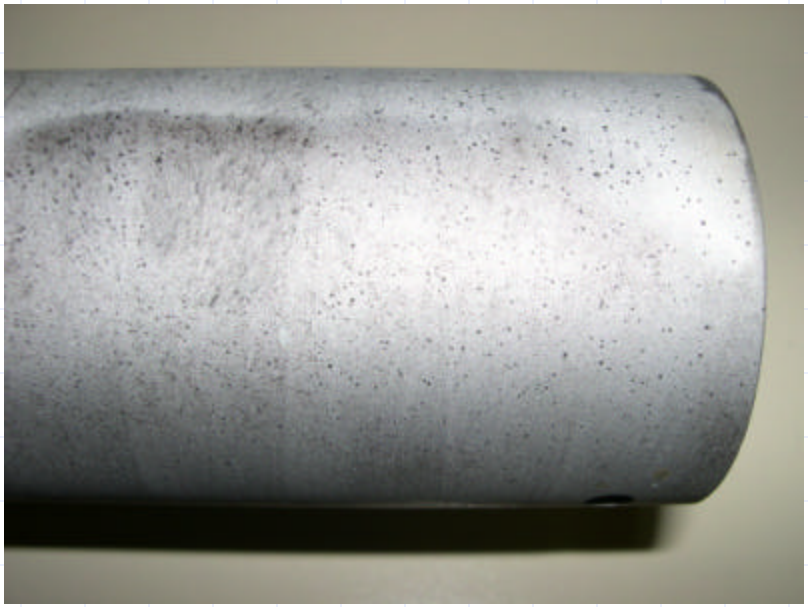


Torque Tube Test Specimen

- PA 24-250 unserviceable unit received from Altus
- Torque Tube cleaned up using 180 grit media
- Precise measurements made after clean up
- Coated with zinc chromate and paint
- Adapter fittings, load reaction fittings and base plate fabricated

Initial Condition

Surface Pitting after Cleanup

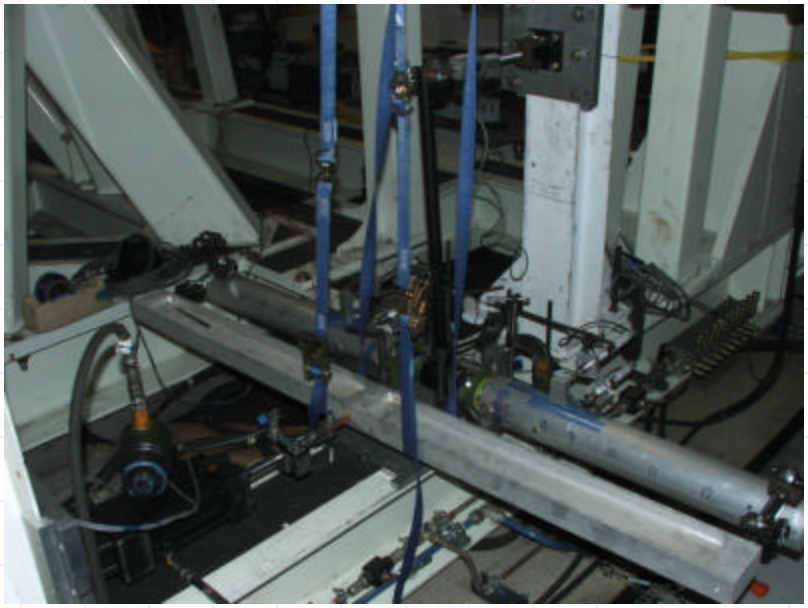


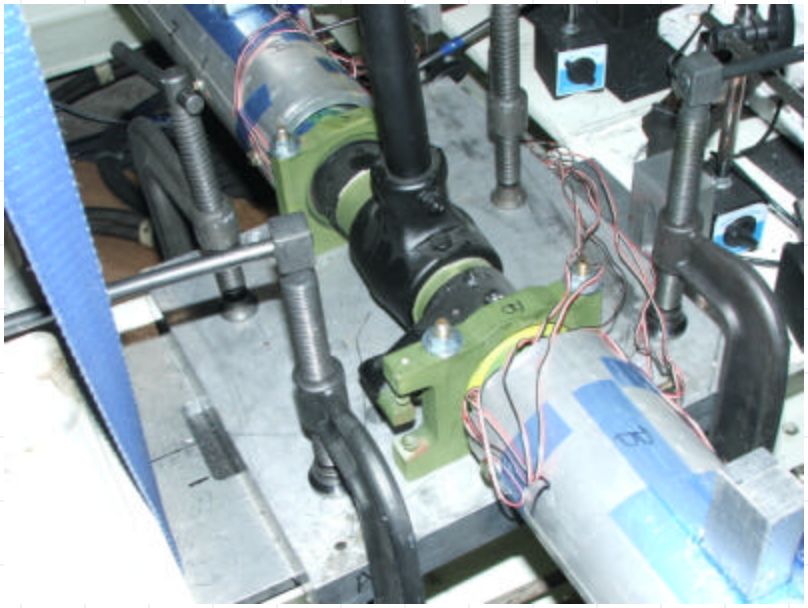
Strain Gaged Specimen

Load Condition Selection

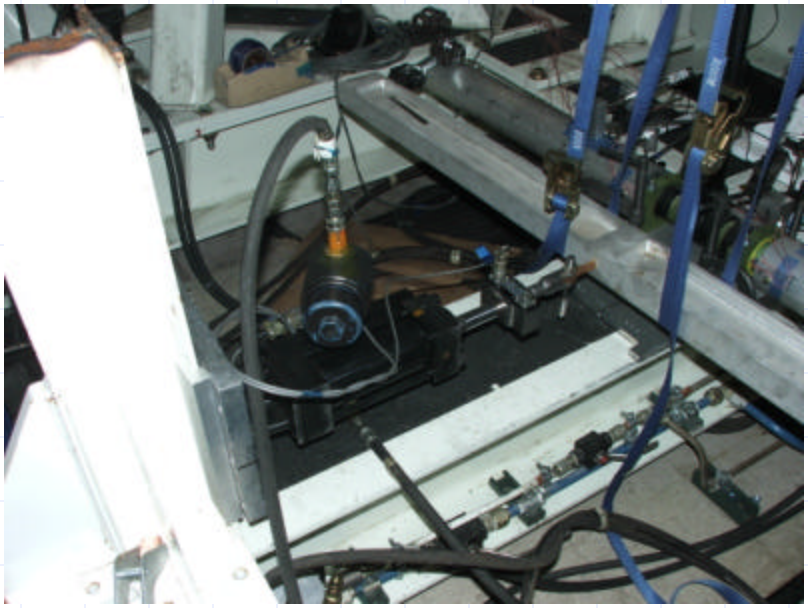
- Select symmetrical pull-up at forward CG at 227 mph CAS (Vne)
  - Largest tail down load at 2000 lb and 5.9” fwd cg (24-260)
  - Tail Down Load = 1753 lb at 3.8g Design Limit Load
  - Moment & Shear satisfied at 42% semi-span
- Torque Load from CAR3/Part 23
  - Maximum control wheel pull load = 200 lb
  - Torque = 5600 in-lb at 3.8g Design Limit Load
- Bending and Torque Conditions Combined
  - Load is offset from Torque Tube centerline by 3.2 inches
  - Load Condition covers all single models (except 400’s)

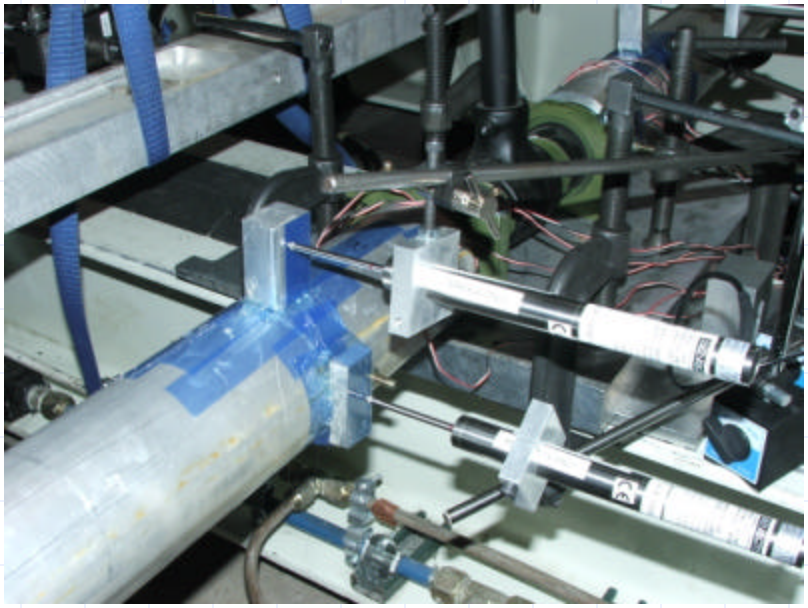
Test Setup



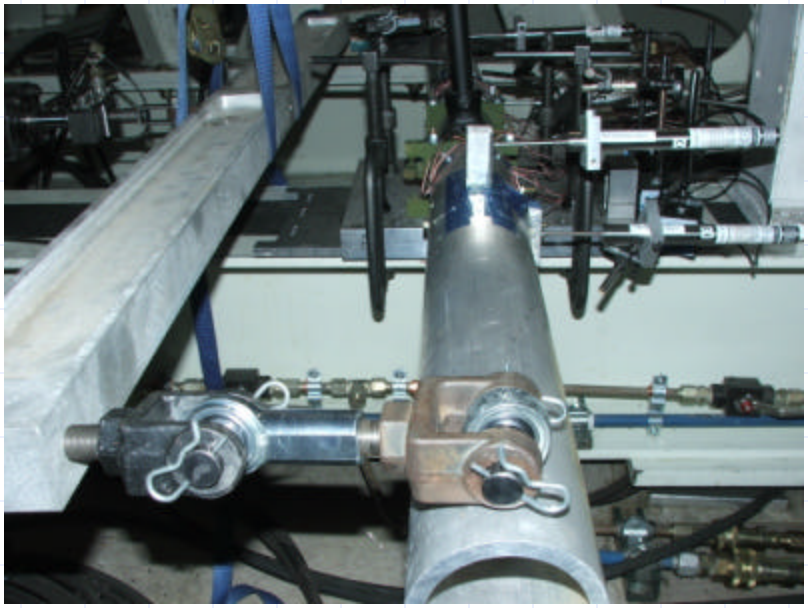


Test Setup

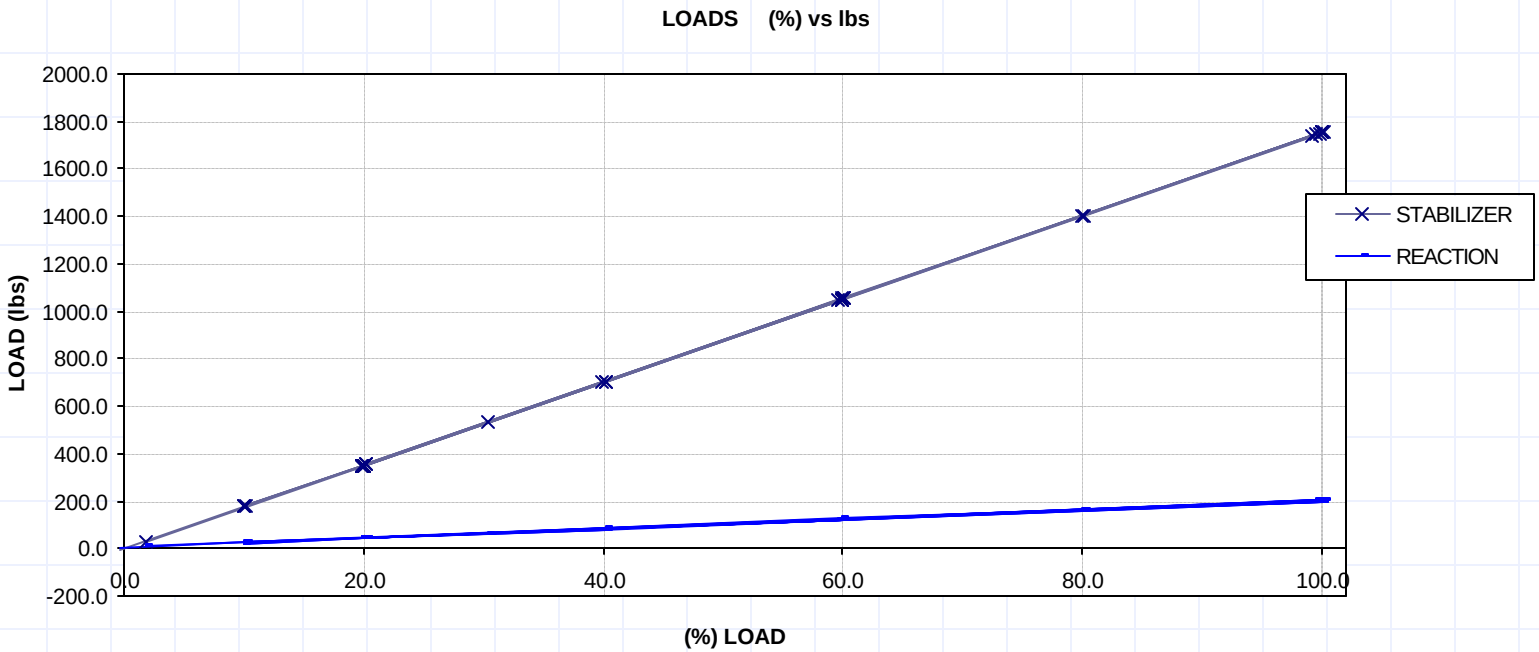




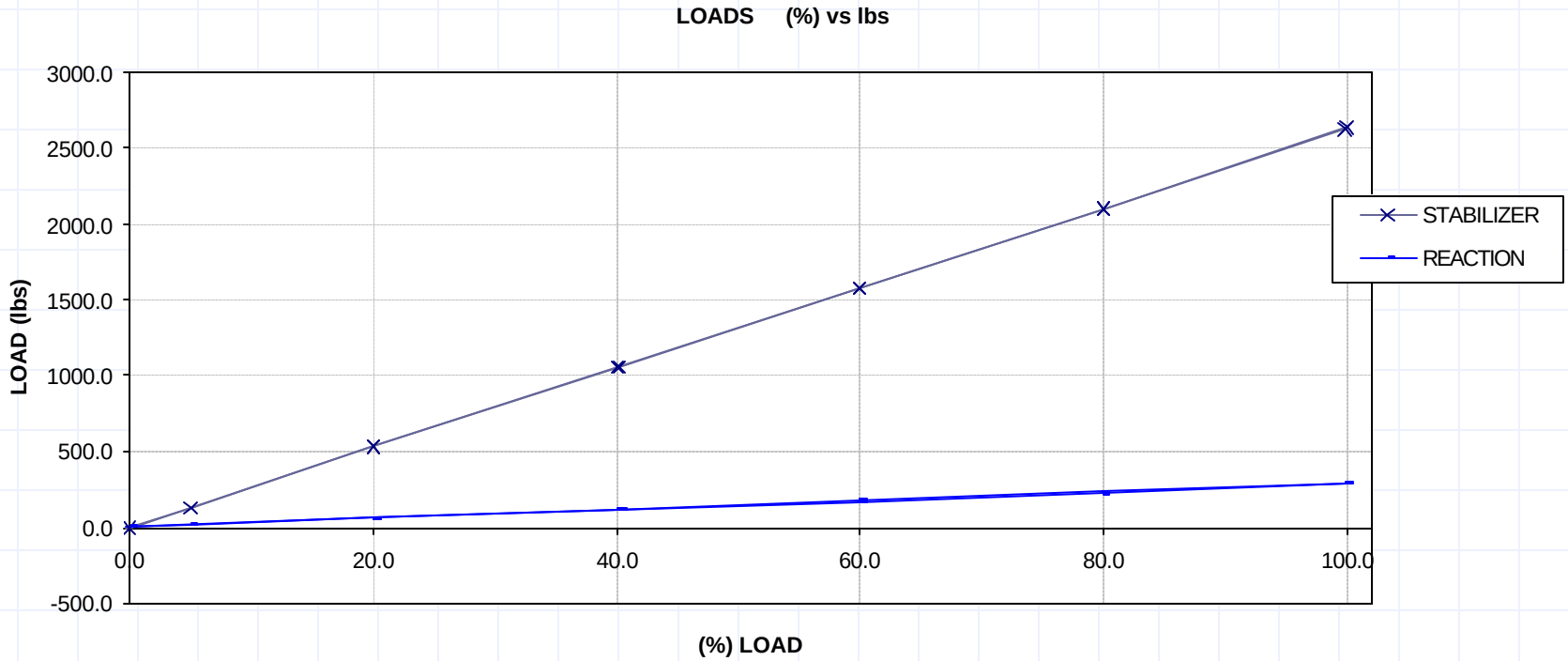
Test Setup



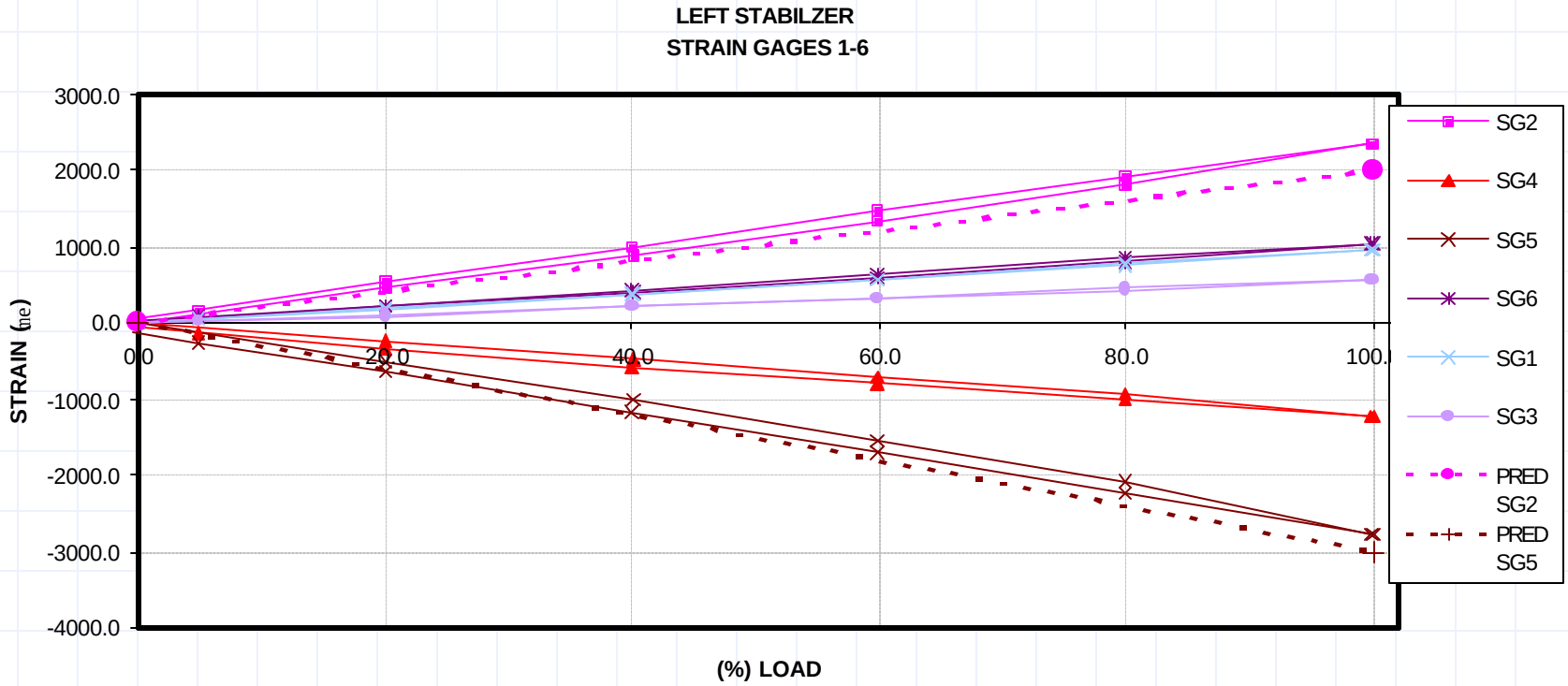
Load Case 1 Load



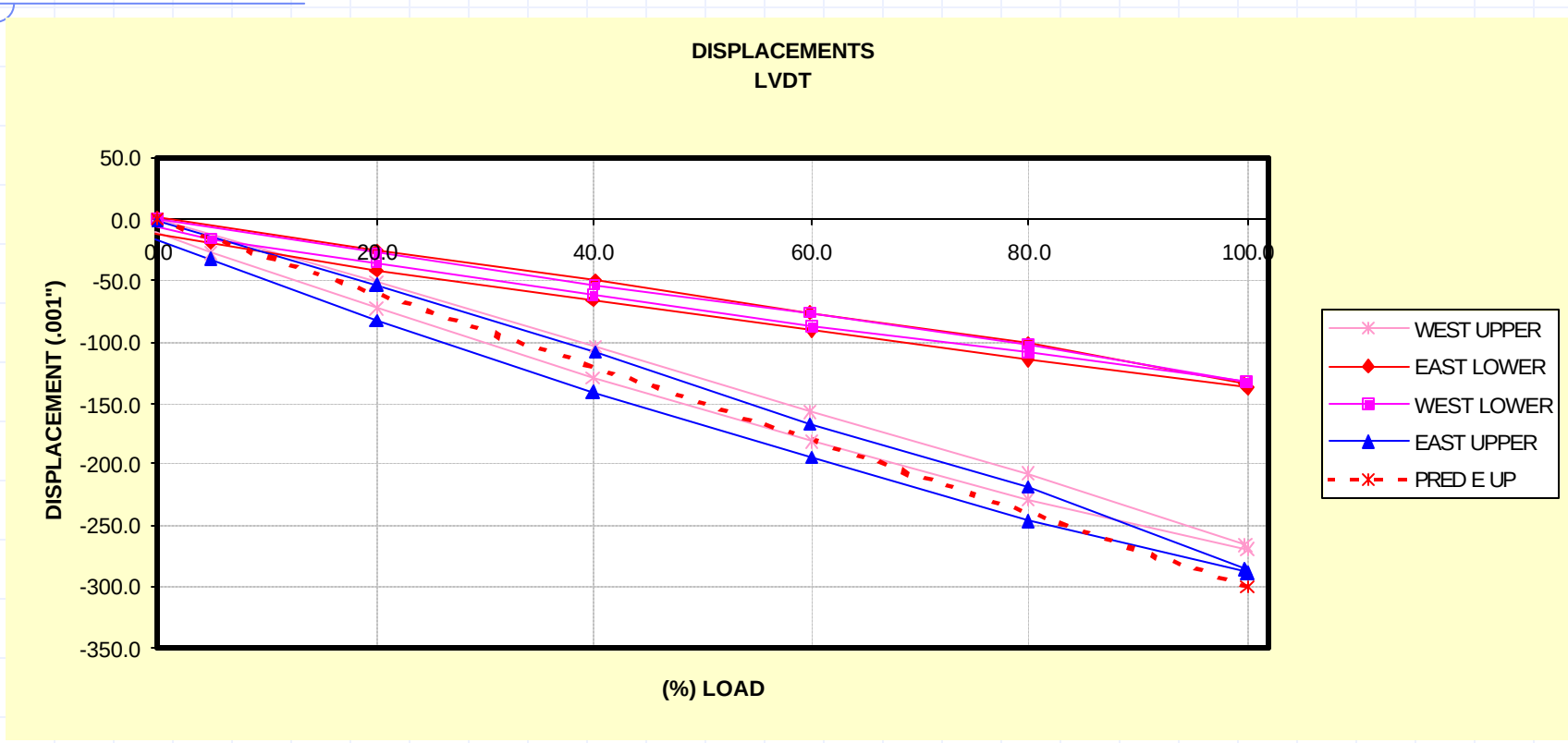
Load Case 3 Loads



Load Case 3 Strains



Load Case 3 Displacements



Summary

- An unserviceable torque assembly was re-furbished and life cycle tested to DLL, and subsequently to DUL.
- Strain and displacement measurements show that during the life cycle testing, the torque tube exhibited linear, elastic characteristics.
- Corrosion on a torque tube, if found, is a Maintenance issue. These tests show conclusively that a corroded torque tube is not an Airworthiness issue.

Conclusions

- SAIB CE-04-88 is now replaced by Piper Service Letter 1160
  - The Service Letter is not mandatory for Part 91 operations
  - The Service Letter requires torque tube inspection at 10 year intervals
- A corroded torque tube is shown to be Airworthy
- The Atlanta ACO has no intentions of issuing an AD on the torque tube based on SL 1160

Counterbalance Horn Basic Data

- Part Number – 20397-00
- Common to all Comanche Models – 24/30/39/400
- Aluminum alloy 2014-T6 forging
- Sliding fit to torque tube - .001” tolerance
- AN 175-33A Bolts through torque tube – Reamed fit
- AN 174-22A Bolts through counterbalance tube – Reamed fit
- Counterbalance tube is a press fit into horn - .0015” maximum interference

The Problem

- First reported by Denny Haskins in Mar 07 Flyer
- Internal cracking initiating at intersection edge of Primary and Secondary bores
- Average TIS when cracking is observed – 3500 hours
- Expected TIS when failure is expected – 5000 hours
- Observed to occur on Singles only (180/250/260)
- NOT ALL SINGLES HAVE SHOWN SIGNS OF HORN CRACKING

So Why are Some Horns Cracking?

- Believed to be due to Maintenance Neglect caused by:

- A. Excessive Trim Tab Movement:
  - Trim Drum vertical play
  - Rod End ball/socket play
  - Trim Tab bushings/bolt play

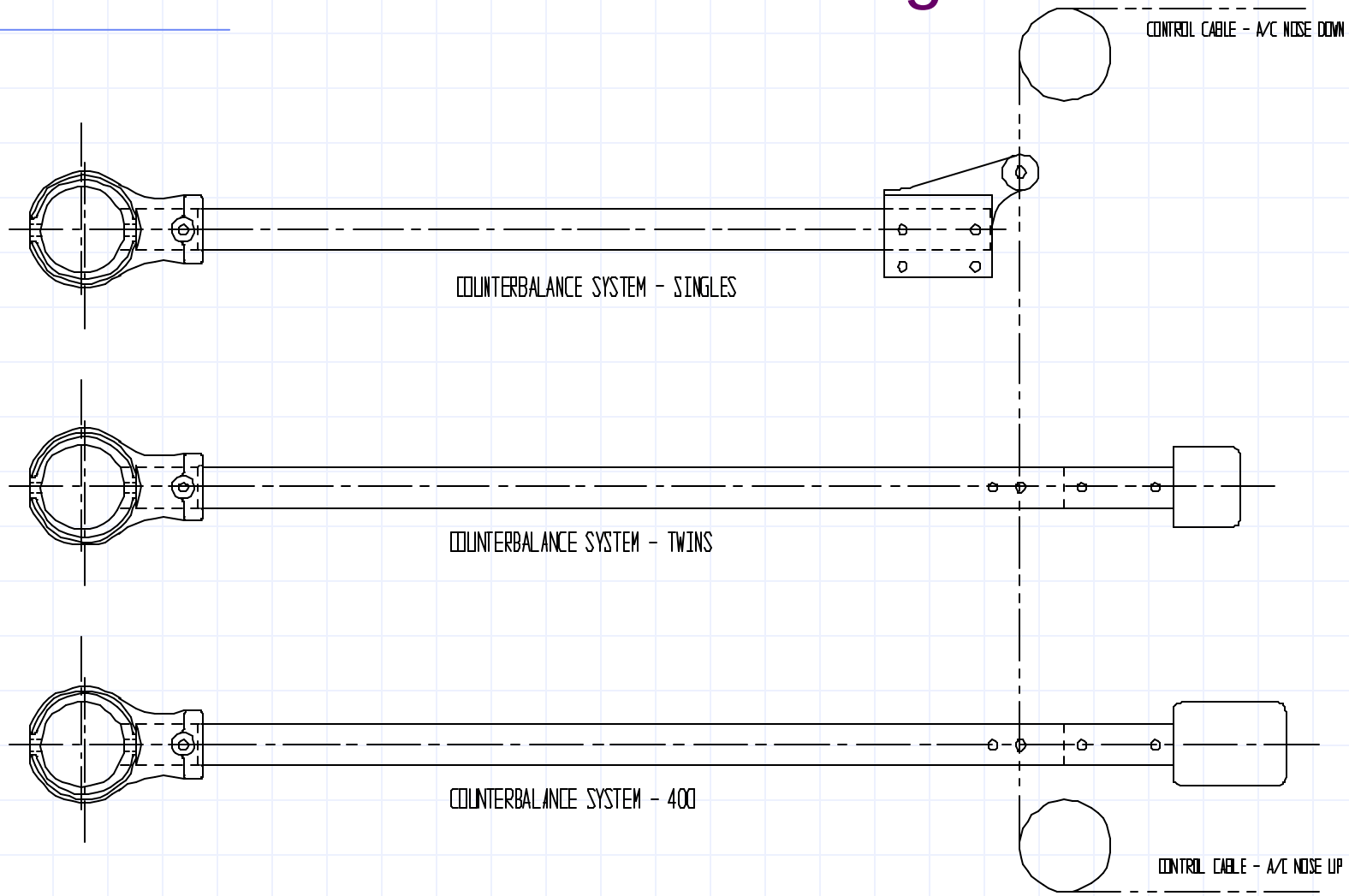
- B. Control Cable tension incorrectly adjusted

- Maximum Tab Movement = .076 inches (.050” recommended)
- Control Cable Pre-Tension = 22 pounds (24 # recommended)

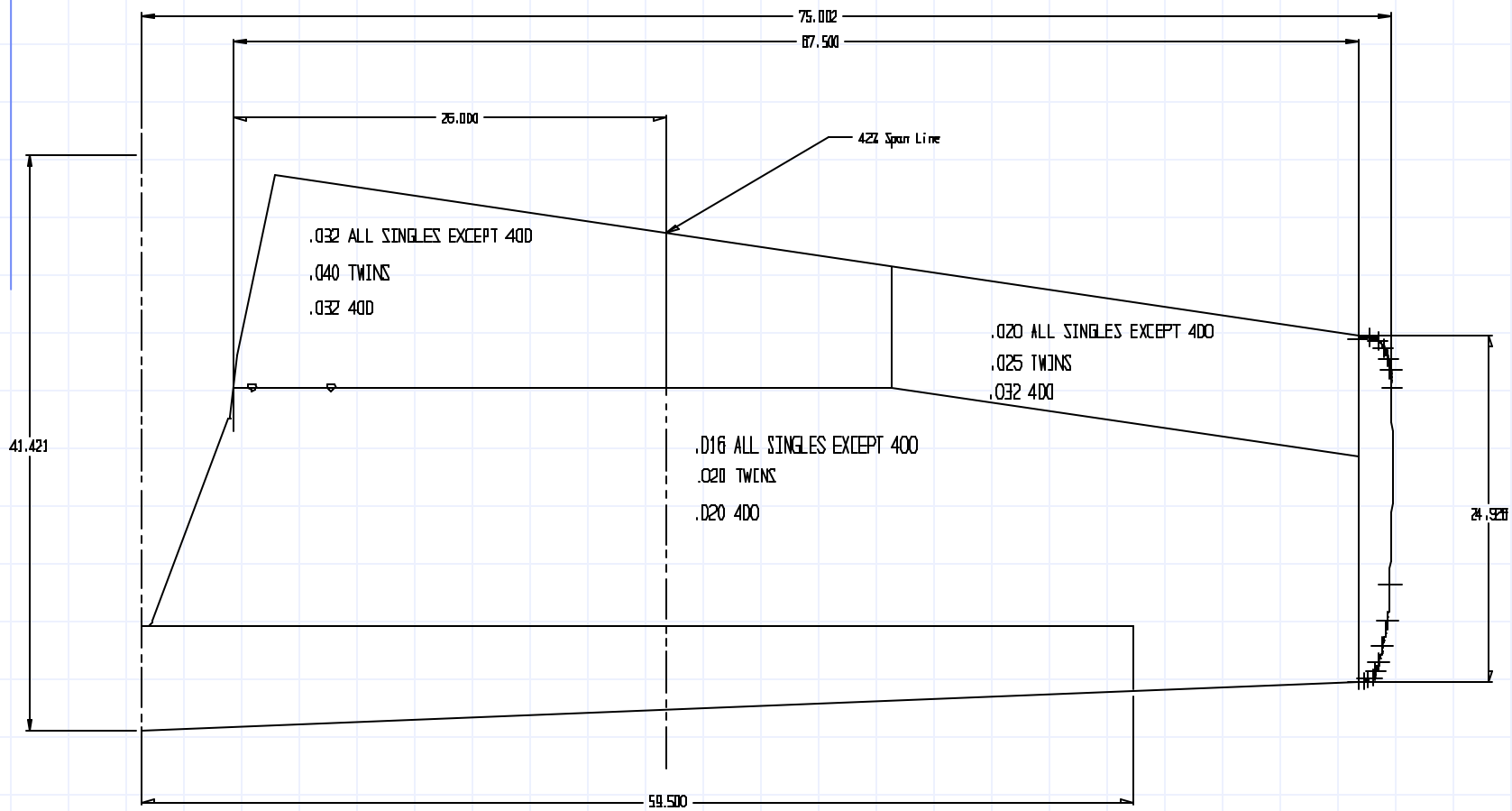
Why Only 180/250/260 Singles?

- Significant differences in design to Twins/400
- Significant differences in balance to Twins/400
- Prop wash inboard
- Thinner torque tube wall thickness
- Smaller Stabilator attachment bolt size
- Thinner Stabilator skin thickness
- Different trim drum support structure

Counterbalance Arm and Weight



Stabilator Skin Thickness Variations



Torque Tube Dimensions

- All Singles except 400
  - 2.3115 OD x .105 wall thickness
- 400's
  - 2.3115 OD x .161 wall thickness
- Twins
  - 2.3115 OD x .161 wall thickness

- GJ = 5.839E6 (singles) vs. 8.316E6 (Twins/400)
- Torsional Stiffness is 30% less on singles than Twins

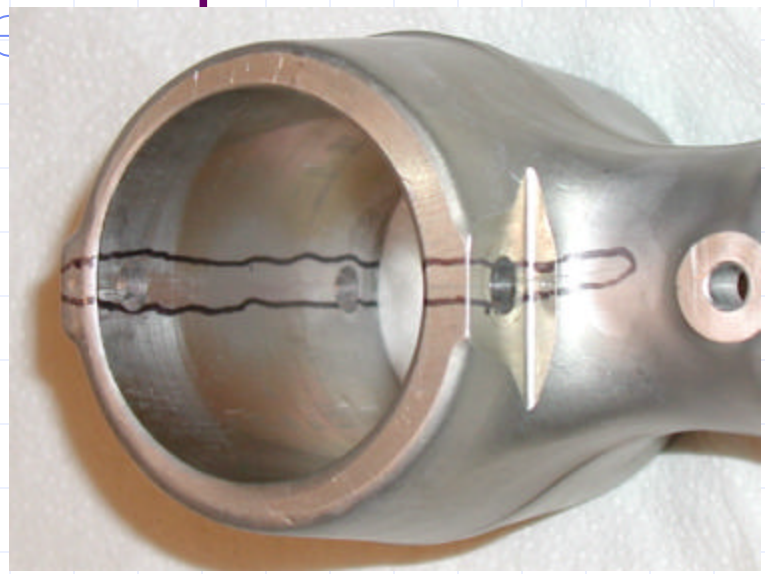
Fatigue Crack Growth

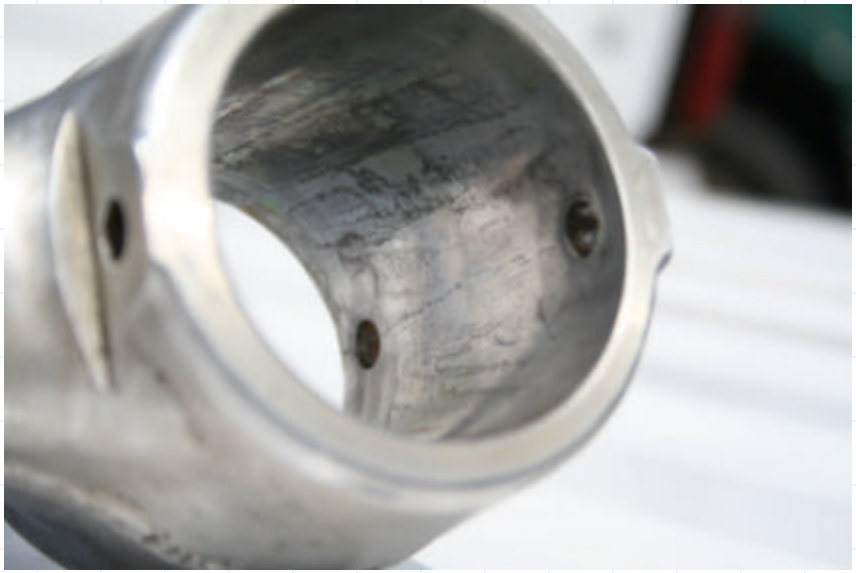
- Initial flaw required, typically .001 inches
- Stress level (including concentration effects) must be sufficient to cause crack to grow
- If stress level is below crack growth threshold, crack will not grow
- Creating radius at bore intersections reduces concentration effects
- Verify at 10 year intervals in conjunction with SL 1160 inspection period

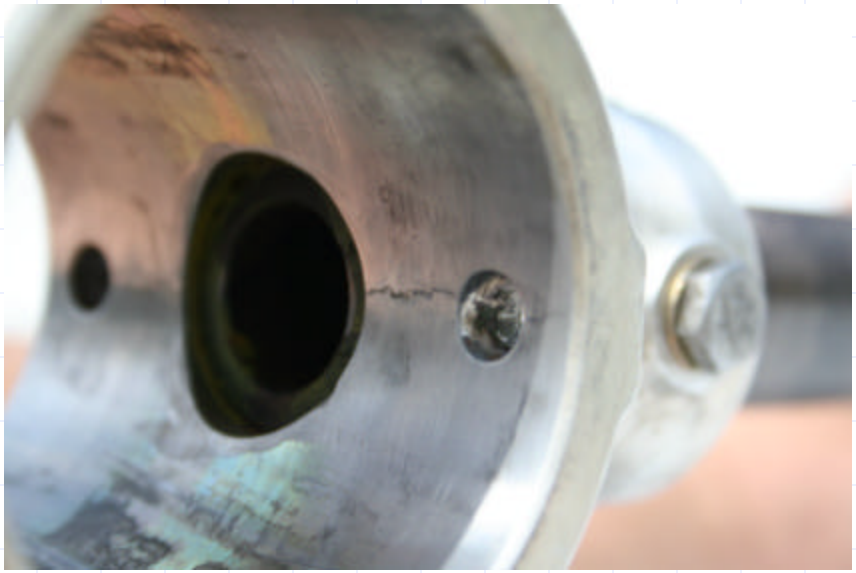
Hypothesis of Fatigue Failure in Horn

- Sharp edge between primary & secondary bores gives a 5.6 stress concentration factor
- Play in trim tab causes stabilator to respond to high frequency impulses from propeller
- Looseness of control cables allows counterbalance tube and weight to oscillate
- High frequency oscillations create bending stress in horn, amplified 5.6 x at the bore intersections
- Cracking migrates to aft side of horn after forward portion cracks and looses circumferential stiffness

Samples of Cracked Horns







Investigation to Isolate Cause

- Determine frequency of counterbalance weight at various rpm's with snug & loose trim tab
- Determine if propeller impulse frequency corresponds to weight frequency
- Determine stresses in horn due to:
  - Frequency response
  - Bolt torque
  - Shrink fit of counterbalance tube

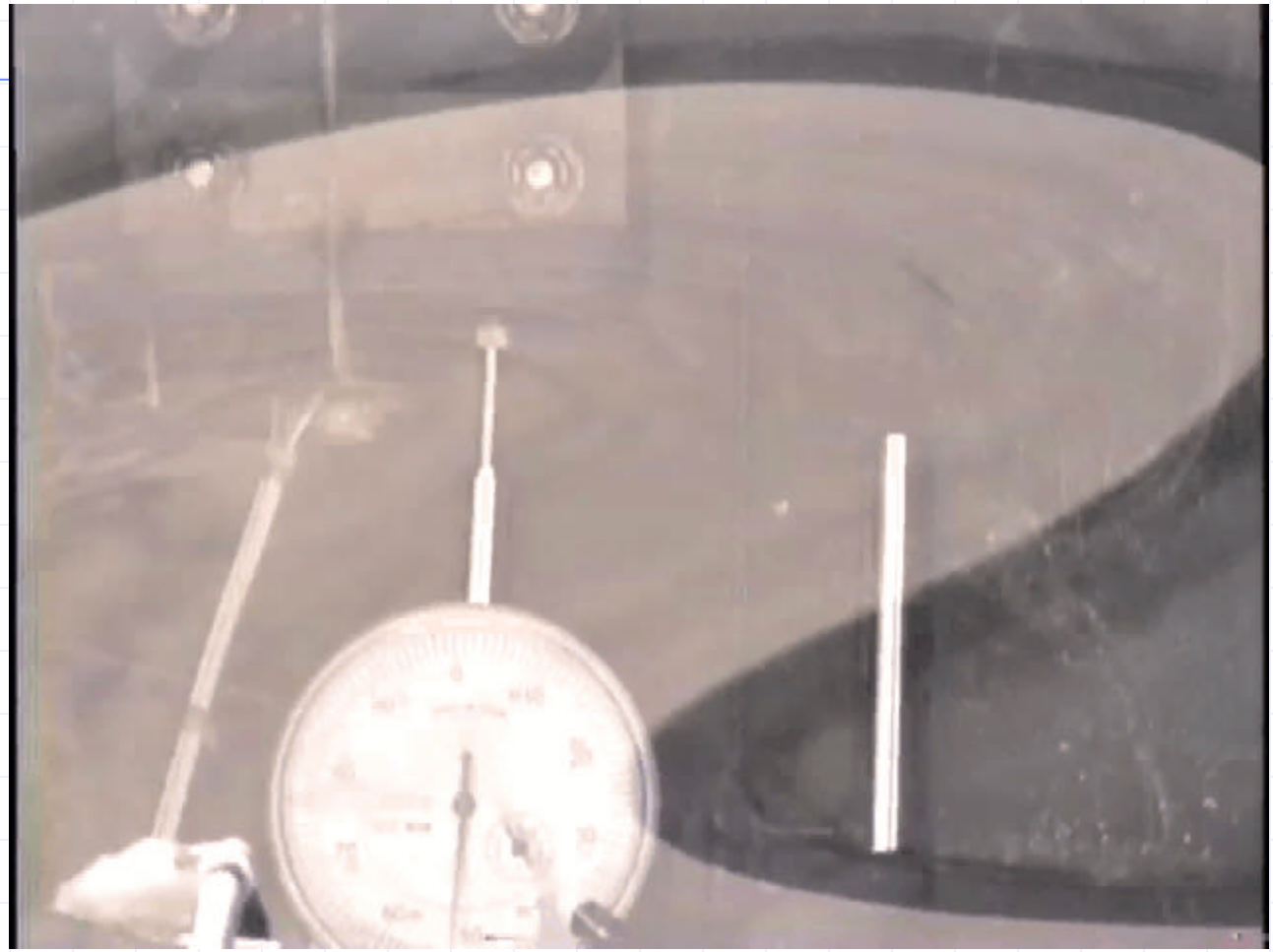
Vibration Test Set-up

- Accelerometer fabricated using electret microphone
- Prop pulses measured with pitot tube/pressure transducer
- Data taken with oscilloscope, captured to video camera
- Stabilator position restrained using split foam cover
- Movement of counterbalance weight measured using Moire Fringe method and dial indicator, captured to 2nd video camera
- Measurements at 2100/2200/2300/2400/2500 rpm
- Excessive trim tab play simulated with undersized tab bushing

Vibration Data to Date

- Counterbalance weight oscillation using dial indicator
  - Plus/minus .010 inches – all rpm's
  - Data from 7/7/07
- Response from accelerometer/pitot tube setup
  - No data collected
  - Check-out electronics and retry
- When operational, perform flight data collection
  - Dial indicator data from mini-cam

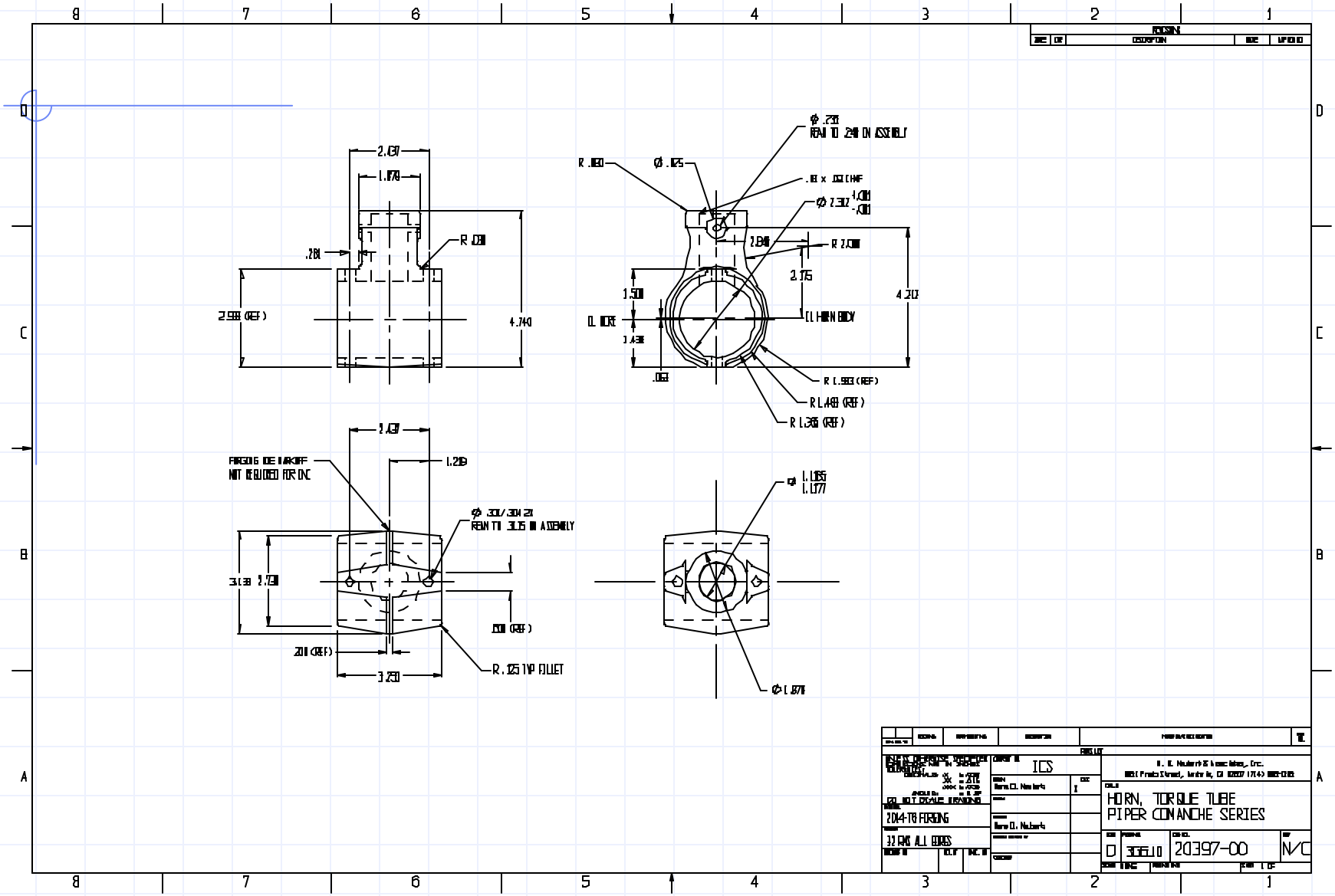
Preliminary Vibration Data



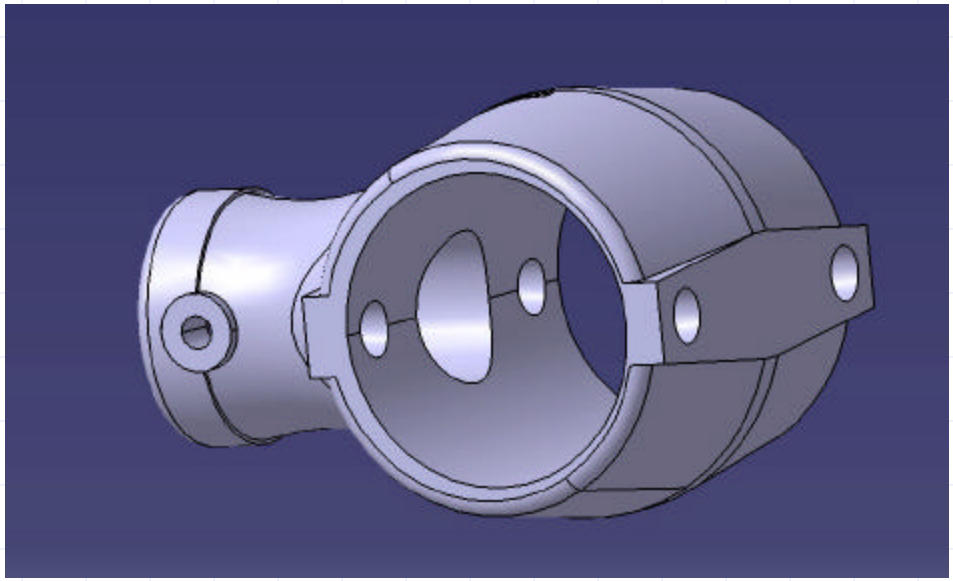
Finite Element Analysis

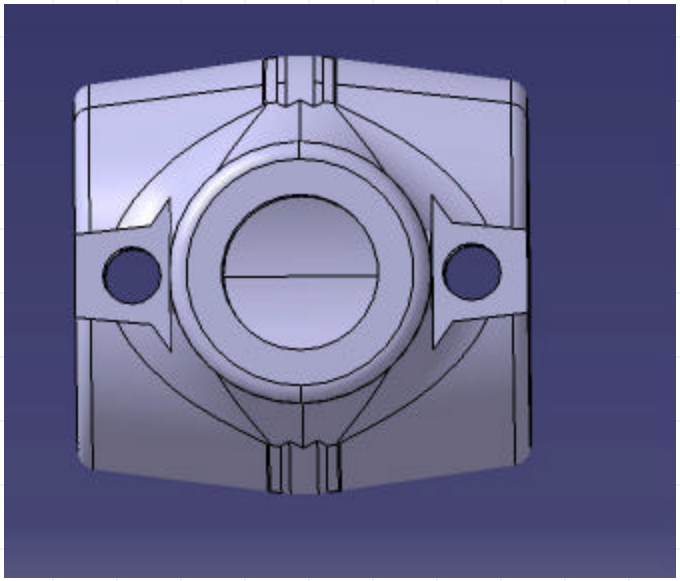
- 3D CAD model supplied by Garrett Sager, ICS member, on 7/11/07, from furnished reversed engineering drawing
- Import Iges file into:
  - Strand 7 FEA software
  - Nastran FEA software
- Perform static and dynamic analysis
  - Bolt torque on horn
  - Interference fit to balance tube
  - Frequency response due to vibration data
  - Modes and mode shapes

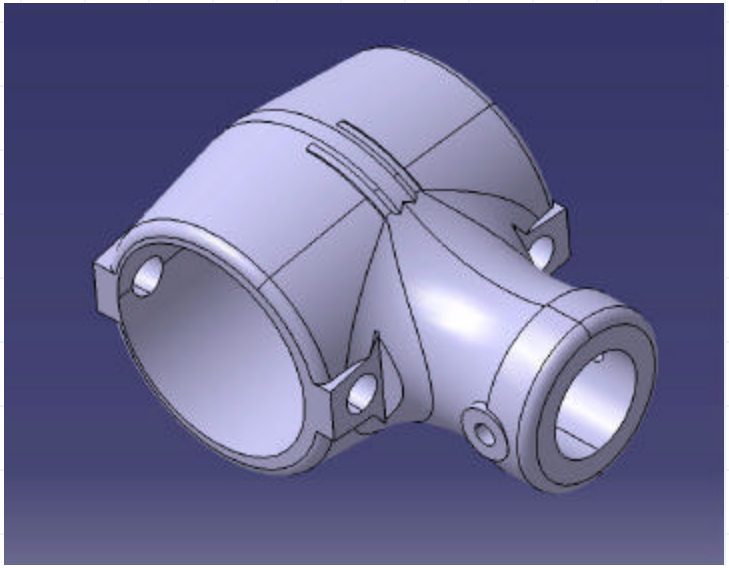
Horn Drawing

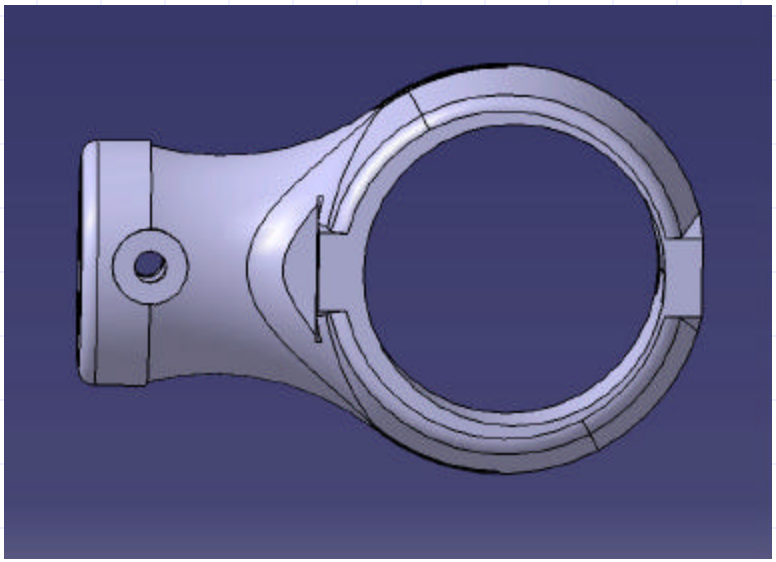


Horn 3D Rendering from CAD file









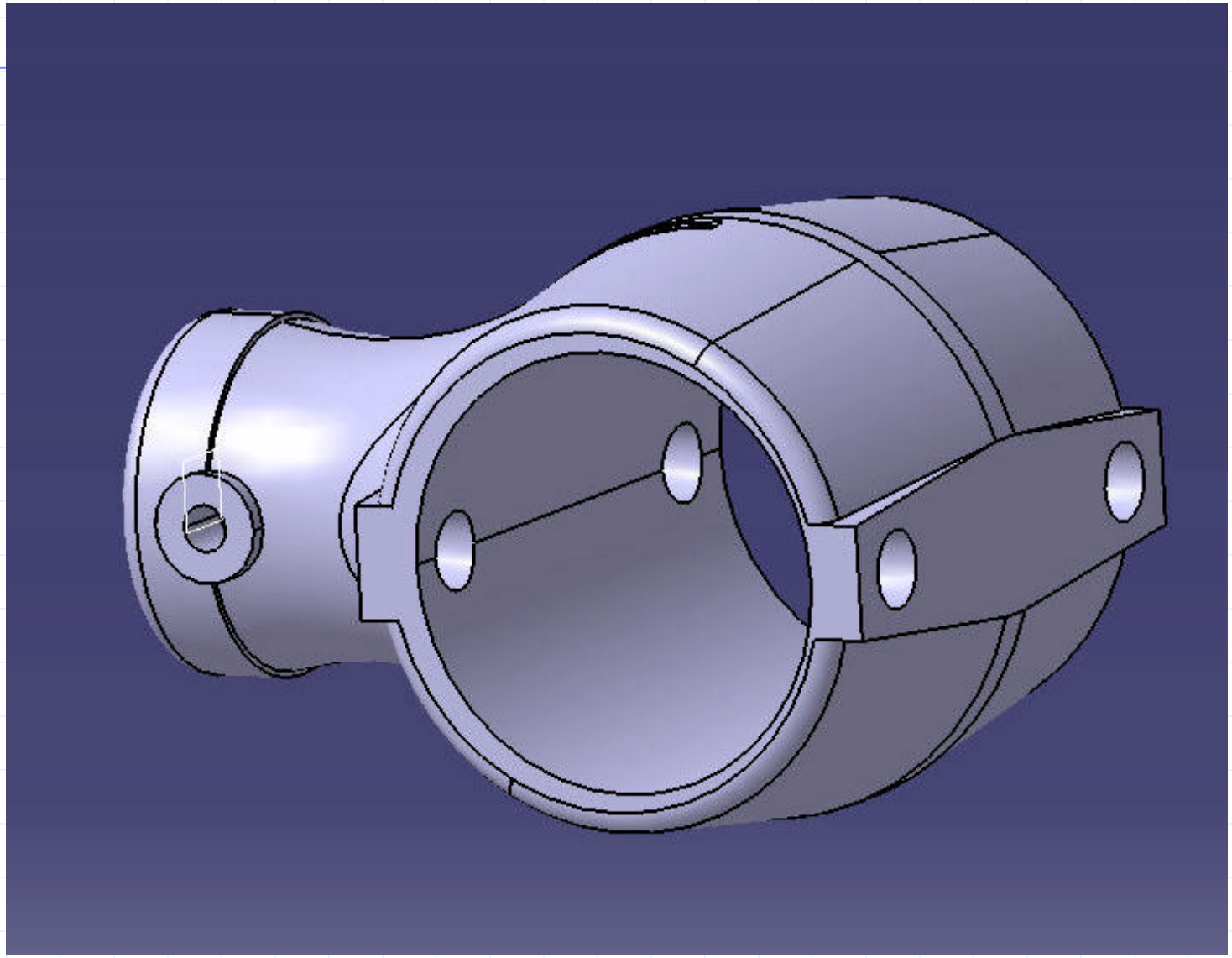
Type Club Support

- Harley McGatha reports Piper willingness to fabricate new production parts (new tooling needed)
  - Price and delivery unknown
  - Pricing data collected – announcement soon

- Fabricate New Production units via PMA by Identicality

  Horn has been reverse-engineered. Critical dimensions are from Piper drawing

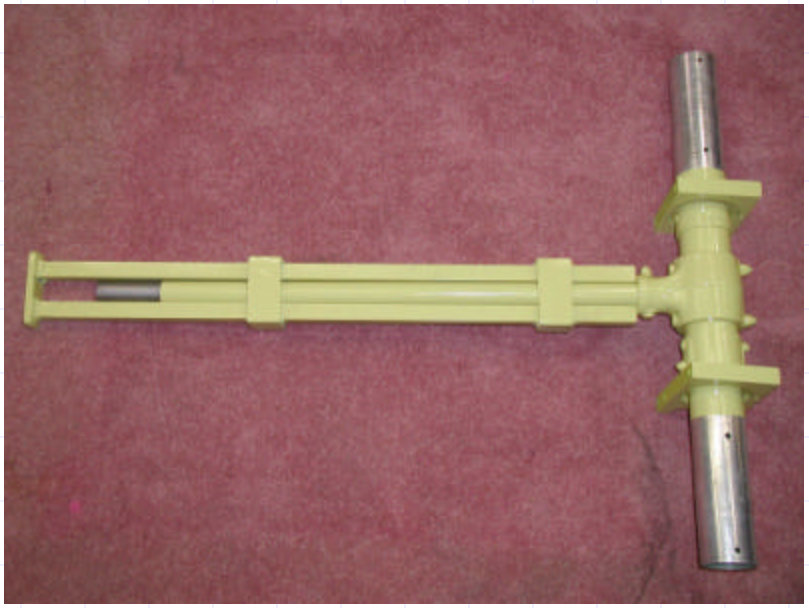
New PMA Horn based on Piper Horn



Removal & Replacement of Counterbalance Tube

- Removal requires a push extraction fixture
- Insertion requires an alignment fixture
  - Heat Horn by convective oven
  - Chill Counterbalance tube in freezer
  - Tapered AN4 bolt to align counterbalance tube hole to horn hole

Disassembly of Counterbalance Tube Arbor Press Required



Denny Haskin's Fixture

Neubert Fixture

Insertion of Counterbalance Tube

- **Alignment Fixture Required**
- **Alignment, Tapered, Long AN4 bolt Required**
- **Heat Horn to 200F in Air Circulating Oven**
  - **Caution: Do not use flame or torch**
- **Chill Torque Tube to 0F in Freezer**
- **Install Rotation Limiter first**
- **Slide tube into horn, align transverse bolt holes with AN4 bolt**
- **Allow to cool to RT, Remove AN4 bolt**

- **YOU WILL HAVE 5 SECONDS TO GET IT RIGHT**

Recommendations

- **SINGLES WITH LESS THAN 3500 HOURS**
  - **Disassemble torque tube assembly at next annual**
  - **Do not remove counterbalance tube**
  - **Inspect horn for cracks, if none found, then**
  - **Create .03” radius at bore intersections**
  - **Polish radius and bore with 600 grit paper**
  - **Repack bearings**
  - **Re-assemble and make log book entry of inspection**
- **Repeat at next SL 1160 Compliance inspection period**

Recommendations

- **SINGLES WITH MORE THAN 3500 HOURS**
  - **Disassemble torque tube assembly within 50 hours**
  - **Do not remove counterbalance tube unless horn is cracked**
  - **Inspect horn for cracks at bore intersections**
  - **If Cracks found, locate serviceable horn/Piper part/PMA part, then**
  - **Create .03” radius at bore intersections**
  - **Polish radius and bore with 600 grit paper**
  - **Repack bearings**
  - **Re-assemble and make log book entry of inspection & replacement**
- **Repeat at next SL 1160 Compliance inspection period**

Summary of Information to Date

- Horn cracking found on SOME singles
  - Related to Time-In-Service >3500 hours
  - Related to looseness in trim drum/tab system
- If Cracked, expected failure at 5000 hours
- Ground run data shows vibration of counterbalance tube at all cruise rpm's
- There are no Piper SL, pending AD's or SAIB.
- THIS IS A TYPE CLUB INVESTIGATION
- FAILURE OF HORN IN FLIGHT WILL BE FATAL.