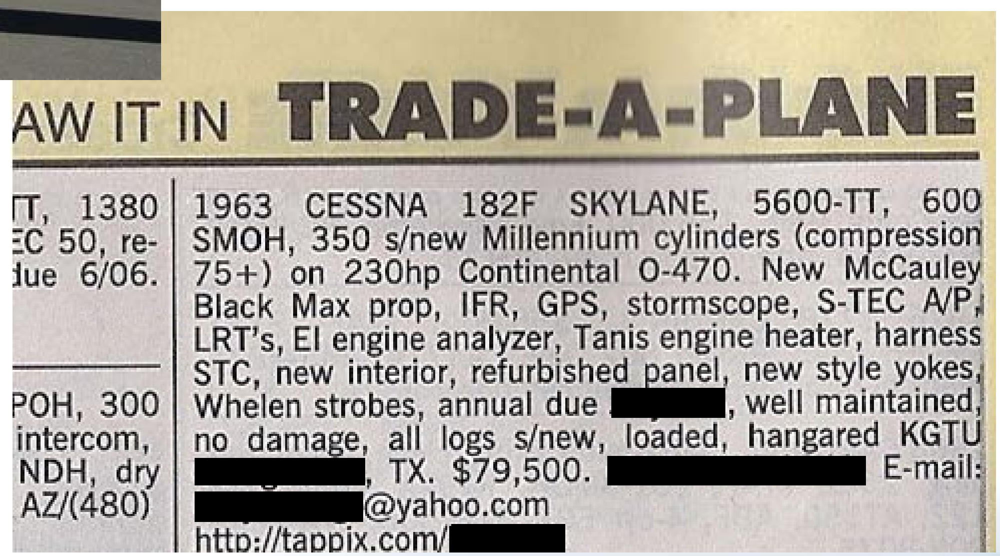
Cessna Single Engine Safety Initiative

Cessna Single Engine Airplanes

- 145,000 produced between 1946-1986
- Average age is 42 years old
- Certified CAR 3
- Made of aluminum
- Flown 100-150 hours annually

Cessna Single Engine Airplanes



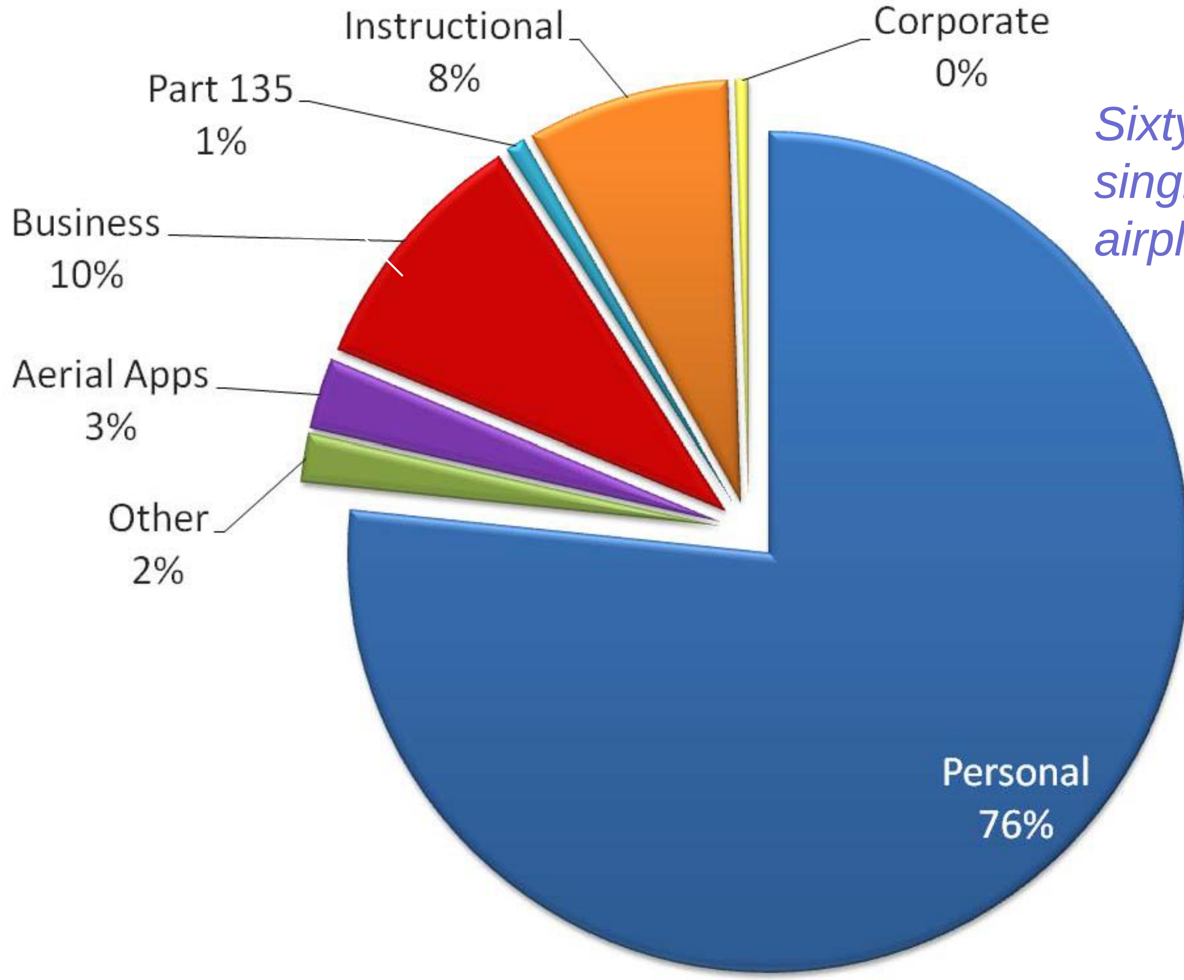
AW IT IN **TRADE-A-PLANE**

TT, 1380
EC 50, re-
due 6/06.

POH, 300
intercom,
NDH, dry
AZ/(480)

1963 CESSNA 182F SKYLANE, 5600-TT, 600 SMOH, 350 s/new Millennium cylinders (compression 75+) on 230hp Continental O-470. New McCauley Black Max prop, IFR, GPS, stormscope, S-TEC A/P, LRT's, EI engine analyzer, Tanis engine heater, harness STC, new interior, refurbished panel, new style yokes, Whelen strobes, annual due [redacted], well maintained, no damage, all logs s/new, loaded, hangared KGTU [redacted], TX. $79,500. [redacted] E-mail: [redacted]@yahoo.com http://tappix.com/[redacted]

General Aviation



Sixty percent of active single engines are Cessna airplanes

2009 Single Engine Usage - Active US Aircraft
Total of 141,000 Airplanes Representing All Manufacturers

Source: FAA General Aviation and Part 135 Activity Surveys - CY 2009

Single Engine Safety Initiative

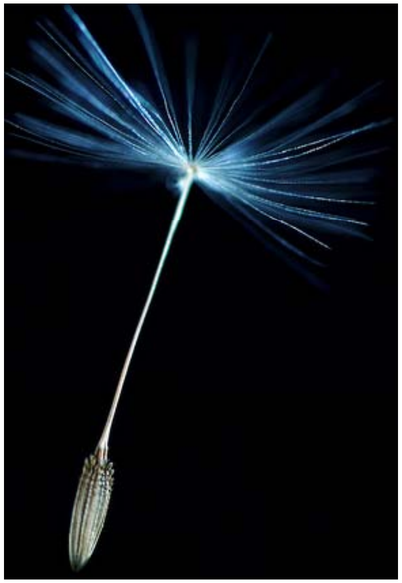
- Cessna has developed a structural inspection program to assure the continued safe operation of single engine airplanes
- Visual inspection techniques are utilized to detect
  - Corrosion
  - Cracks caused by metal fatigue

Single Engine Safety Initiative

- Why Inspect?
  - Corrosion (rust) and metal fatigue are inevitable

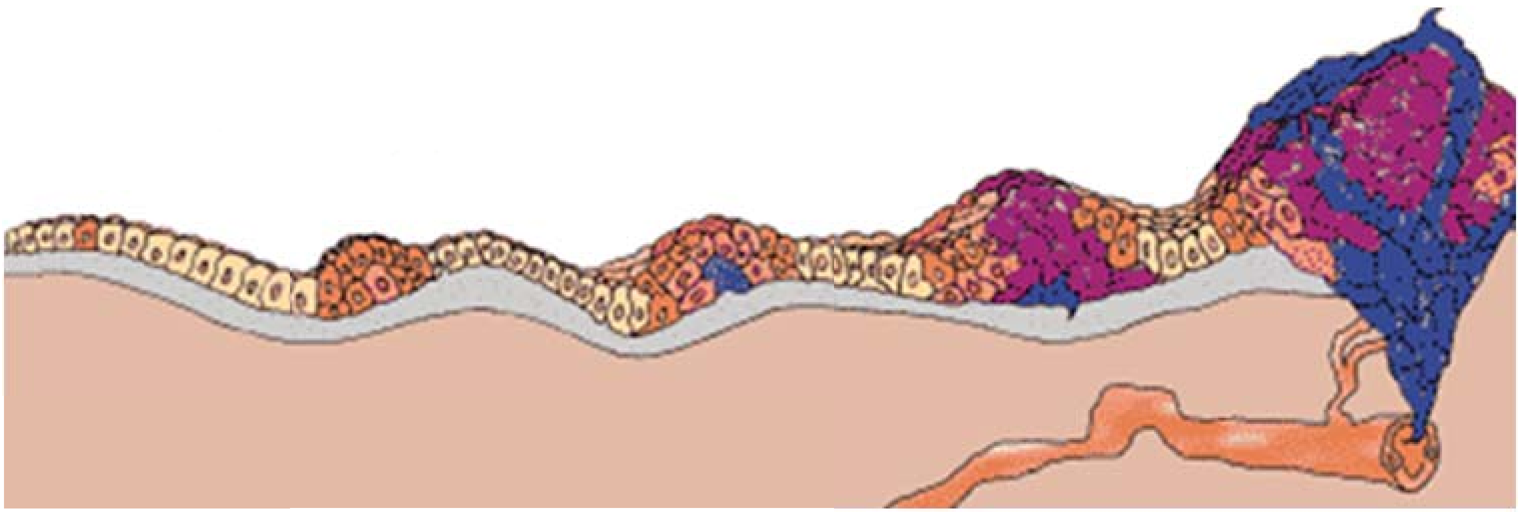
  - Corrosion and metal fatigue reduce the load carrying capability of the airframe
  - Like people, airplanes age, and more frequent and intrusive inspections are required to maintain health (safety)

Visual Inspections




Undetectable → | Detectable → | → Hazardous

Visual Inspections



Undetectable → | —— Detectable → | —————————————→ Hazardous

Visual Inspections

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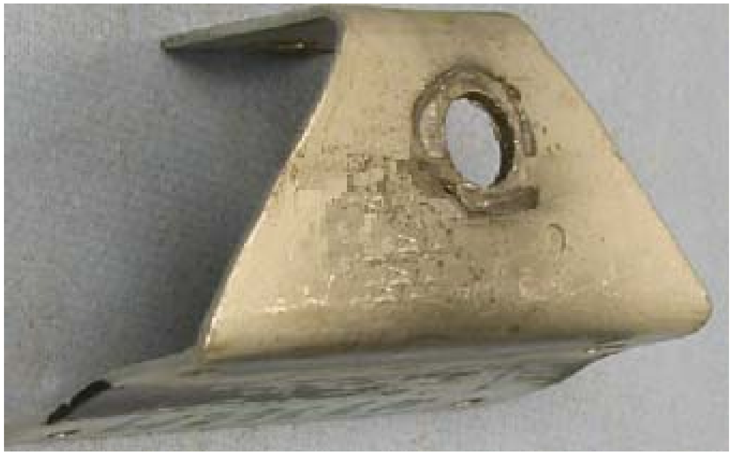
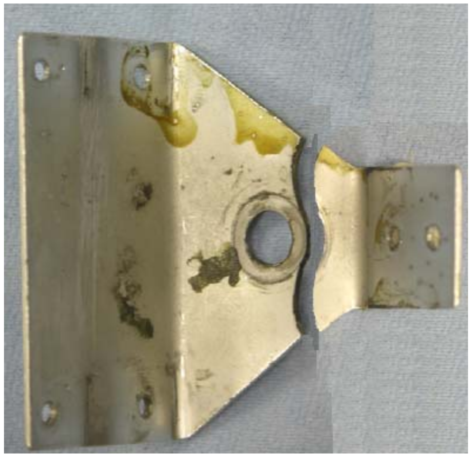
Visual Inspections





Undetectable → Detectable → Hazardous

Single Engine Safety Initiative

- Visual Inspections Work
  - Fifty percent of 300/400 series wing/fuselage attach fittings needed to be replaced

What is Corrosion?

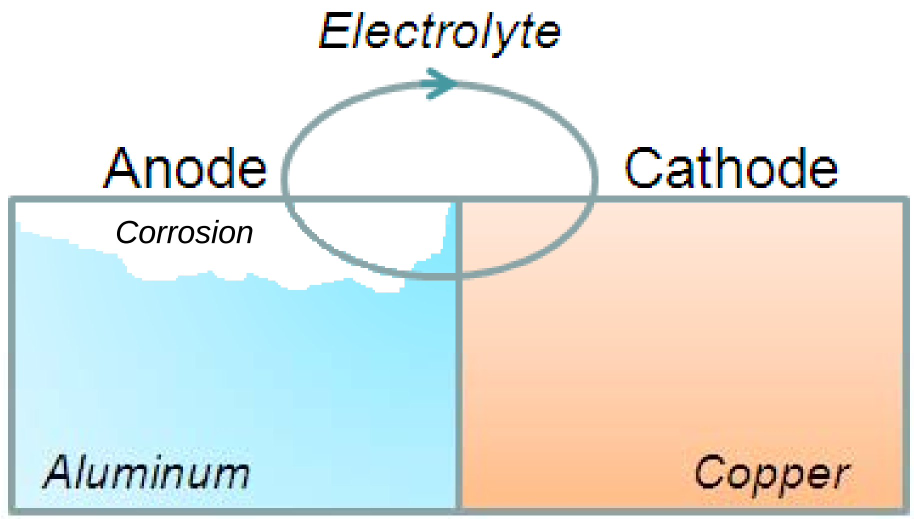
- Corrosion is the attack on metal by an electrochemical reaction to the surrounding environment
- Electrochemical corrosion can best be compared to a battery cell
  - In order for corrosion to occur, the following must be present:
    - →A metal that gives up electrons (anode)
    - →A metal that will accept electrons (cathode)
    - →An electrical connection between the two metals (metal-to-metal contact)
    - →A conductive liquid – typically water with some chemical impurity (salt, acid, chemical, etc.)

What is Corrosion?

- Pure aluminum is
  - Highly resistant to corrosion
  - Too soft to be used as a structural material
- Thus airframes are made of various high-strength aluminum alloys
  - The most common aluminum alloy used in airframes is “2024”
  - "2024“ is composed of 95% aluminum, 4% copper, and small amounts of manganese and molybdenum

What is Corrosion?

- 2024-T3 (aluminum sheet) has:
  - Excellent strength and toughness properties
  - Three of the four requirements for corrosion to occur
  - The only thing missing is the conductive liquid (electrolyte)



Corrosion Prevention

- Thus, the key to corrosion prevention is to keep the airframe free of moisture
- A major contributing factor to corrosion is the environment
  - Aircraft that operate in coastal environments are more susceptible to metal corrosion
    - →While water vapor already has a corrosive effect, the water vapor and salt combination found in coastal environments creates a powerful corrosive agent
  - Aircraft that operate in areas that contain high amounts of industrial particles and fumes in the atmosphere also are more susceptible to corrosion

Corrosion Prevention

- There are several common options available to shield the aluminum from electrolytes including:
  - Cladding
  - Chemical Treatments
  - Sealants
  - Corrosion Prevention Compounds (CPCs)

Corrosion Prevention

- Cladding
  - 2024 sheet can be coated ("clad") with very thin layers (.001”) of pure aluminum to protect from corrosion
    - →The resulting material is known as "2024-T3 Alclad"
  - The sheet material is vulnerable when the cladding is compromised
    - →At edges, drilled rivet holes, or if it is scratched
    - →Most airframe corrosion occurs at seams and joints, which is why cladding alone is not sufficient
    - →Additional steps are necessary to protect seams, holes, and un-clad parts from exposure to electrolytes

Corrosion Prevention

- Chemical Treatments
  - Alodine or other chemical treatments are used to enhance the corrosion resistance of the pure aluminum cladding
- Sealants
  - Paint is the most commonly used sealant for corrosion protection
    - →Modern polyurethane aircraft paints create a thick, impenetrable barrier that effectively keeps moisture away from the metal, and lasts a long time -- 10 years or more
    - →A good paint job is the best defense against airframe corrosion

Corrosion Prevention

- Sealants
  - Paint only protects the exterior of the airframe
  - It is difficult to paint the inside of an airframe once it is all riveted together
  - The airframe interior of most pre-1986 airframes were not painted (primed)
- Corrosion Preventive Compounds (CPCs)
  - Effective means for protecting those parts of an airframe that were not originally protected from corrosion

Corrosion Prevention

- Corrosion Preventive Compounds (CPCs)
  - Guidelines for application and use of CPCs will be provided in the revised Service Manual
    - →CPCs must be reapplied periodically
  - The following CPCs are approved for use on Cessna airplanes

Dry film compounds:	AV-8, AV-15, AV-30, Cor-Ban 22, Cor-Ban 23 and Cor-Ban-35
Non-dry grease:	Cor-Ban 27L
Non-dry oil:	Corrosion X

Corrosion Prevention

- Continual inspections and preventative maintenance are required to keep the airframe metal from corroding
  - Thorough rinsing and cleaning of airplane will remove salt and other corrosive agents
    - →Exposed areas such as the landing gear and wheel wells need extra attention, as well as any other joints, gaps, and hinges where debris collects
  - Chipped or delaminating paint needs to be properly striped or sanded and re-painted
  - During severe weather or wet conditions, airplanes should be covered and sheltered

Results of Corrosion

- Corrosion is responsible for approximately
  - 7% of the airworthiness directives
  - 20% of service difficulty reports (SDRs) [1]
- Corrosion can be deadly
  - Corrosion contributed to 91 accidents/incidents in the United States between 1983 and 1994 [2]
  - These and other accidents have resulted in hundreds of fatalities [3]
- As airplanes continue to age, these numbers are likely to increase

1 Swift, S., "Rusty Diamond", 24th ICAF Symposium, May 2007.

2 Hoeppner D,, Chandrasekaran V., Taylor A., "Review of Pitting Corrosion Fatigue Models", 20th ICAF Symposium, 1999.

3 Aviation Safety Network Database, http://aviation-safety.net/index.php

Corrosion and Metal Fatigue

- Corrosion and metal fatigue both reduce the load carrying capability of the airframe
- Corrosion and fatigue are not entirely independent processes - corrosion affects the expected fatigue life of airframe parts
  - Corrosion pitting creates a stress concentration which leads to crack initiation and potentially faster crack growth
  - Corrosion reduces the thickness of a part and therefore increases the stress in the part

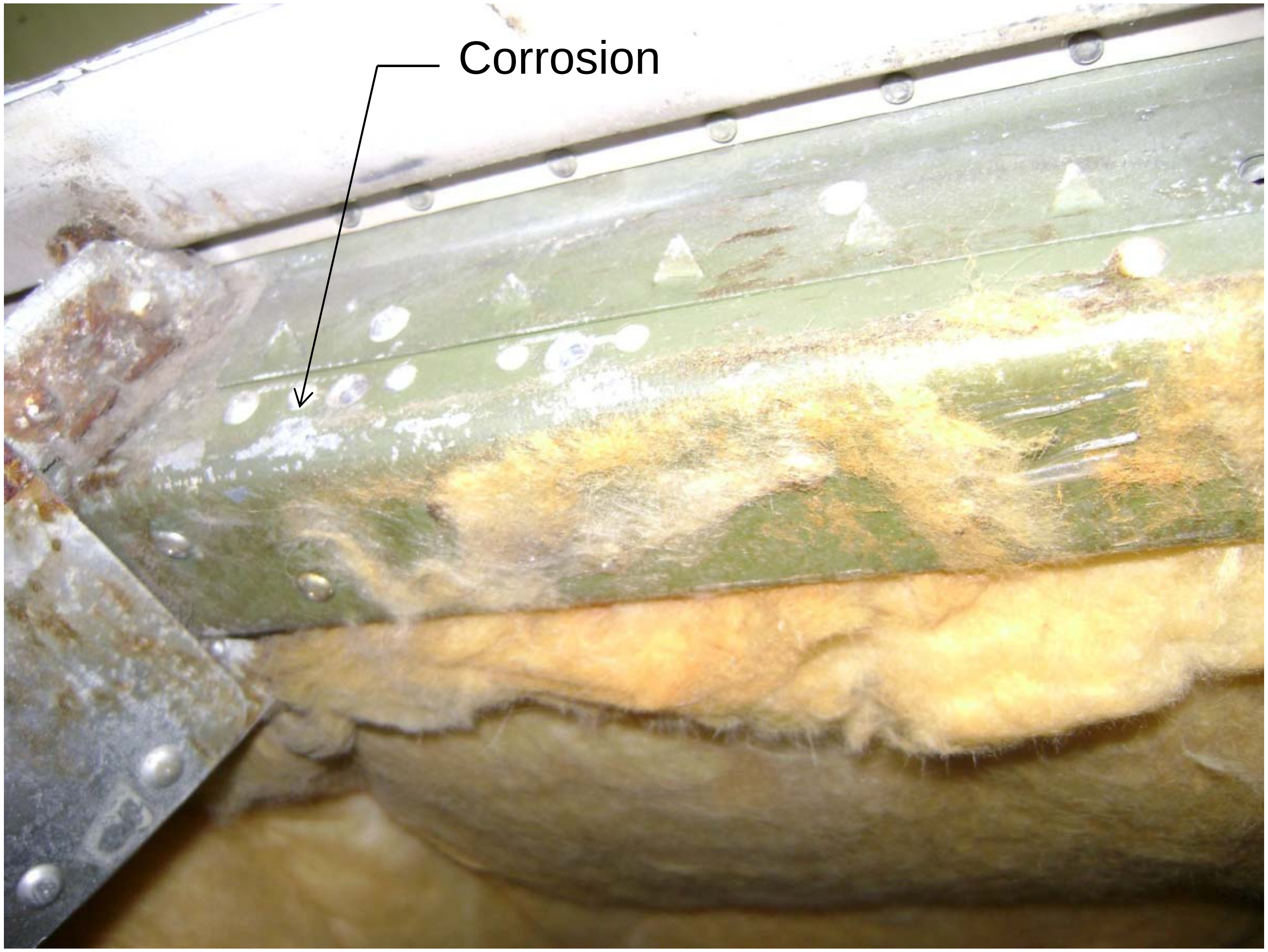
Corrosion Examples

- Cabin Interior – All Models
- Models 177/210 Cantilever Carry-Thru
- Models 177/210 Cantilever Wing Attachments
- Model 200 Series Elevators
- Main Landing Gear – All Models
- Strut Braced Wings
- Airframe Ribs – All Models

Cabin Interior – All Models

- Cabin is susceptible to corrosion given that it:
  - May leak when it rains
  - May be stored in un-insulated hangar or on the flight line
  - Stays warm as the airplane goes through thermal cycles during flight
    - →Condensation will form on the interior skin
    - →Moisture is absorbed by insulation and upholstery materials
  - Not often treated with corrosion prevention products
  - Headliner is not always removed during an annual

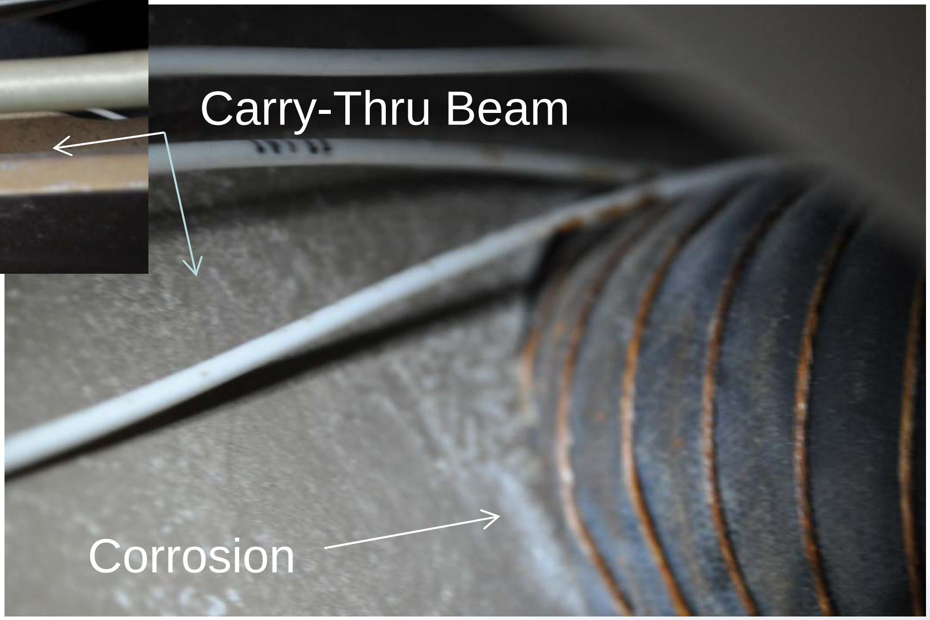
Cabin Interior – All Models



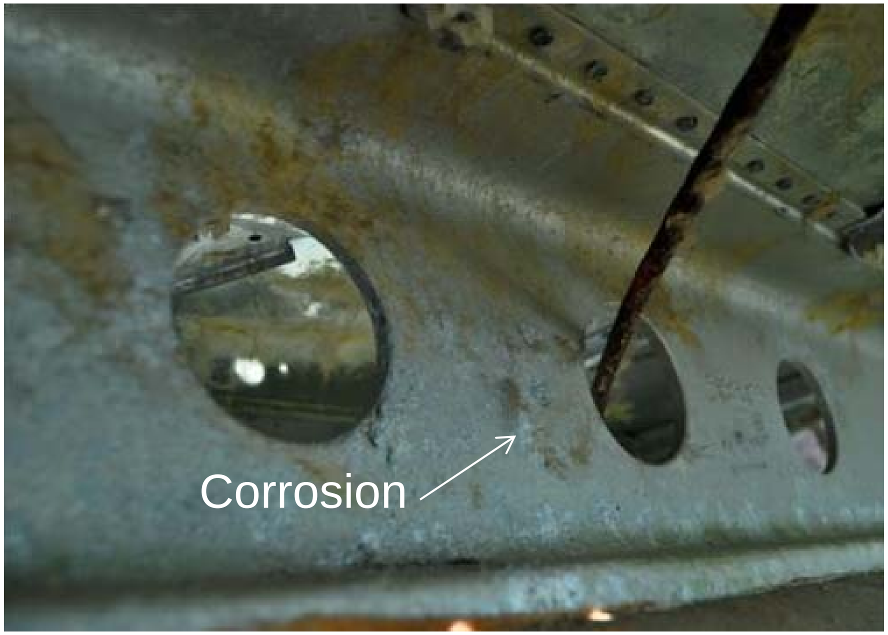
Models 177/210 Cantilever Carry-Thru

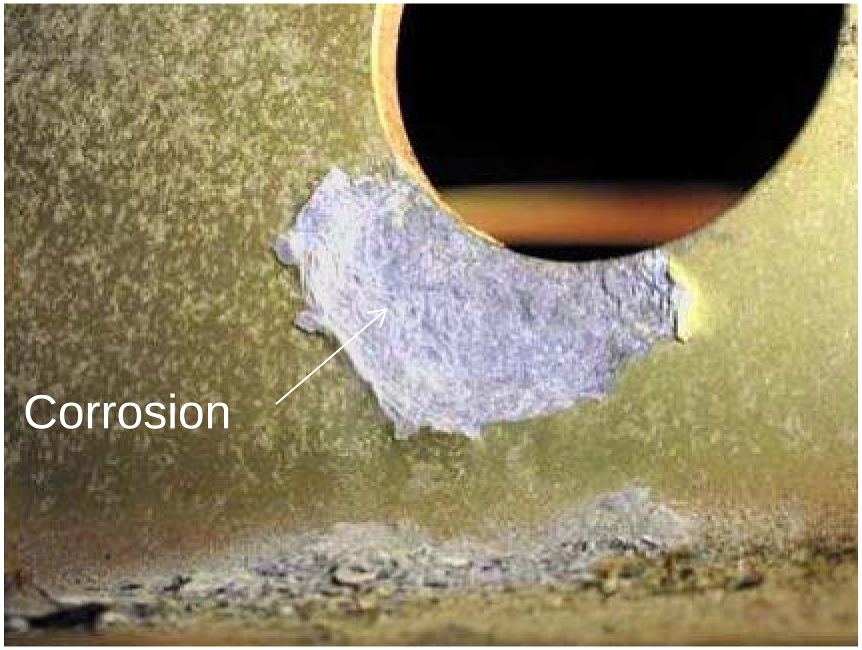
- Provides the primary means of carrying wing loads across the fuselage
- Made of 2014-T6 material
  - High strength material but is very susceptible to corrosion
- Corrosion occurs when
  - Ducting contacts lightening holes in beam, or
  - Moisture accumulates on I-beam surface
- Limited repairability

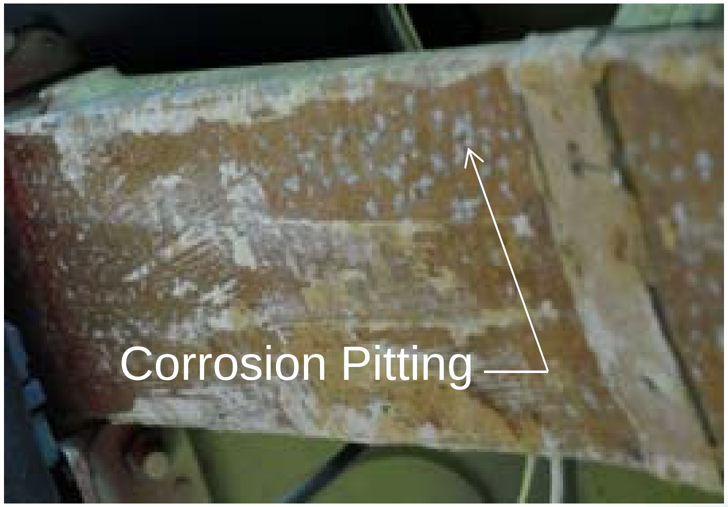
Models 177/210 Cantilever Carry-Thru



Models 177/210 Cantilever Carry-Thru



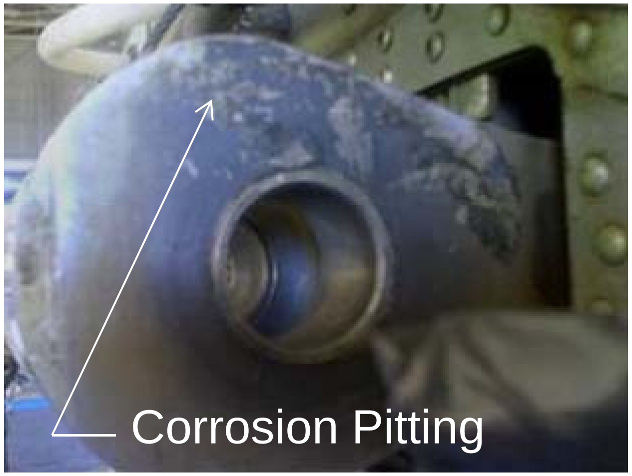




Models 177/210 Cantilever Wing Attach

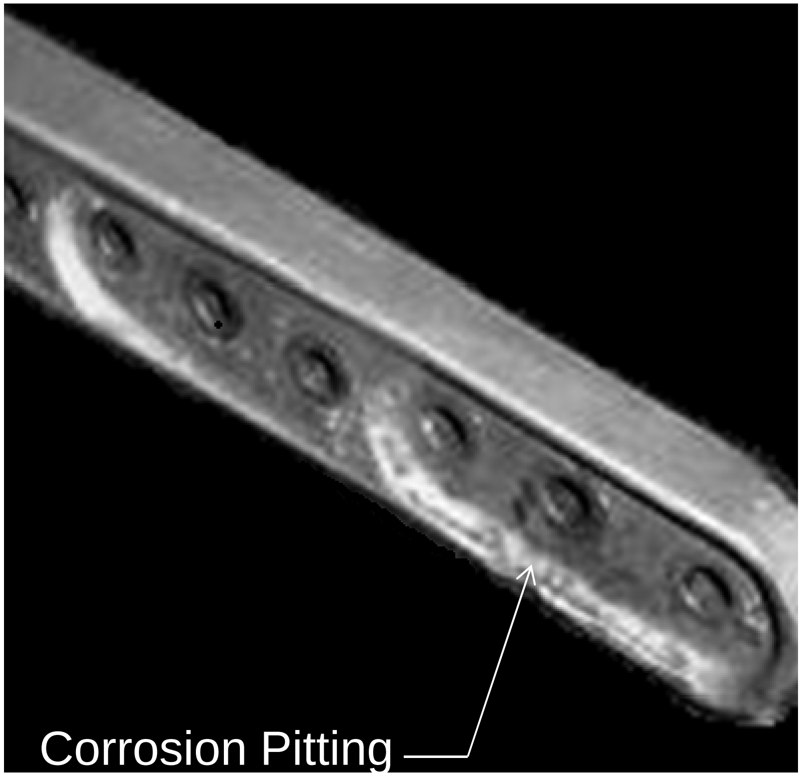
- Primary load carrying member
- Corrosion is common on the carry-thru lugs and the wing attach fittings
  - Tight fitting faces act as a moisture trap
- Made of 2014-T6 material
  - High strength material but very susceptible to corrosion

Models 177/210 Cantilever Wing Attach



Carry-Thru Spar Lug

Wing Attach Fitting

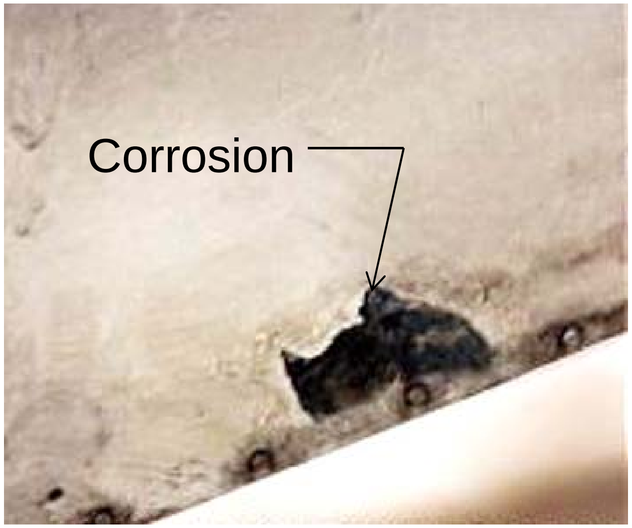


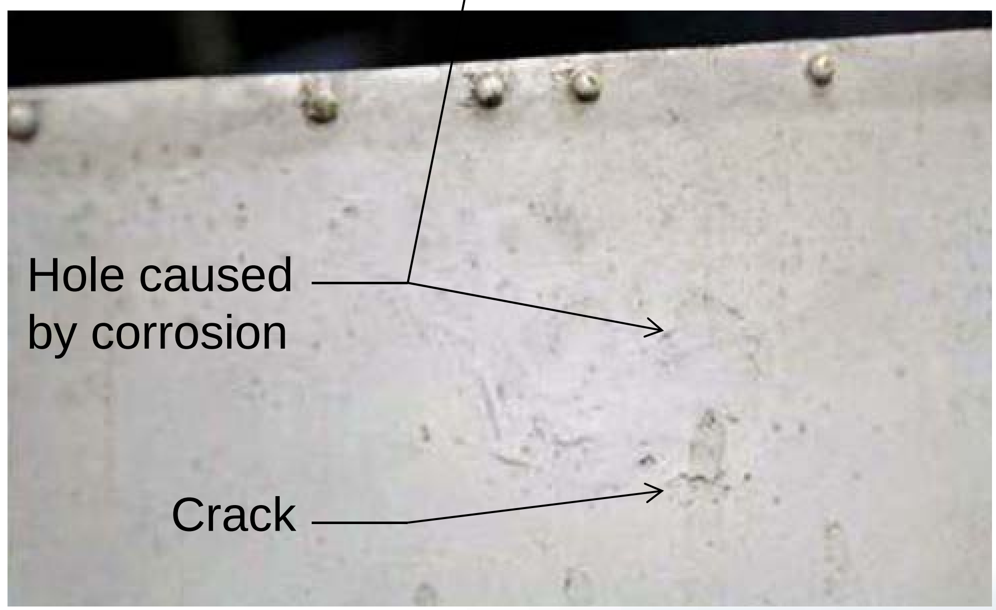
Wing Attach Fitting

Model 200 Series Elevators

- Foam filled trim tab and foam filled trailing edge
  - Absorbs moisture
    - →Results in corrosion
    - →Changes elevator balance
  - When trim tab skin thins due to corrosion, the actuator can pull the fasteners through skin and disconnect
  - Not repairable
  - Inspect for pinholes, surface roughness, bubbling
  - FAA SAIB CE-05-27R1 recommends replacement of tab and trailing edges with non foam filled parts

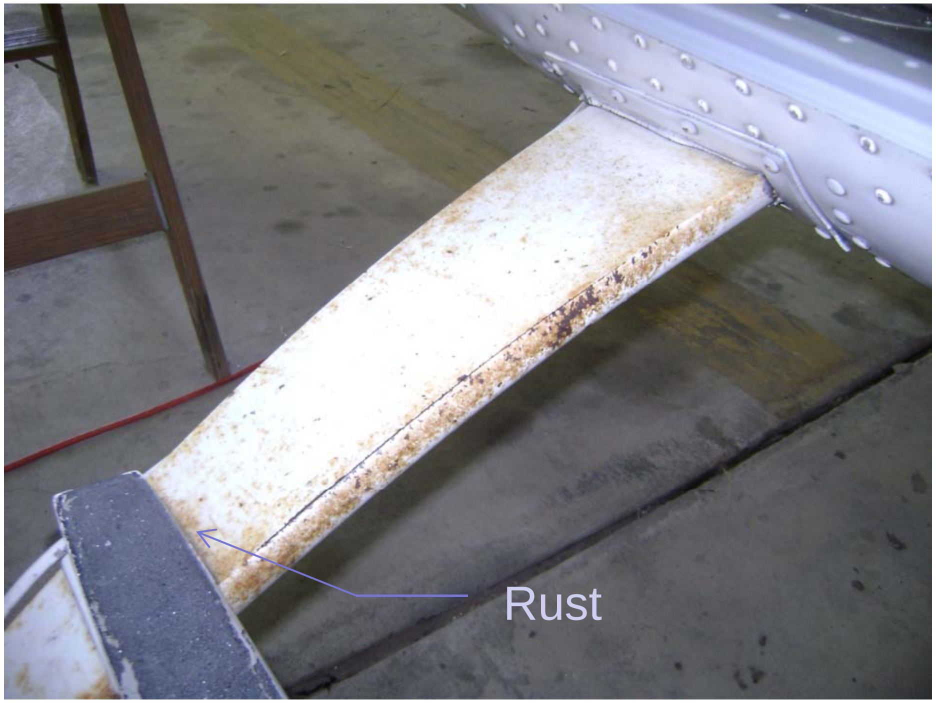
Model 200 Series Elevators





Main Landing Gear

- Made from 6150M High-Strength Steel
- A pit as small as .005” can initiate a fatigue crack which will result in fracture of the gear
- Keep surface painted with polyurethane paint and blend out pits per Service Manual

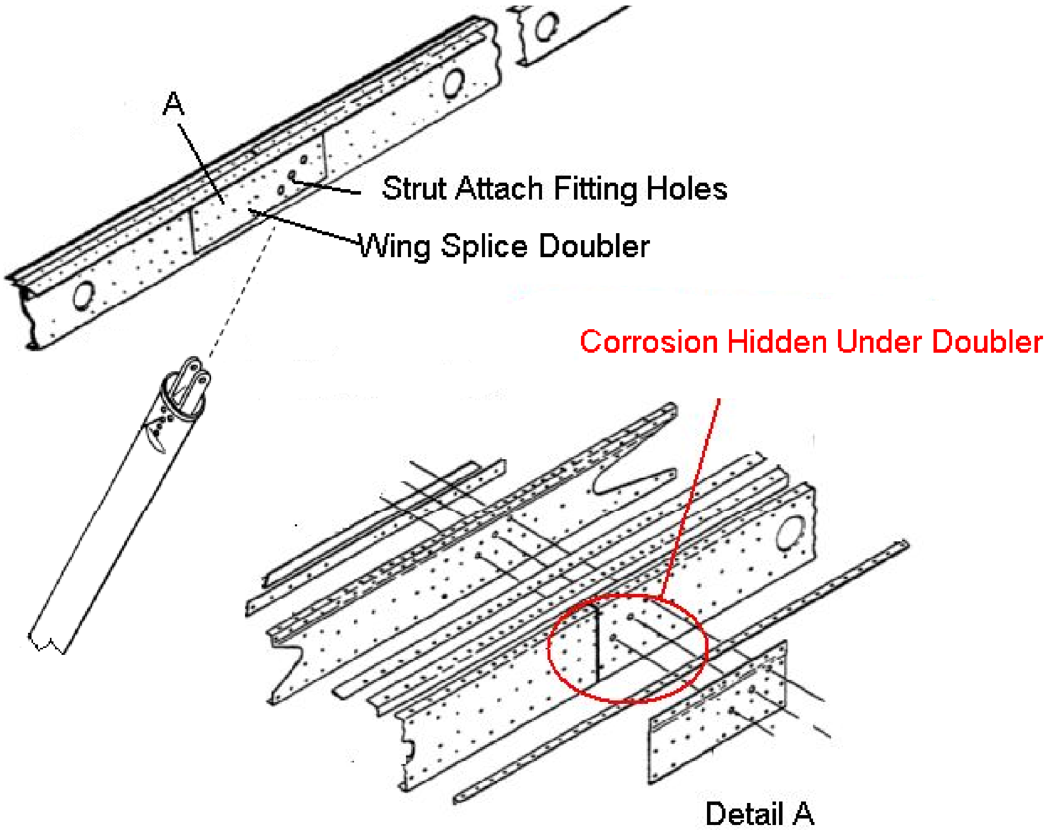


Model 182 Flat Spring Gear

Main Landing Gear

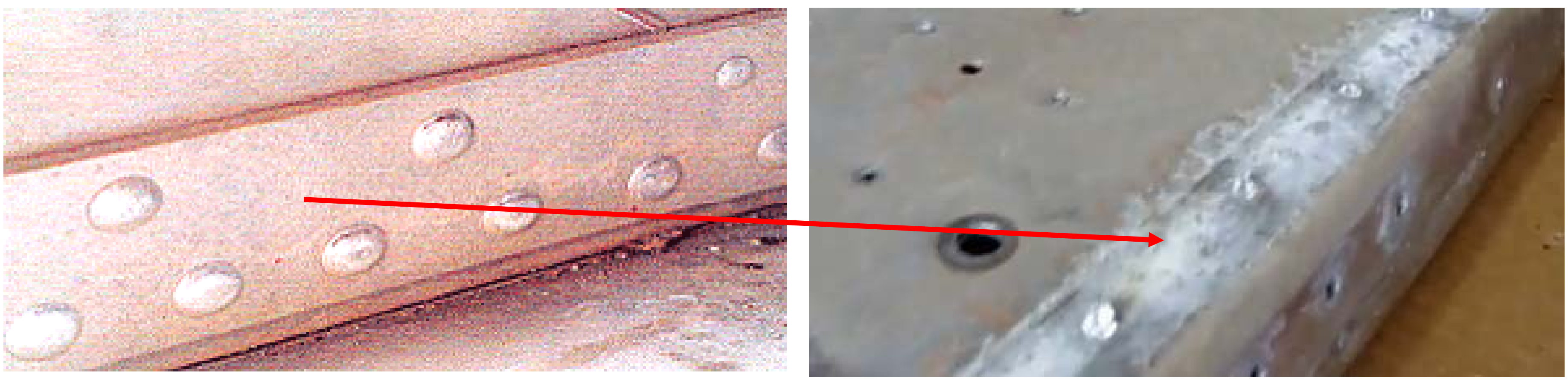
Strut Braced Wing Front Spar

- Wing spar made from several sheets of 2024-T3 aluminum clad riveted together
- Strut attaches at wing splice joint
- Corrosion observed in underlying sheets



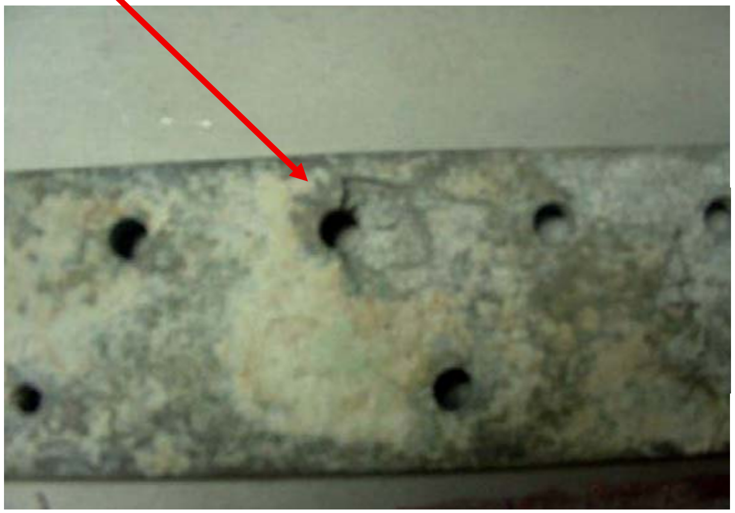
Strut Braced Wing Front Spar

- Corrosion is often indicated by the discovery of a missing rivet
  - If rivet is missing, corrosion is likely to be severe
- Australia asks owners to remove leading edge after 15 years, inspect and reassemble with primer



Strut Braced Wing Front Spar

Front Spar



Doubler

Source: CASA General Aviation Aircraft Corrosion

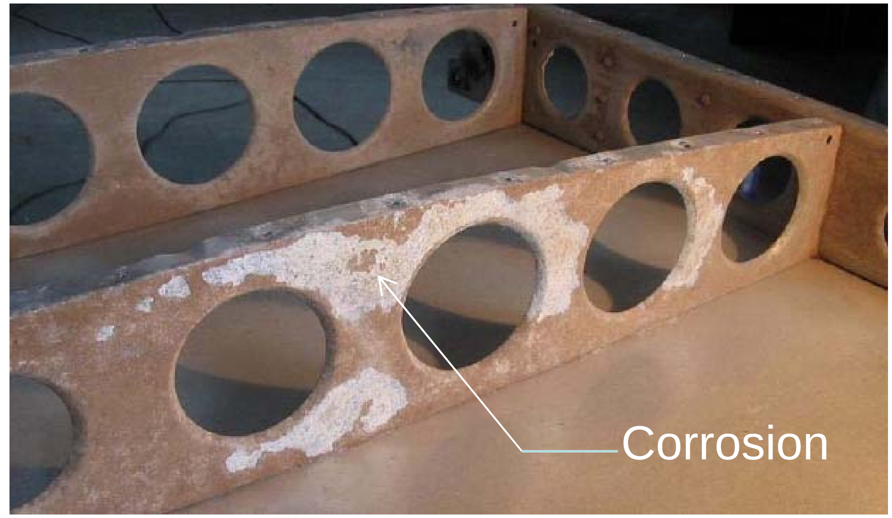
Strut Braced Wing Front Spar

Spar Splice

Source: CASA General Aviation Aircraft Corrosion

Strut Braced Wing Front Spar

Airframe Ribs



"A repair station found severe corrosion in the front and rear wing to fuselage attachments. There was so much corrosion (many of the rivets had broken off the wing's rear attachment), and when the corrosion was removed many more rivets fell out. The vertical stabilizer was opened up and more significant corrosion was found."

Source: FAA Maintenance Alert 43-16A, May 2006

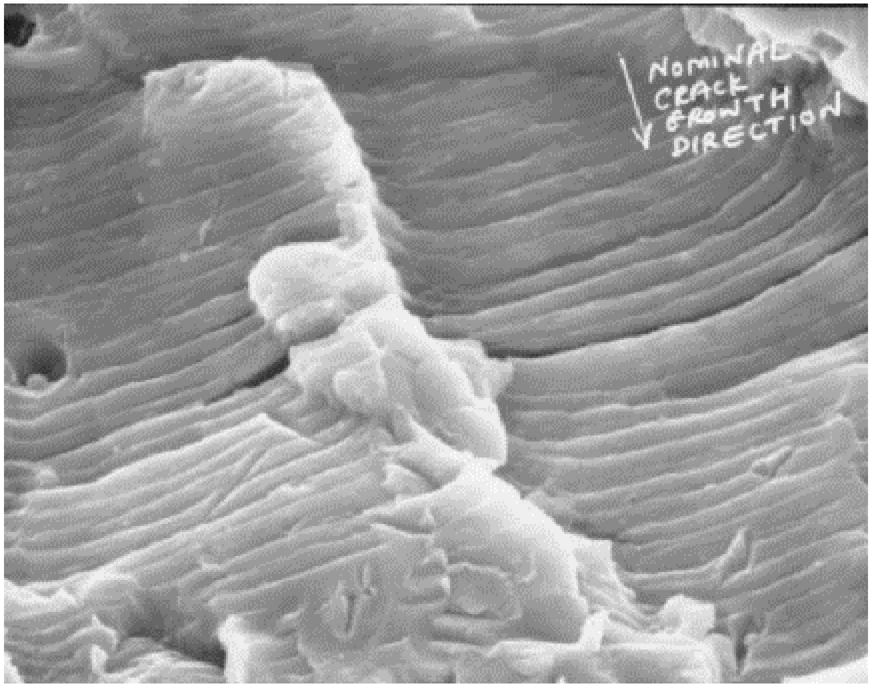
Metal Fatigue

- Aviation has had to address metal fatigue in the design and inspection of airframes since 1954
- Fatigue can be deadly
  - Metal fatigue contributed to 2240 deaths in 1885 airplane accidents between 1927 and 1980[1]
    - → The five most common fatigue crack initiation sources in these accidents were: (1) bolt, stud or screw; (2) fastener or other hole, (3) fillet, radius or sharp notch; (4) welds and (5) corrosion
  - Over 700 people have died in fatigue related accidents since 1980[2]

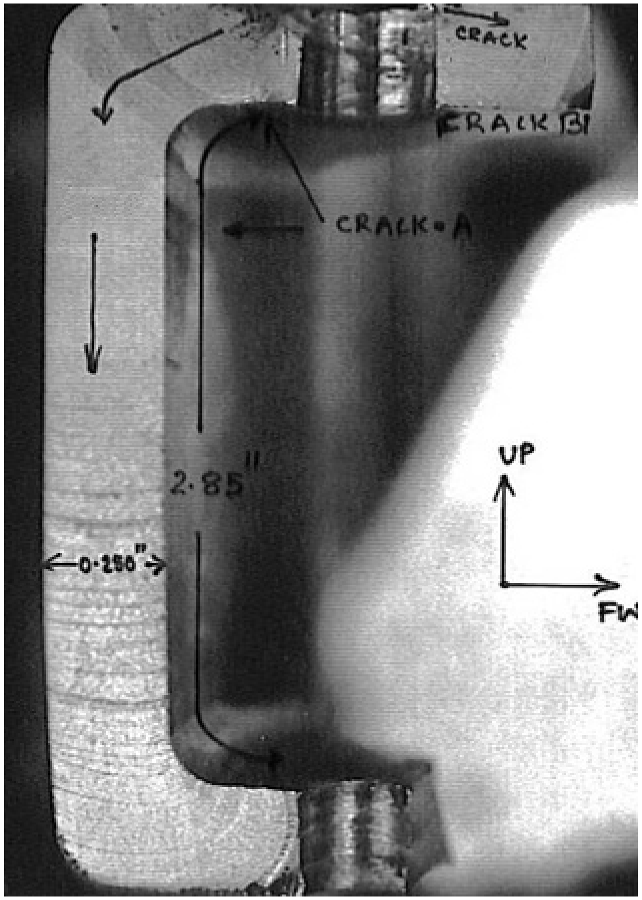
[1] Campbell and Lahey 1984, 'A Survey of Serious Aircraft Accidents Involving Fatigue Fracture', *International Journal of Fatigue,* January 1984

[2] 'Investigation into Ansett Australia Maintenance Safety Deficiencies and the Control of Continuing Airworthiness of Class A Aircraft', Appendix 8 from the Australian Transport Safety Bureau's web site, www.atsb.gov.au.

What is Metal Fatigue?



Fatigue Under Microscope

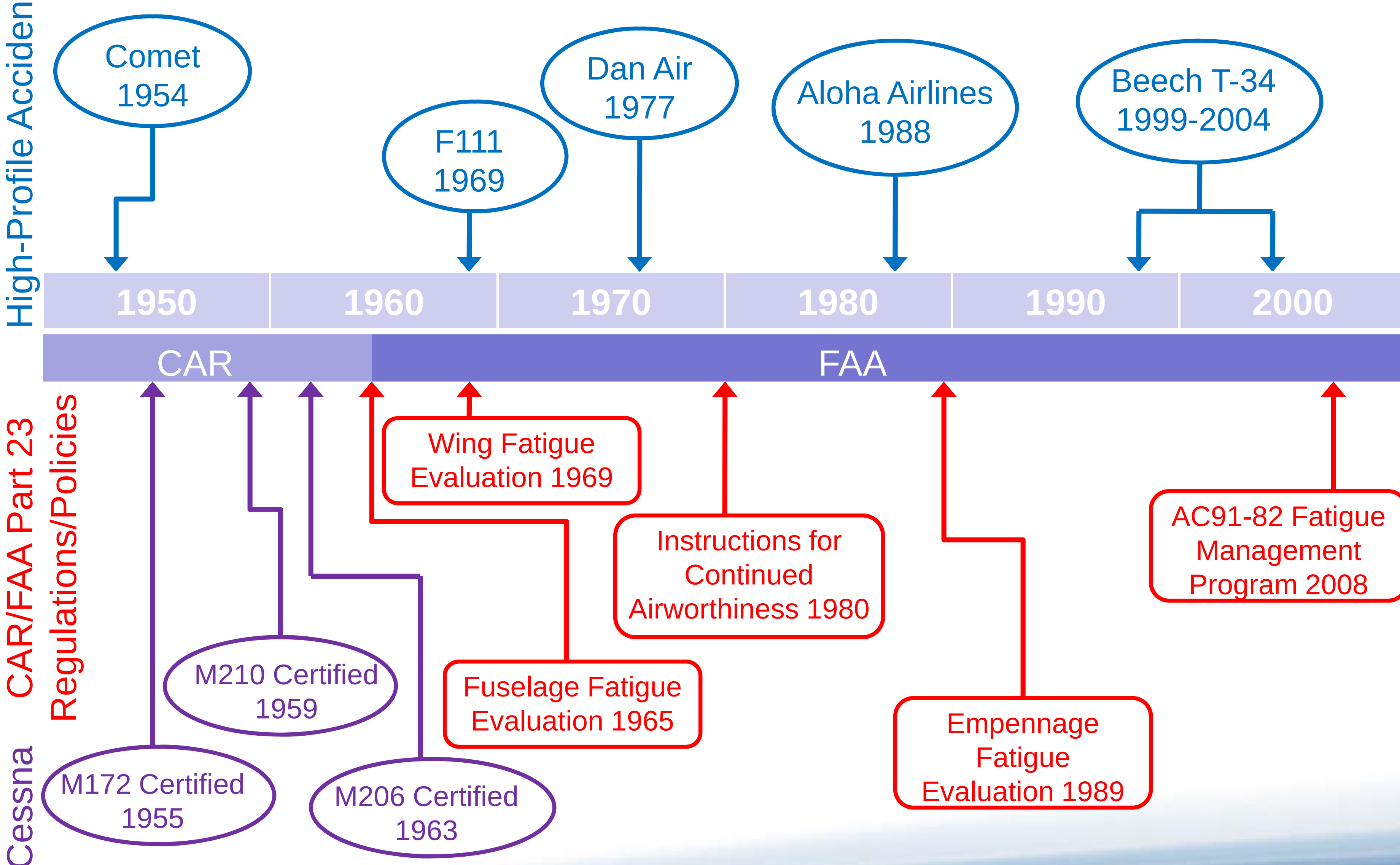


Typical Fatigue Failure

Metal Fatigue

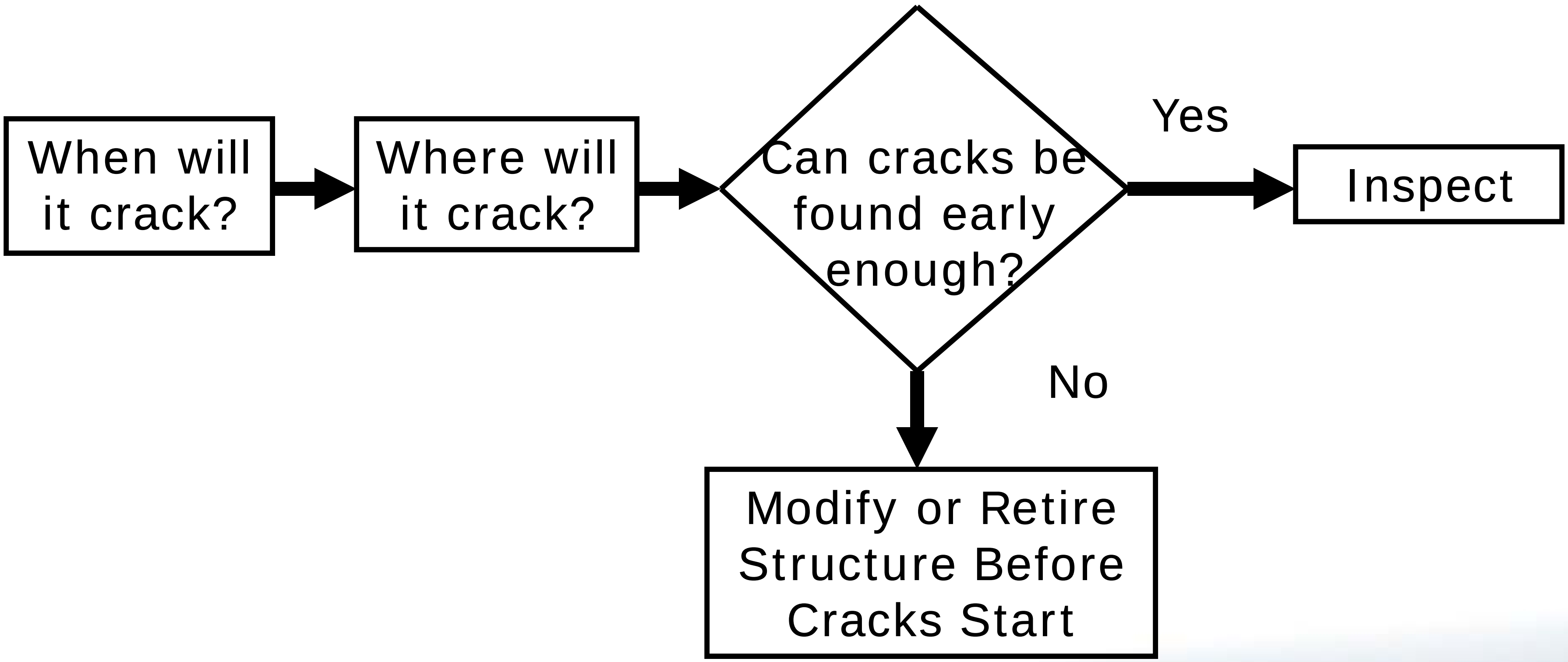
- Due to some high-profile accidents caused by metal fatigue FAA Regulations have changed through the years in order to improve safety. Each accident led to:
  - Changes in certification requirements
  - Changes in existing inspection programs

FAA Regulations Through the Years



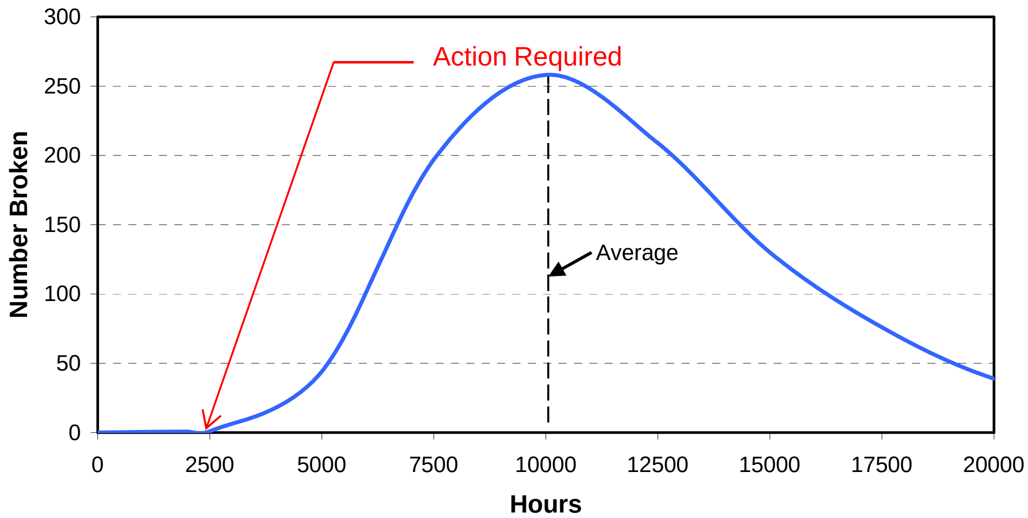
How to Control Metal Fatigue

- Primary questions to ask



How to Control Metal Fatigue

- When will it crack?
  - Suppose 1000 identical wing spars were fatigue tested with the same loads
  - Assume the average wing spar breaks at 10,000 hrs
  - They won't all break at the same time



How to Control Metal Fatigue

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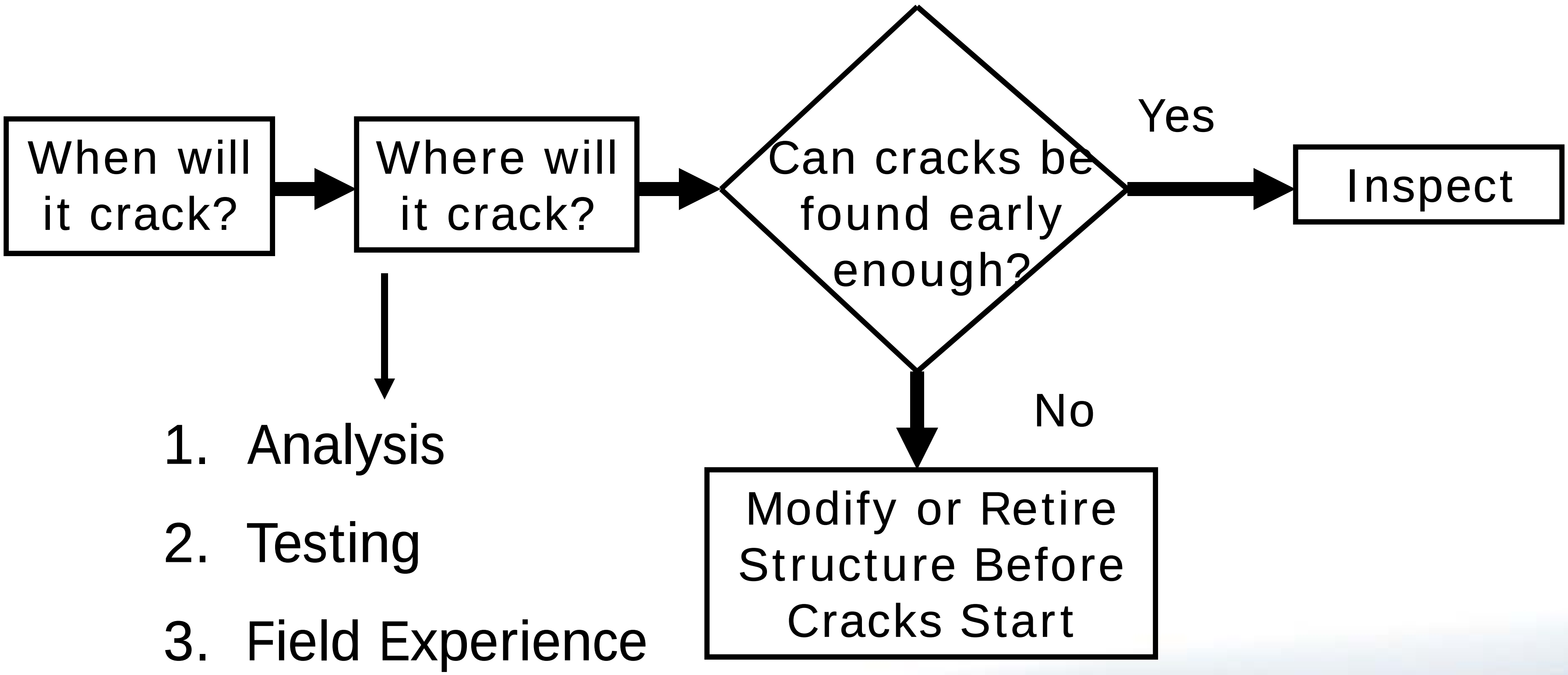
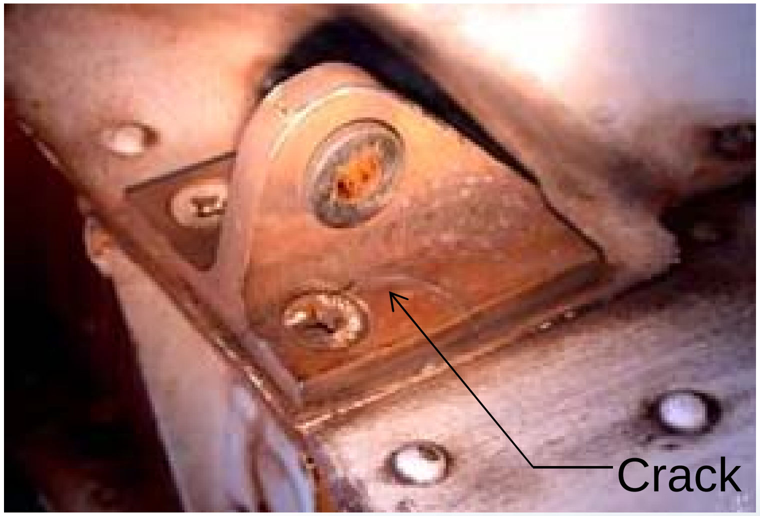


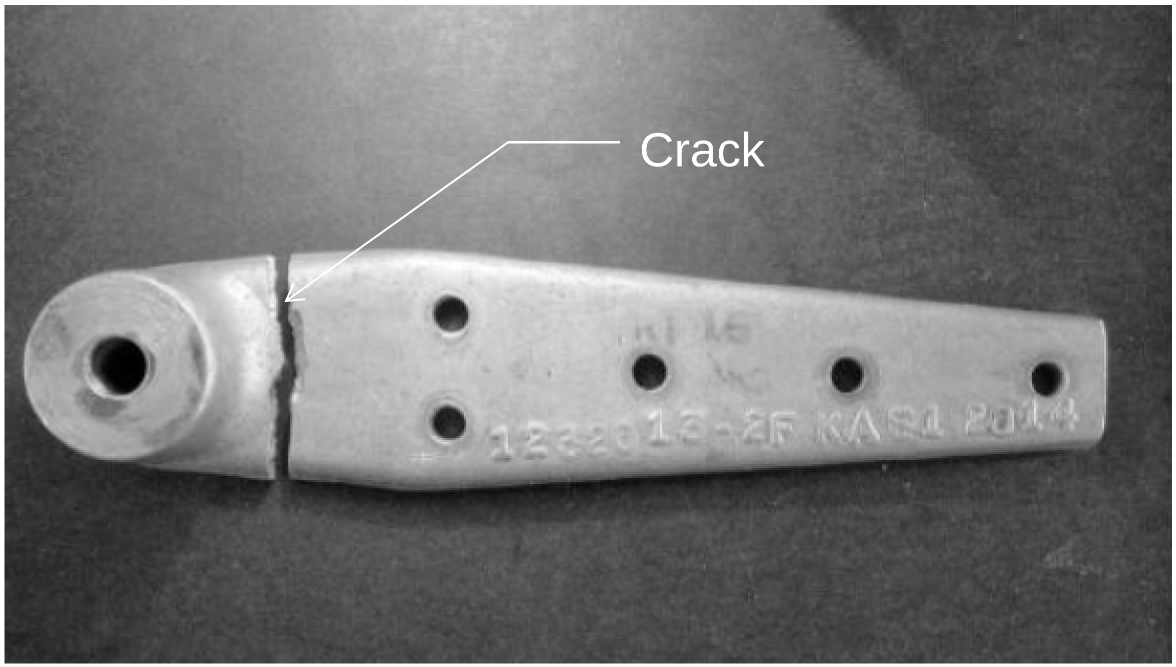
Metal Fatigue Examples

- 200 Series Horizontal Stabilizer
- 200 Series Aft Bulkhead
- Models 177/210 Cantilever Carry-Thru

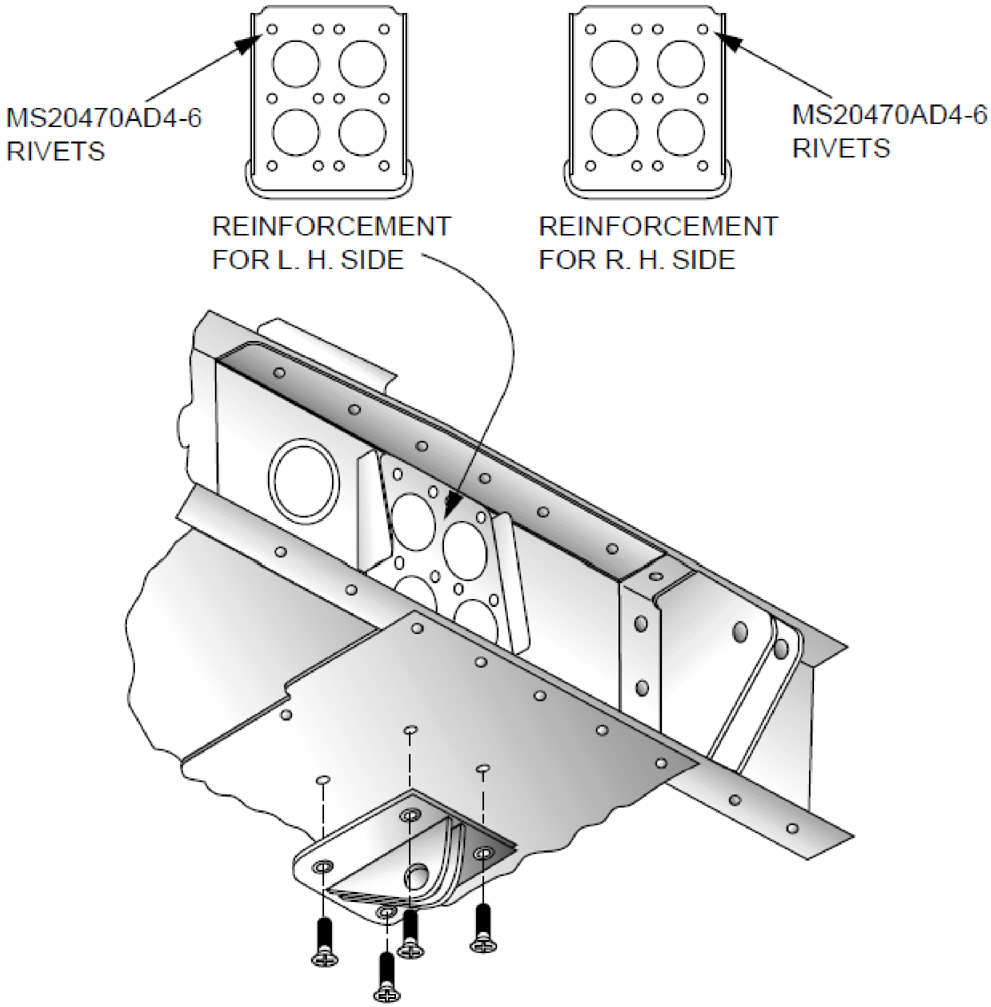
200 Series Horizontal Stabilizer Front Spar



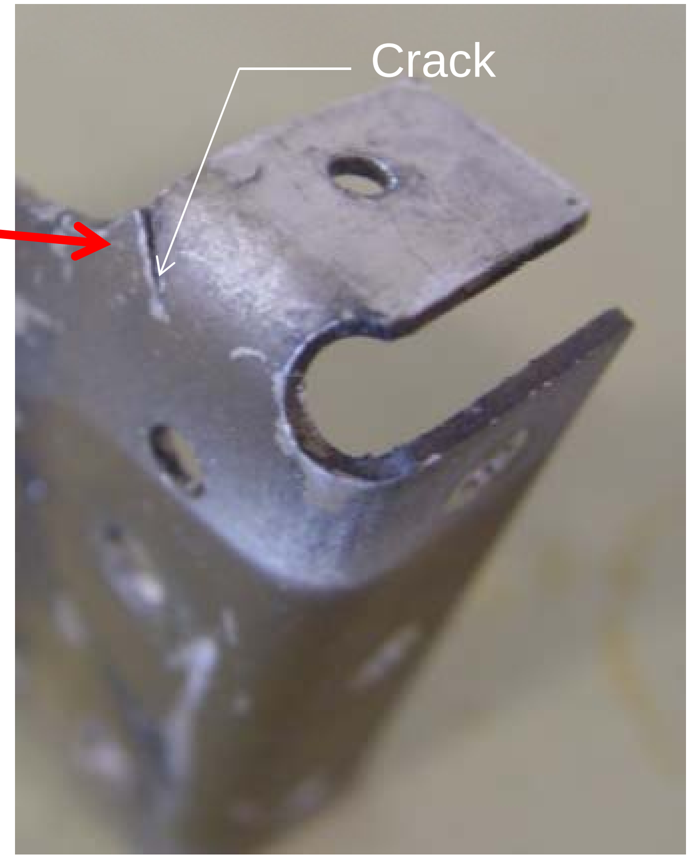
200 Series Horizontal Front Spar Attach



200 Series Horizontal Stabilizer Trim Actuator Brackets



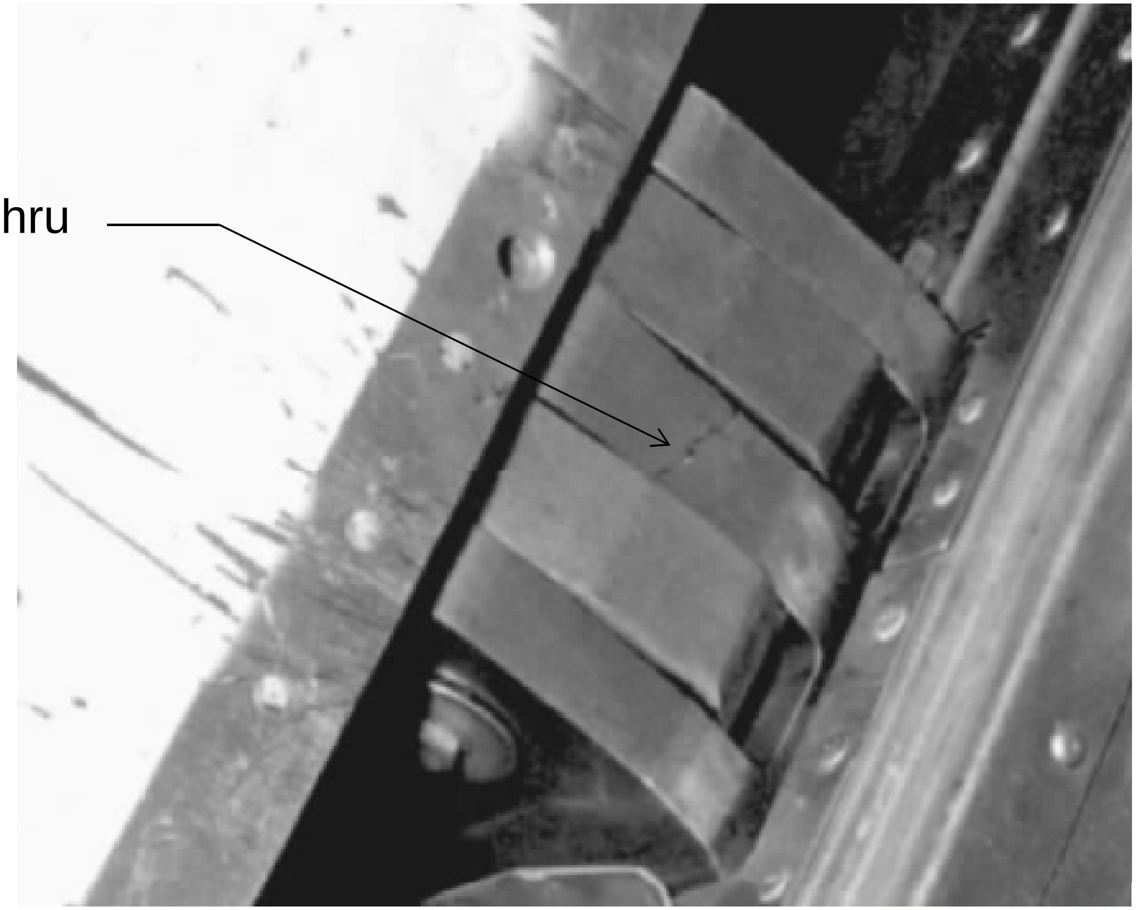
200 Series Aft Bulkhead



Source: FAA Maintenance Alert 43-16A, May 2011

Models 177/210 Cantilever Carry-Thru

Cracked Carry-Thru
Center Lug



Inspection Program Details

- Inspections
  - Based on field history
  - Reviewed by customer focus group
- Inspection Details
  - Corrosion prevention and control program
    - →Directed visual inspections for corrosion completed during annual
  - ~15-20 visual inspections to inspect for cracks
    - →Borescope and magnifying glass required to complete inspections
  - ~5 inspections based on existing service bulletins

Inspection Program Details

- Specialized NDI techniques required
  - When corrosion is found
  - When cracking is suspected
  - When required by existing service bulletin
  - For high time airplanes (12,000+ hours) or severe usage airplanes (6,000+ hours)
- Single Engine NDI training program is available
  - Developed and taught by National Center for Aviation Training (NCAT)

Single Engine NDI training program

- Instruction
  - Beginning Summer 2012 all but 40 hours of the training program will be available online
  - NCAT will travel to other locations including foreign countries to support this program as required
  - NCAT will provide equipment and commercially available standards when training is completed at their facility

NDI Training Program

- Minimum Classroom Training Requirements - some requirements may be completed on-line
  - Penetrant Inspection (16 hours)
  - Magnetic Particle Testing (16 hours)
  - Eddy Current (40 hours)
  - Ultrasonic Testing (40 hours)
    - → (NCAT will review a reduced training syllabus for UT when direct reading thickness gauging)
- Completion of training will qualify individual to perform NDI inspections on Cessna single engine airplanes
  - Equivalent of a level 1 NDI technician

Inspection Program Availability

- Revised inspection program will be published in the airplane service manual
  - 200 Series airplanes – November 2011
  - 100 Series airplanes – April 2012
  - Compliance Date
    - →200 Series airplanes – December 2013
    - →100 Series airplanes – June 2014

Conclusion

- Safety is a partnership between owners, manufacturers and the FAA

Conclusion

- Report anomalies to the manufacturer customer service
  - Corrosion
  - Cracks in major structural elements
  - Suspect repairs
- Send pictures!!