Corrosion

Fatigue, exacerbated by corrosion, resulted in a failure of the lap joint and the loss of a substantial portion of the upper fuselage on this now infamous Aloha Airlines Boeing 737. The incident occurred in 1988 and forced the regulatory authorities (FAA, TC, etc) to come to terms with aging aircraft issues.

Corrosion

Mechanism:

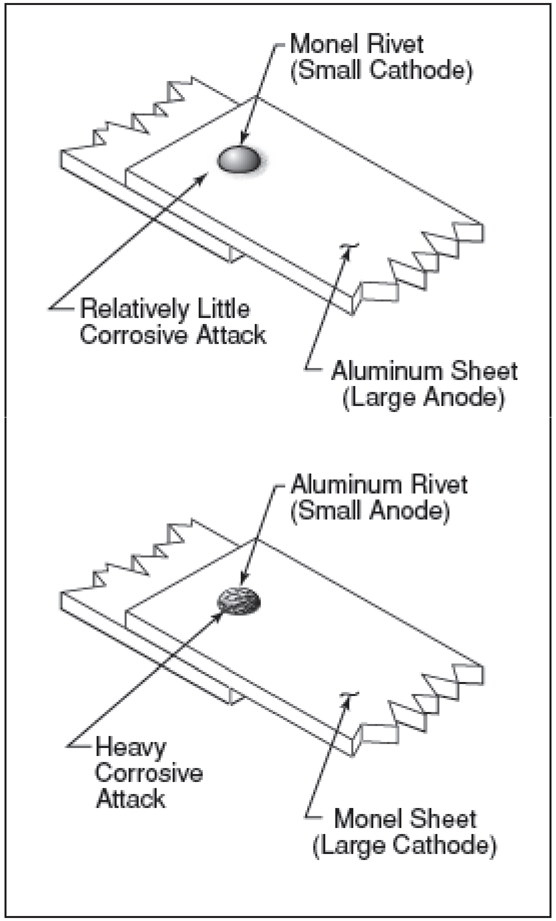
- Electrochemical process
- Requires:
  - Anode, Cathode and Electrolyte
- Anodes and cathodes may consist of two parts made from different materials
- Anodes and cathodes may also be present in the grain structure of a material
- Electrolyte may be lavatory spillage, galley spillage, water, air or any other fluid

CORROSÃO E FADIGA – FATIGUE AND CORROSION

ANODIC - High Corrosion Potential

Lithium
Magnesium Alloys
Zinc (plate)
Beryllium
Cadmium (plate)
Uranium (depleted)
Aluminum Alloys
Indium
Tin (plate)
Stainless Steel 430 (active)
Lead
1010 Steel
Cast Iron
Stainless Steel 410 (active)
Copper (plate)
Nickel (plate)
AM 350 (active)
Chromium (plate)
Stainless Steels 350, 310, 301, 304 (active)
Stainless Steels 430, 410 (passive)
Stainless Steel 13-8, 17-7PH (active)
Brass, yellow, Naval
Stainless Steel 316L (active)
Bronze 220
Copper 110
Stainless Steel 347 (active)
Copper-Nickel 715
Stainless Steel 202 (active)
Monel 400
Stainless Steel 201 (active)
Stainless Steels 321, 316 (active)
Stainless Steels 309, 13-8, 17-7 PH (passive)
Stainless Steels 304, 301, 321 (passive)
Stainless Steels 201, 316L (passive)
Stainless Steel 286 (active)
AM355 (active)
Stainless Steel 202 (passive)
Carpenter 20 (passive)
AM355 (passive)
Titanium Alloys
AM350 (passive)
Silver
Palladium
Gold
Rhodium
Platinum
Carbon/Graphite

CATHODIC - Low Corrosion Potential



Effect of Area Relationship in Dissimilar Metal Contacts

Corrosion - Types

Crevice	Intergranular
Exfoliation	Stress Corrosion
Fretting	Filiform
Galvanic	Corrosion Fatigue
Pitting	Microbiolgical
Surface	Erosion
Hot	

Corrosion - Types

Crevice corrosion tends to occur in any crevice where a stagnant solution has pooled, is the same thing as galvanism only it occurs under waht is also called "closed cell" corrosion by virtue of the fact that little or no air is allowed to get to it

A crevice is any cavity that will trap and hold water, while at the same time reducing or eliminating air exposure to the water/metal interface.

Corrosion - Types

Intergranular corrosion is an attack on the grain boundaries of the metal.

Scanning Electron Micrograph of a Corroding Aluminum Surface

Corrosion - Types

Exfoliation corrosion tends to manifest itself into distinct layers associated with the rolling or drawing process. This C130 antenna base plate (right) has not done too well in the warm, salt laden air of this South American coastal country.

Corrosion - Types

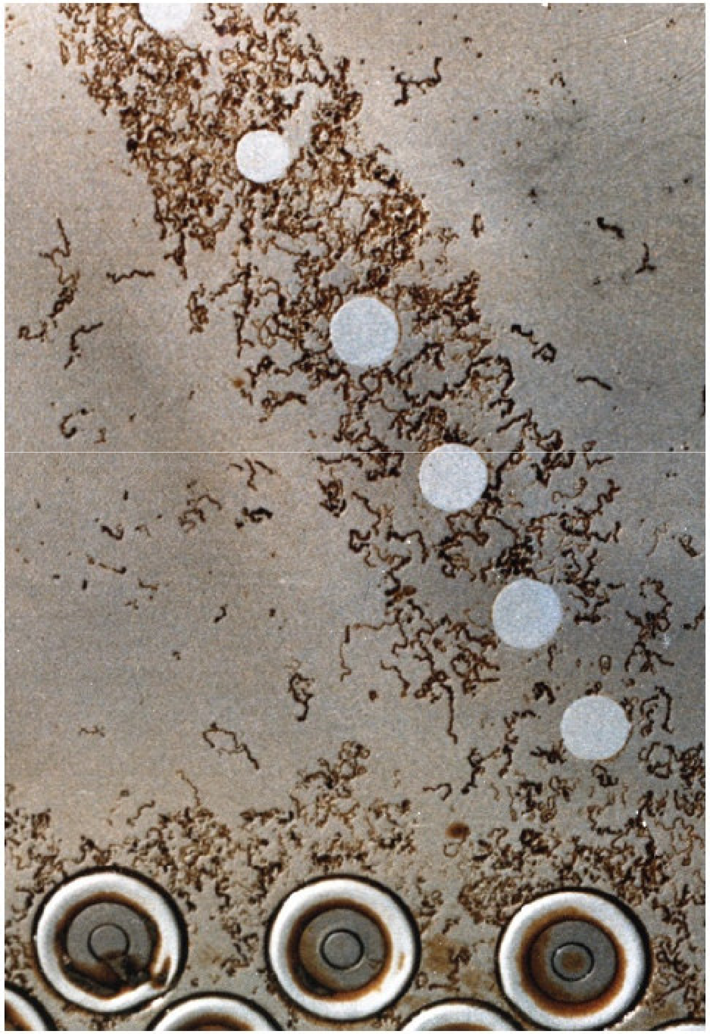
Stress corrosion cracking appears in materials that are particularly sensitive to this phenomena and when the part in question is subject to prolonged exposure to static tensile loads in a corrosive environment. These static loads may result from operations or from manufacturing processes such as forming, welding, heat treatment, machining and grinding which may produce residual stresses. The micrograph on the right (X500) illustrates intergranular SCC of an Inconel heat exchanger tube with the crack following the grain boundaries.

Corrosion - Types

Fretting corrosion occurs at contact areas between materials under load subject to repeated vibration

Corrosion - Types

Filliform corrosion is a form of crevice corrosion which occurs on metal surfaces having a thin (~4mils) organic protective coating. It is recognized by its wormlike trace of corrosion products beneath the coating.

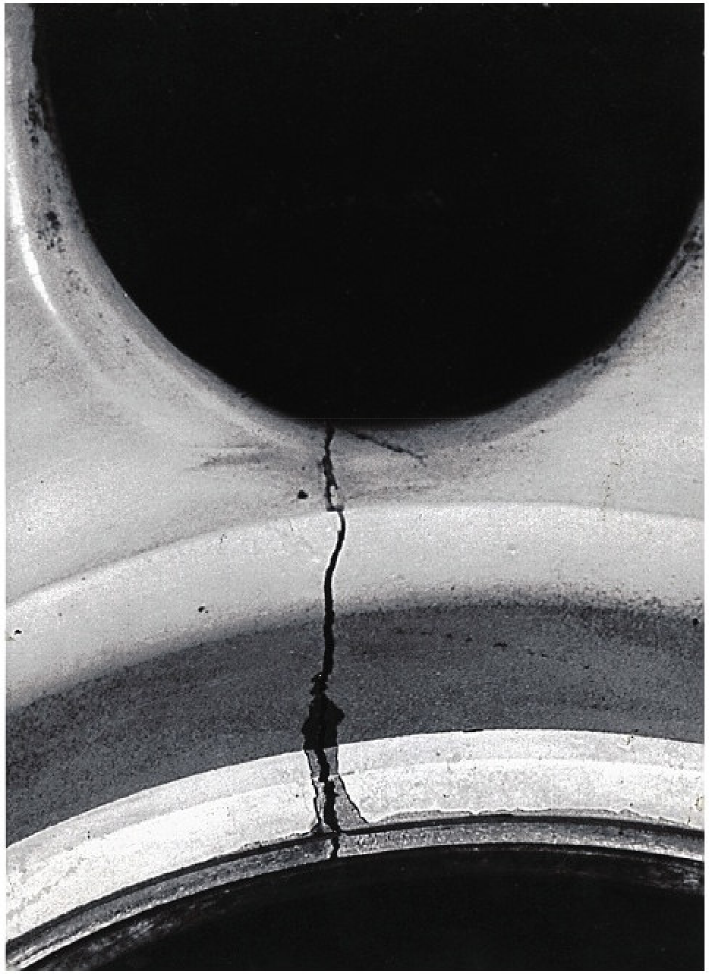


Corrosion - Types

Galvanic corrosion occurs when different metals are in contact with each other and with an electrolyte, such as seawater.

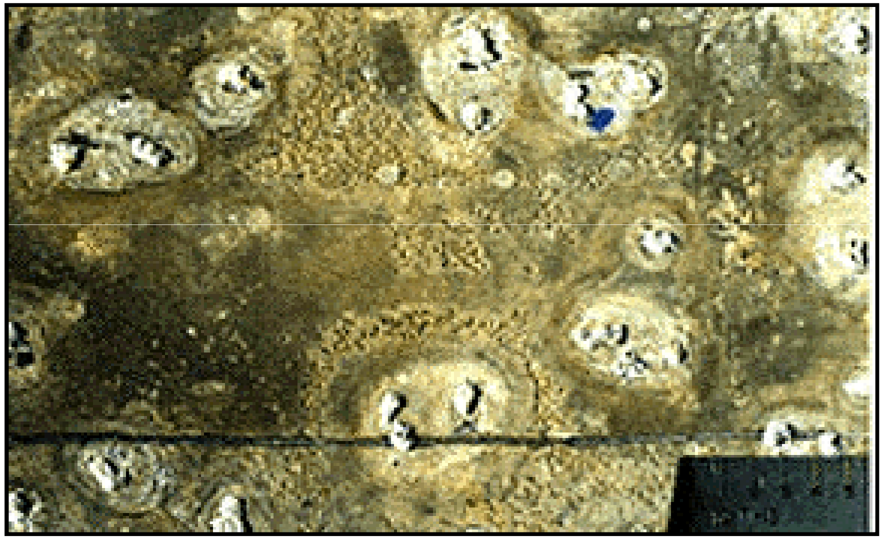
Corrosion - Types

Corrosion Fatigue is the cracking of metals caused by the combined effects of cyclic stress and corrosion



Corrosion - Types

Pitting corrosion is highly localized corrosion occurring on a metal surface. Pitting is commonly observed on surfaces with little or no general corrosion. Pitting typically occurs as a process of local anodic dissolution where metal loss is exacerbated by the presence of a small anode and a large cathode.



Corrosion - Types

Microbiological corrosion results from microbial growth that tends to hold moisture, which then causes corrosion; digestion of the substrate as food for the microorganism; or corrosion of the surface beneath the growth by secreted corrosive fluids.

Mold originated corrosion

Corrosion - Types

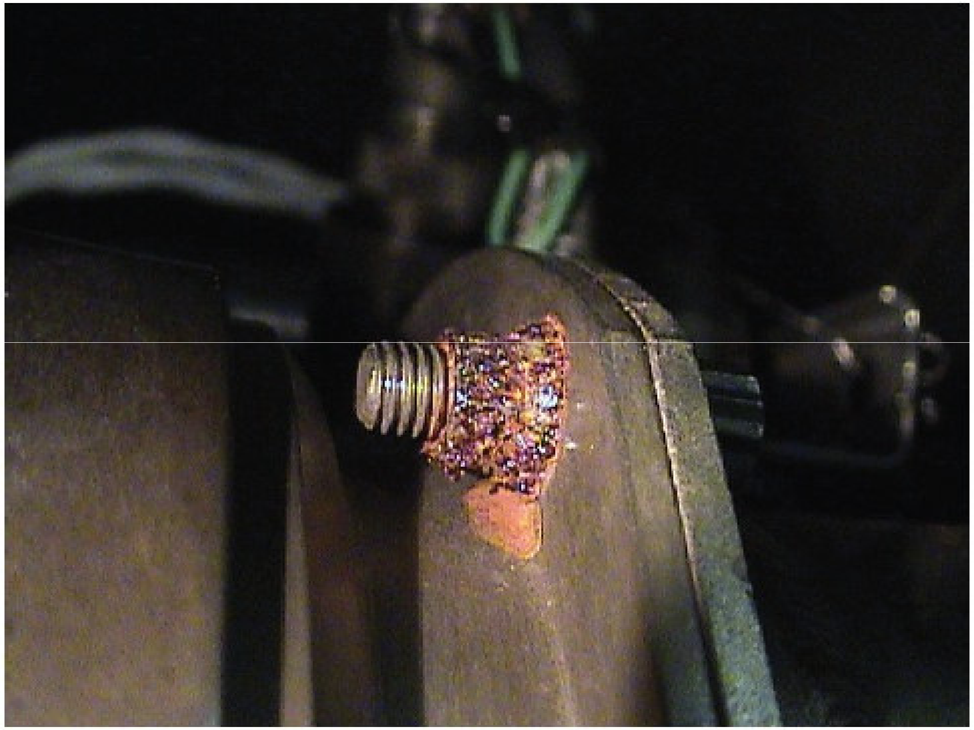
Surface corrosion is characterized by white powdery deposits. This photo was taken inside the center wing dry bay - the BL20 longeron system, the aft spar web, upper spar cap and rib diagonal all require a close look. More severe corrosion is most certainly present.

Corrosion - Types

Erosion corrosion is the increase in the rate of attack on a metal due to the action of a corrosive fluid against the metal surface.

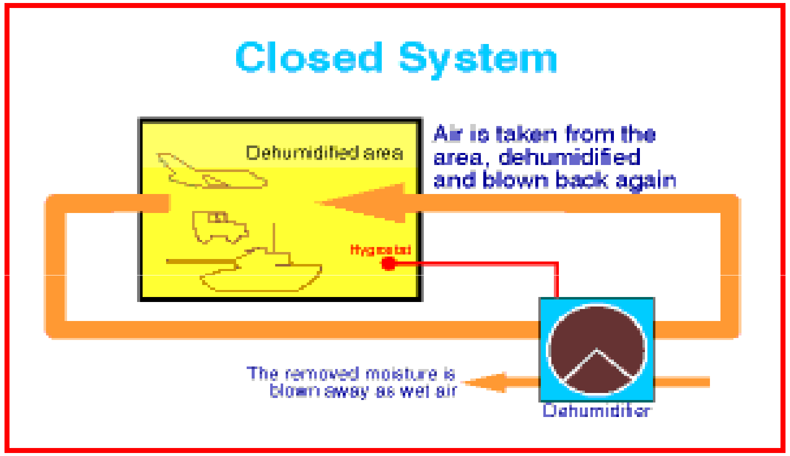
Corrosion - Types

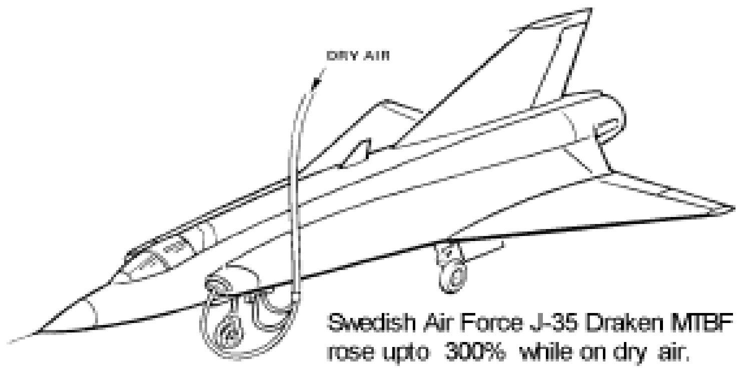
Hot corrosion tends to manifest



3-9.12. HOT CORROSION. Also called hig
temperature oxidation. Corrosion in the absence (
water can occur at high temperatures, such as thos
found in turbine engine combustors, turbine sections
and afterburners. When hot enough, metals can react
directly with the surrounding gases, producing oxide
scale (see Figures 3-21 and 3-22). Contaminants,

Corrosion - Prevention





Swedish Air Force J-35 Draken MTBF rose upto 300% while on dry air.

Dehumidification Systems

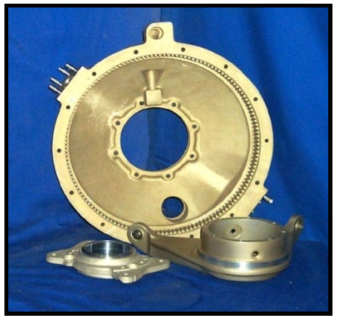
The higher the humidity, the more rapid the effects of corrosion. Systems are available to dehumidify the air within enclosed spaces on the aircraft. Practical issues are system power sources with aircraft on the ramp and access to all aircraft confined spaces.

Corrosion - Prevention (Chemical Coatings)

Anodizing (Aluminum)

- Anodizing is an ***electrochemical*** conversion process that converts the surface of aluminum to an oxide
- While aluminum naturally forms aluminum oxide on its surface, this is a very thin film. Anodizing provides a much thicker oxide coating—several mils thick if required.
- The hardness of this aluminum oxide coating rivals that of diamond thus anodizing improves *abrasion resistance*.

Alodining (Aluminum)



- Alodining is a ***chemical*** conversion process involving the application of a protective chromate conversion coating on aluminum
- Provides corrosion prevention and improves adhesion of painting processes

Corrosion - Prevention (Chemical Coatings)

Passivation & Pickling (Stainless Steels)

- Both pickling and passivation are chemical treatments applied to the surface of stainless steel to remove contaminants and assist the formation of a continuous chromium-oxide, passive film
- Pickling and passivation are both acid treatments and neither will remove grease or oil. If the item is dirty, it may be neccesary to use a detergent or alkaline clean before pickling or passivation

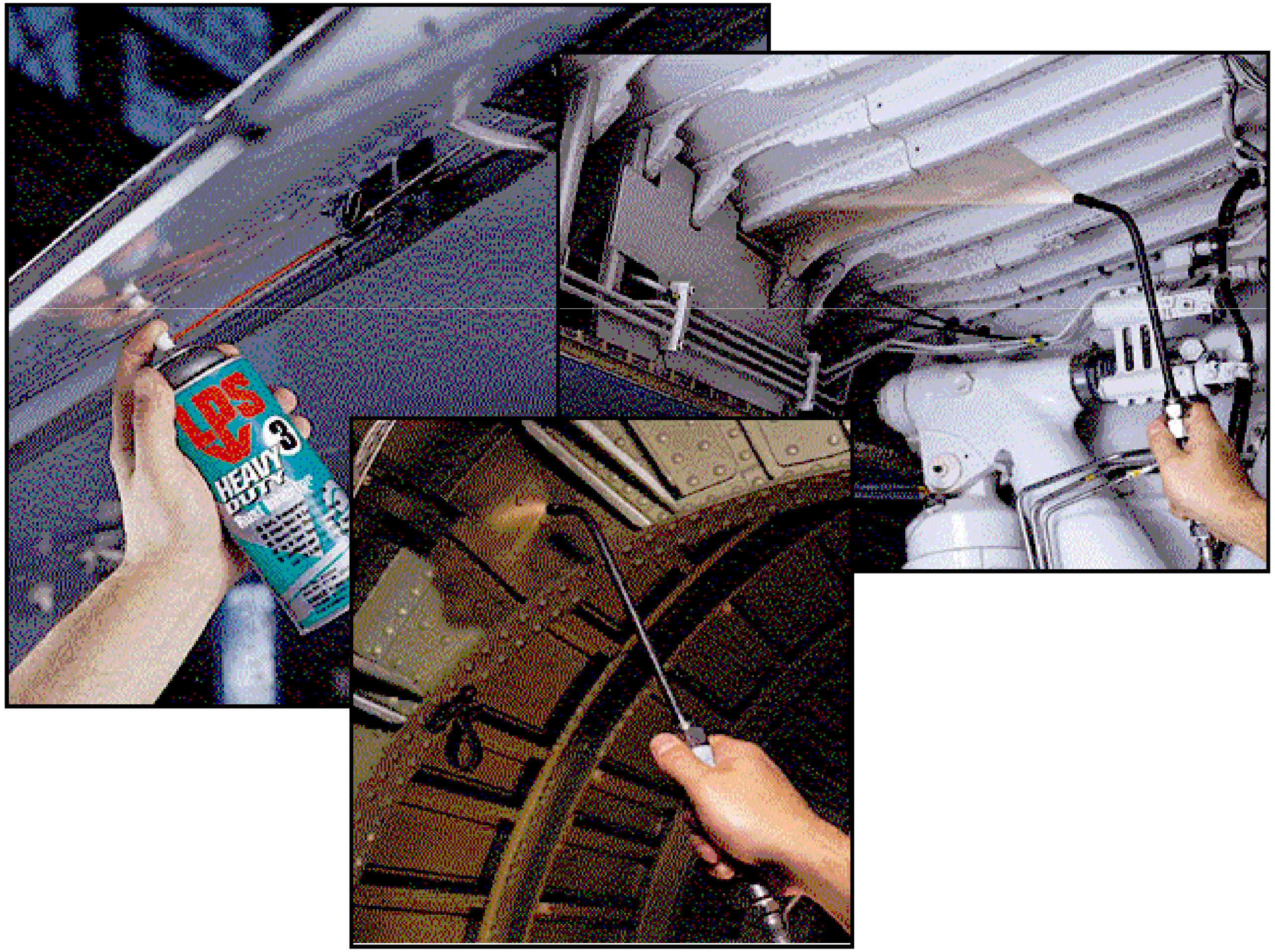
Cadmium Plating (Steels)

- Cadmium plating is an electrochemical process by which cadmium is plated onto carbon and low alloy steels

Corrosion - Prevention (Coatings)

Paints and primers constitute the majority of aerospace coatings. Epoxy primers are typically used for all non-fuel areas and polyurethane primers for fuel exposed applications. Top coats generally consist of polyurethanes and laquers. Specific coating requirements are documented in the aircraft maintenance manuals.

Corrosion - Prevention (Inhibiting Compounds)



Inhibiting compounds are applied over the OEM finish (chemical and coatings). Some are oily and water displacing, some will cure to waxy finish and others to a tough hard finish - all have their respective good and bad points and preferred applications.

Corrosion - Prevention (Sealants)

Why Seal?

- Maintain fuselage pressurization
- Prevent fuel tank leakage
- *Preclude the ingress of water and corrosive fluids*
- Maintain aerodynamic smoothness
- Channel fluids to drains
- Fire protection at firewalls

Corrosion - Prevention (Sealants)

Categories & Types

- There are an enormous number of sealant options specified by the OEM for use on a typical aircraft
- Each are designed to operate in vastly different environments

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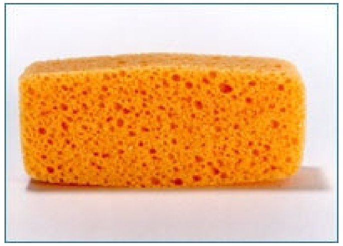
Corrosion - Prevention (Cleaning)

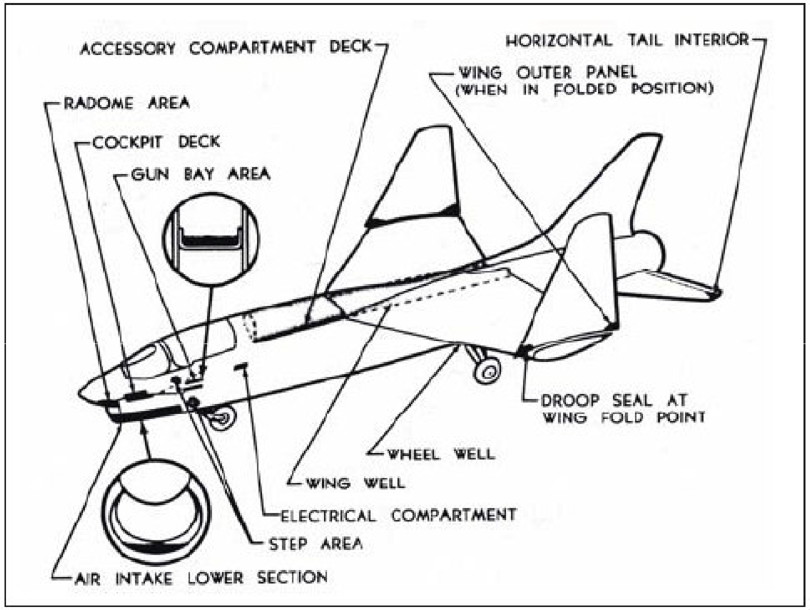


Cleaning of the Aircraft is the most effective tool in the battle against corrosion. Frequent cleaning removes harmful corrosion-causing deposits from the Aircraft surface. Cracks, corrosion and deviations in contour are easier to find after cleaning.

- References to the frequency at which Aircraft should be cleaned and equipment used are provided.
- Pre-wash preparation procedures.
- Interior and Exterior Washing procedures and references.
- Fuel tank cleaning and rinsing.
- Methods for cleaning and necessary steps after washing are given.

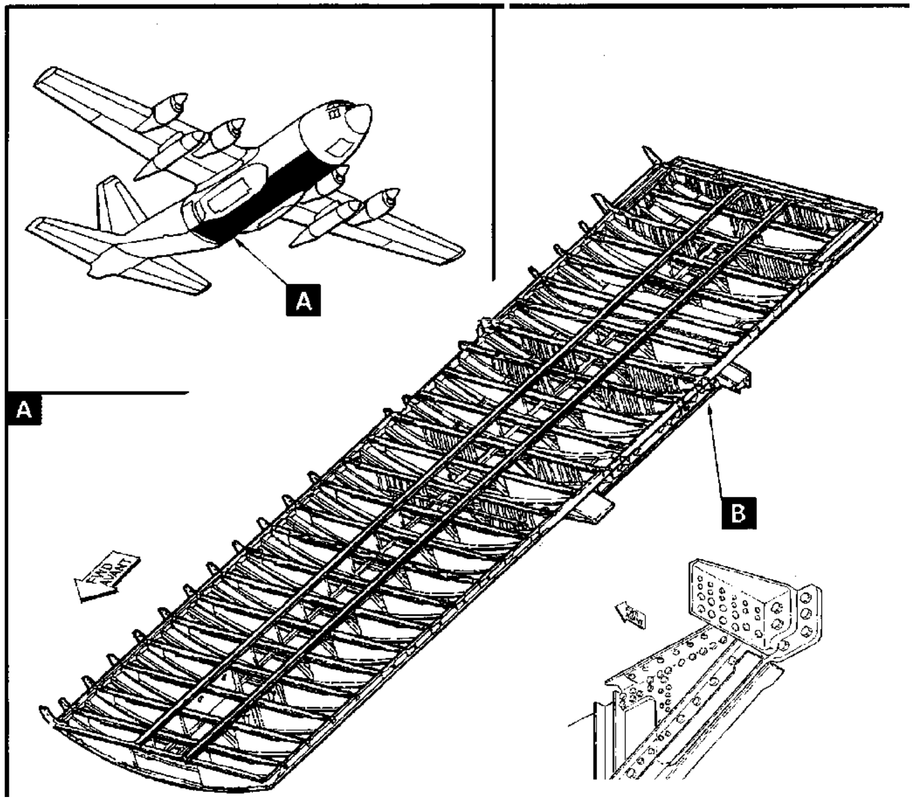
CORROSION PRONE AREAS

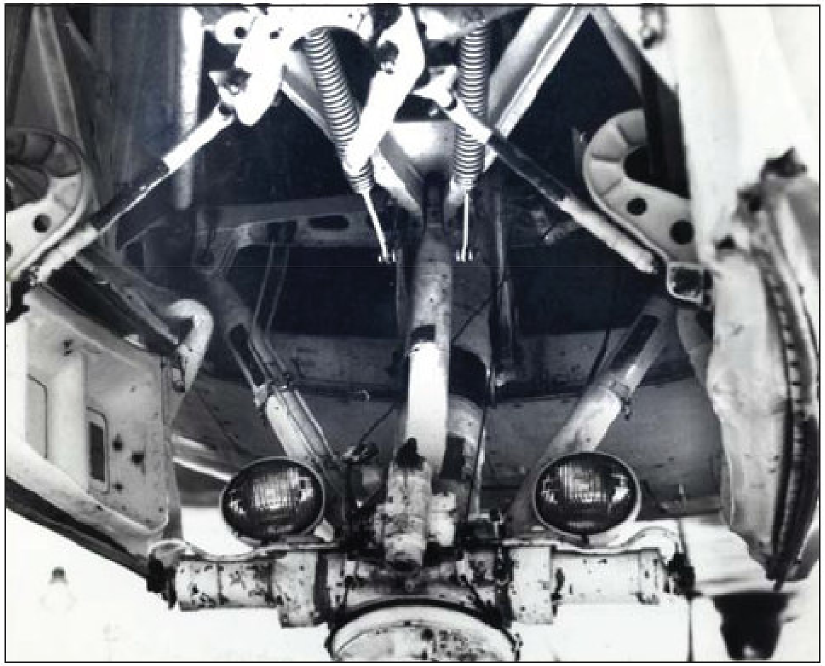
There are certain areas on an aircraft where corrosion is most likely to occur than in others, either due to the equipment on their vicinities (battery compartment, lavatory) or due to the geometry (water puddle) or direct contact with the environment (wheel wells).



Common Water Entrapment Areas

CORROSION PRONE AREAS





Typical 'Corrosion Prone Areas'

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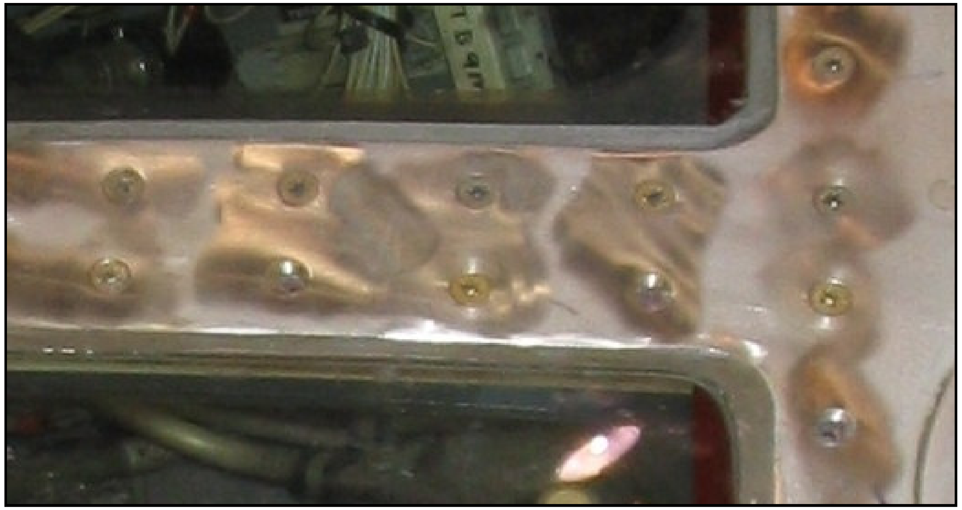
CORROSION REMOVAL AND PREVENTION

When corrosion is detected, a specific and immediate program for corrective action is required. Each type of corrosion has its own peculiarities and will require special treatment. Complete treatment involves thorough inspection of all corroded and adjacent areas and evaluation of the corrosion damage, paint and corrosion removal, application of chemical surface treatments, sealing, and application of paint finishes.



For areas of several square inches, paint may be removed mechanically using abrasive mats or flap wheels and brushes, **taking care not to remove underlying metal**. Chemical paint removal, may be used for areas larger than several square inches. Plastic or glass media blasting, may be used at Intermediate and Depot level maintenance activities to remove paint and corrosion.

FIM DO MÓDULO II

MÓDULO III

3. Reparações Estruturais

Aerospace Materials & Fasteners

Common modern aerospace materials consist of:

- Aluminum
- Steel
- Titanium
- Composites

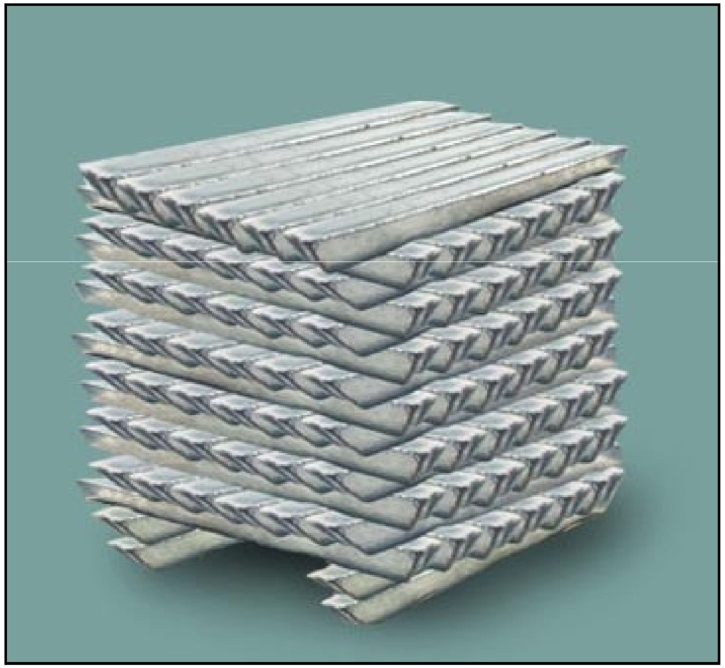
Aerospace Materials & Fasteners

Aluminum

- Discovered in the late 19th century: viewed as a semi-precious metal
- In its pure form, it is weak
- it was not until alloying was discovered in the early 1900's that structural applications became apparent
- Typical alloying elements:
    - Copper
    - Silicon
    - Iron
    - Zinc
- Results in a 6-8 fold increase in strength!

Aerospace Materials & Fasteners

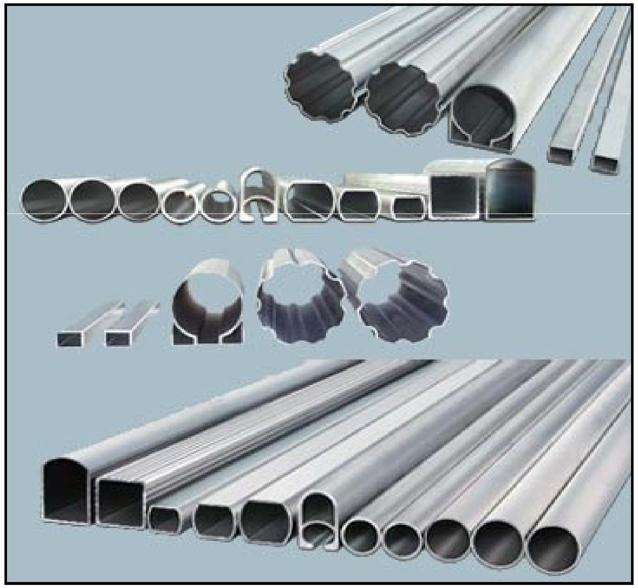
Aluminum Billets

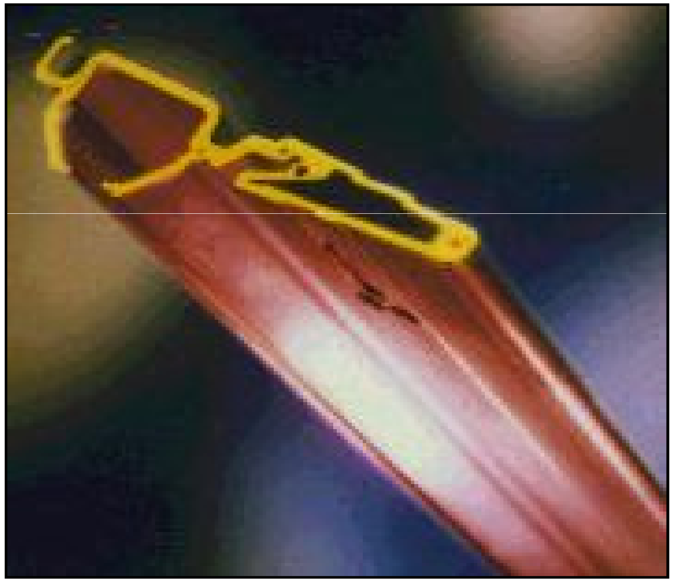


Aluminum is refined from bauxite, alloyed with the desired elements and turned into billets. These are sent for further processing which broadly consists of rolling (into sheet or plate), extruding or forging.

Aerospace Materials & Fasteners

Aluminum Extrusions





Billets are heated and forced through a die much like tooth paste from a tube. The outcome is some potentially very complex shapes.

Aerospace Materials & Fasteners

Aluminum Forgings

40,000 Ton Forging Press

Forging is a manufacturing process whereby metal is pressed, pounded or squeezed under great pressure into high strength parts known as forgings. This is usually done by heating the metal, but some forgings are produced without heating.

Aerospace Materials & Fasteners

Aluminum Casting

Photo shows liquid aluminum being poured into a sand casting.

Molten aluminum is poured into a mold to duplicate a desired pattern. This method does not enjoy widespread use in the aerospace industry due to manufacturing uncertainties.

Aerospace Materials & Fasteners

Aluminum Plate and Sheet

- When aluminum is passed between rolls under pressure, it becomes thinner, and longer in the direction in which it is moving. This simple process is the basis for aluminum's most widely used forms: plate, sheet, and foil.
- Aluminum can be flat-rolled and re-rolled until it reaches the desired thickness or gauge. Where the rolling process is stopped determines whether the final product will be plate (a quarter-inch thick or more), sheet (0.249" to .006"), or foil (less than 0.006").
- Sheet may be clad or un-clad

Aerospace Materials & Fasteners

Aluminum Advantages:

- Light
- Easily produced
- Easily worked
- No longer a semi-precious metal: available at relatively low cost

Aerospace Materials & Fasteners

- Common Aluminum Alloys in Aerospace:
  - 2000 Series (Principle alloying element: Copper)
    - Example: 2024-T3
  - 5000 Series (Principle alloying element: Magnesium)
  - 6000 Series (Principle alloying elements: Magnesium & Silicon)
  - 7000 Series (Principle alloying element: Zinc)
    - Example: 7075-T6
- The 5000 and 6000 series alloys are weldable
- Primary aerospace aluminum alloys are 2000 and 7000 series

Aerospace Materials & Fasteners

Aluminum Reference Numbering System:

7075-T6

Heat treatment coding:

- 0, Annealled

-T3, Solution treated then work hardened

-T4, Solution treated and naturally aged

-T6 Solution treated and artificially aged

7000 series alloy with zinc as primary alloying element

- 1000 series, pure aluminum

- 2000 series copper

- 6000 series, magnesium

-7000 series, zinc

Denotes revision number WRT original alloy

Index Numbers

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Aerospace Materials & Fasteners

Steel

- Iron has been known and used since prehistoric times - the writings of the most early civilizations refer to it, and there is evidence that it was known more than 7000 years ago
- Steel is made by alloying iron with carbon
- Other alloying elements may include:
  - Manganese, Chromium, Nickel
  - Molybdenum, silicon, vanadium
  - sulpher, phosphorous

Aerospace Materials & Fasteners

Aerospace Steels:

- Carbon
  - Contains up to 1% carbon as only alloying element
  - Example: AISI 1025
- Low Alloy
  - In addition to carbon, contains up to 1% of additional alloying elements
  - Example: 4130, 4340, 300M
- Intermediate Alloy
  - Example: 5Cr-Mo-V
  - Same as Low Alloy, but contains greater than 1% of additional alloying elements

Aerospace Materials & Fasteners

Aerospace Steels (Cont'd):

- High Alloy
  - Contains little carbon and large amounts of other alloying elements (in the order of 20%)
  - Example: 18 Ni & AF1410
- Precipitation Hardened Stainless Steels
  - These are stainless steels that are hardenable by heat treatment
  - Example: 15-5PH, 17-4PH
- Austenitic Stainless Steels
  - These are stainless steels that are not hardenable by heat treatment - cold working is utilized
  - Example: AISI 301

Aerospace Materials & Fasteners

Steel

Advantages:

- Volume efficient (strength to volume ratio)
- Strong
- Remains strong under high heat

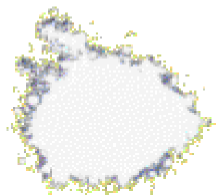
Disadvantages:

- Heavy
- Susceptible to corrosion
- 3X stiffer than aluminum

Aerospace Materials & Fasteners

Titanium

- Discovered in the late 18th century
- Methods to commercially extract and refine it had to wait until 1947
- Typically alloyed with aluminum, Tin and Zirconium, Molybdenum and Vanadium to increase strength



Extracted Titanium Dioxide Powder

Pure Titanium Metal

Titanium Alloyed Part

Aerospace Materials & Fasteners

Titanium

Advantages:

- Strong
- Remains strong under high heat
- Relatively light

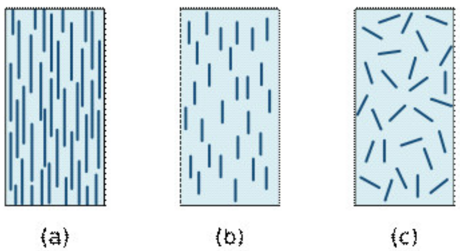
Disadvantages:

- Cost
- Less workable than aluminum

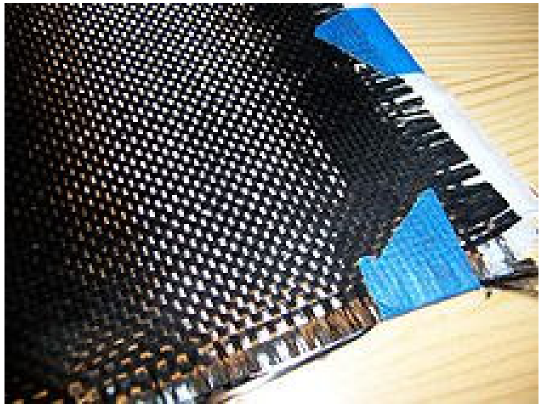
Aerospace Materials & Fasteners

Composites

Engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure.



Typologies of fibre-reinforced composite materials:
a) continuous aligned fibre-reinforced
b) discontinuous aligned fibre-reinforced
c) discontinuous random-oriented fibre-reinforced.



Aerospace Materials & Fasteners

Composites

Advantages:

- Strong
- Easy to work
- Relatively light

Disadvantages:

- Not suitable for high temperatures
- High manpower

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Aerospace Materials & Fasteners

Relative Stiffness, Density and Strength:

	Aluminum (7075-T6)	Titanium (Ti-6Al-4V)	Steel (301 full hard)
Stiffness (x1,000,000 psi)	10	16	26
Density (pounds/cubic inch)	0,10	0,13	0,29
Strength (x1,000 psi)	80	140	185

Aerospace Materials & Fasteners

General Relative Merits:

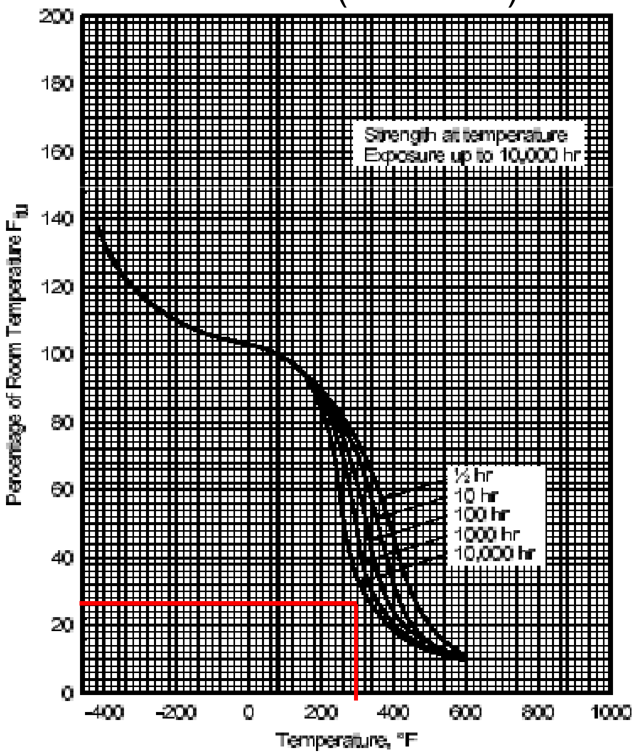
	Aluminum	Steel	Titanium	Composite
Heat	Poor	Good	Good	Poor
Corrosion	Good	Fair	Good	High
Strength	Moderate	Very High	High	High
Space	Poor	Good	Good	Good
Weight	Good	Fair	Good	Good
Cost	Cheap	Cheap	Expensive	High
Workability	Easy	Moderate	Difficult	Easy

There is no single best solution - the designer needs to consider many factors before selecting the best material for the job. Confusing the issue is the fact that there are many aluminum, steel and titanium alloy options available for use within each major group.

Aerospace Materials & Fasteners

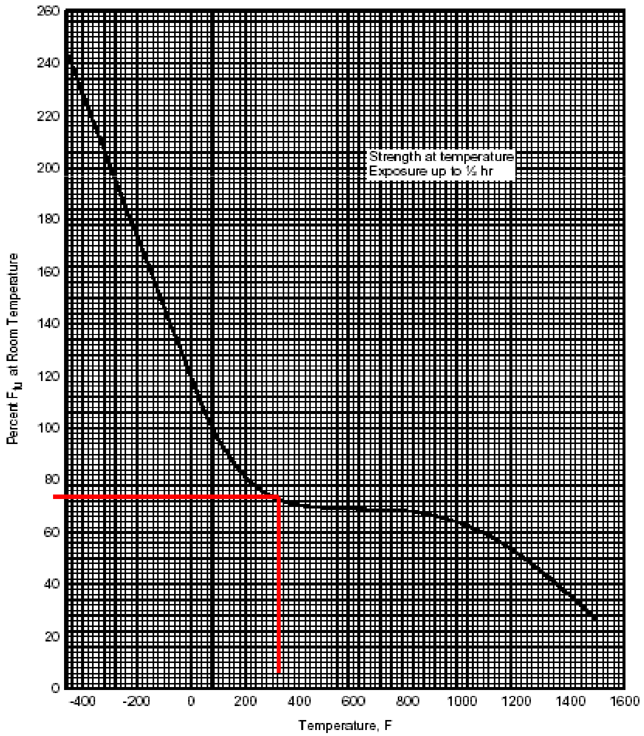
Relative Thermal Merits at 300 deg F:

Aluminum (7075-T6)



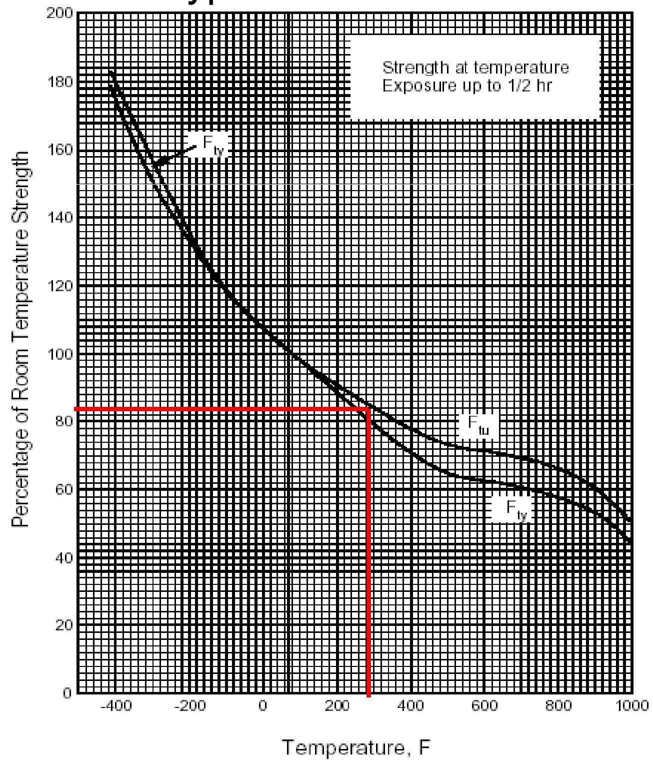
25%

Steel (AISI 301)



75%

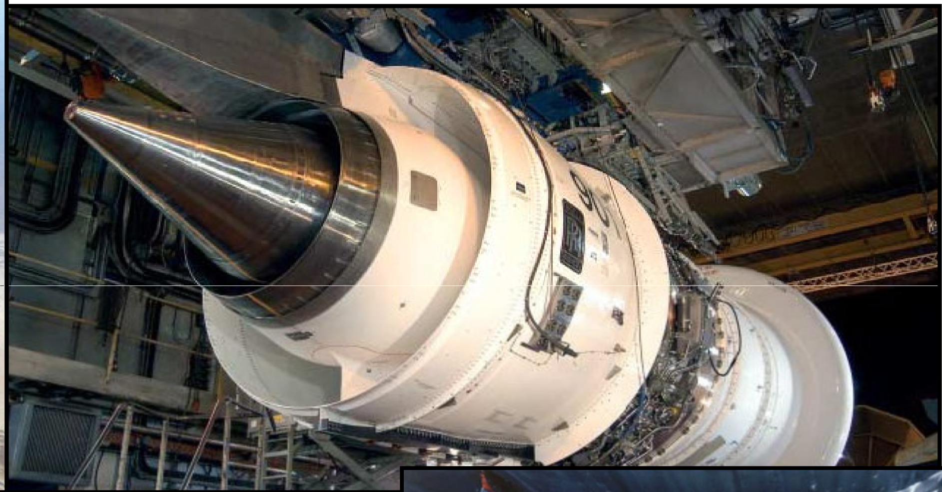
Typical Titanium



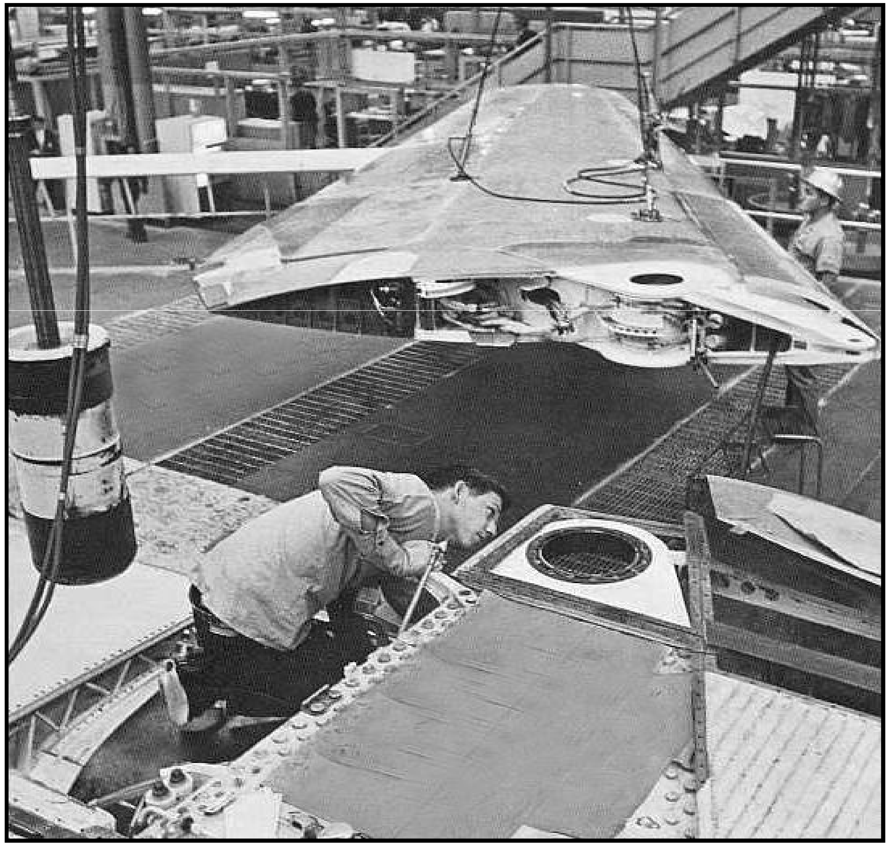
84%

Aerospace Materials & Fasteners

Heat issues

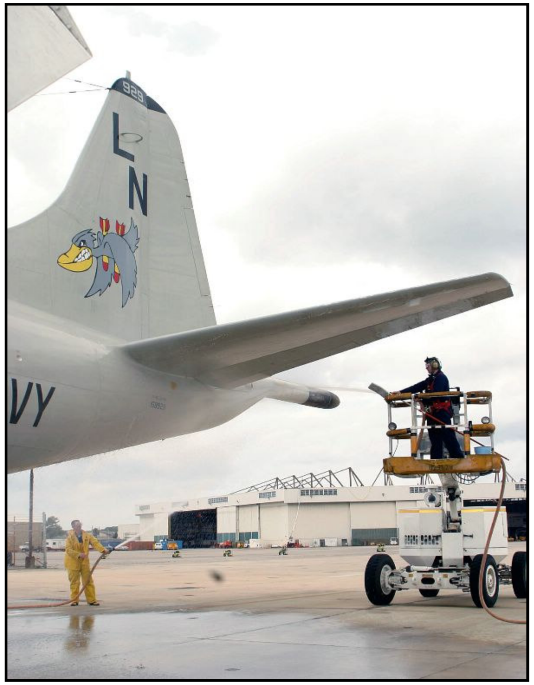


Aerospace Materials & Fasteners



Strength and Space
Issues

Aerospace Materials & Fasteners



Corrosive Environment

Aerospace Materials & Fasteners

Fasteners

- Aerospace fasteners are typically fabricated from aluminum, titanium or steel
- They are designed to exacting standards
  - Design is for shear or tension applications
  - Shear fasteners have a lower profile head
- To produce a consistent product, they are fabricated using proven processes and are subject to tight quality control

Aerospace Materials & Fasteners

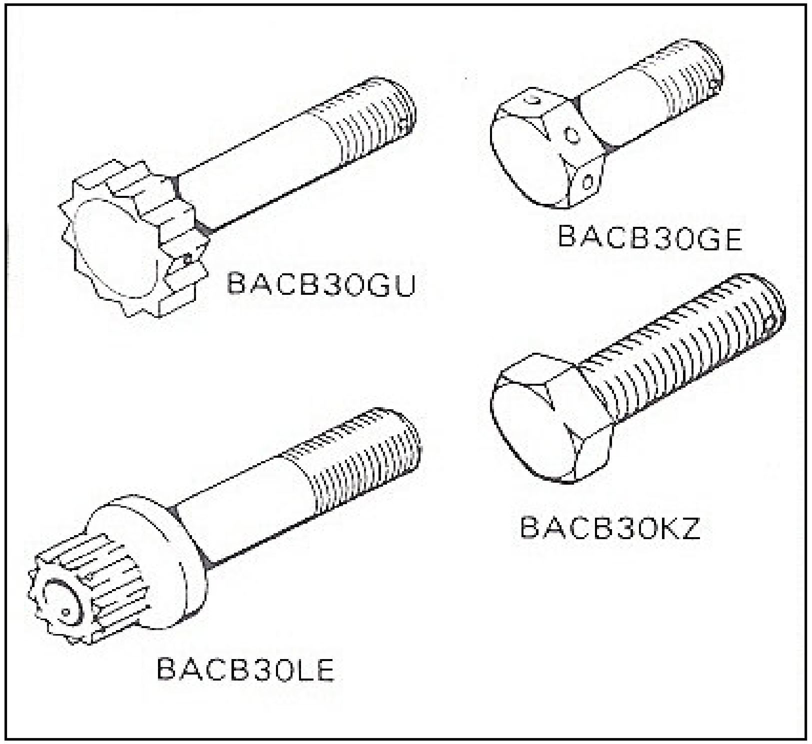
Fasteners

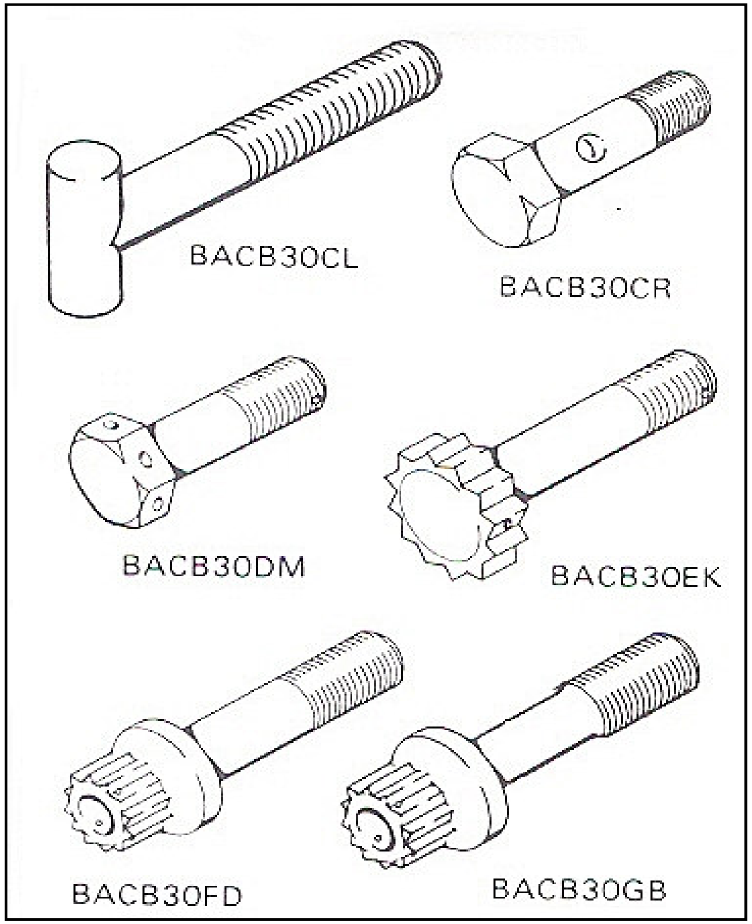
- Broadly speaking, aerospace fasteners may be categorized as permanent or non-permanent
  - A permanent fastener is a fastener that must be destroyed to remove it
  - A non-permanent fastener may be removed non-destructively

Aerospace Materials & Fasteners

Non- Permanent Fasteners

(Protruding Head)

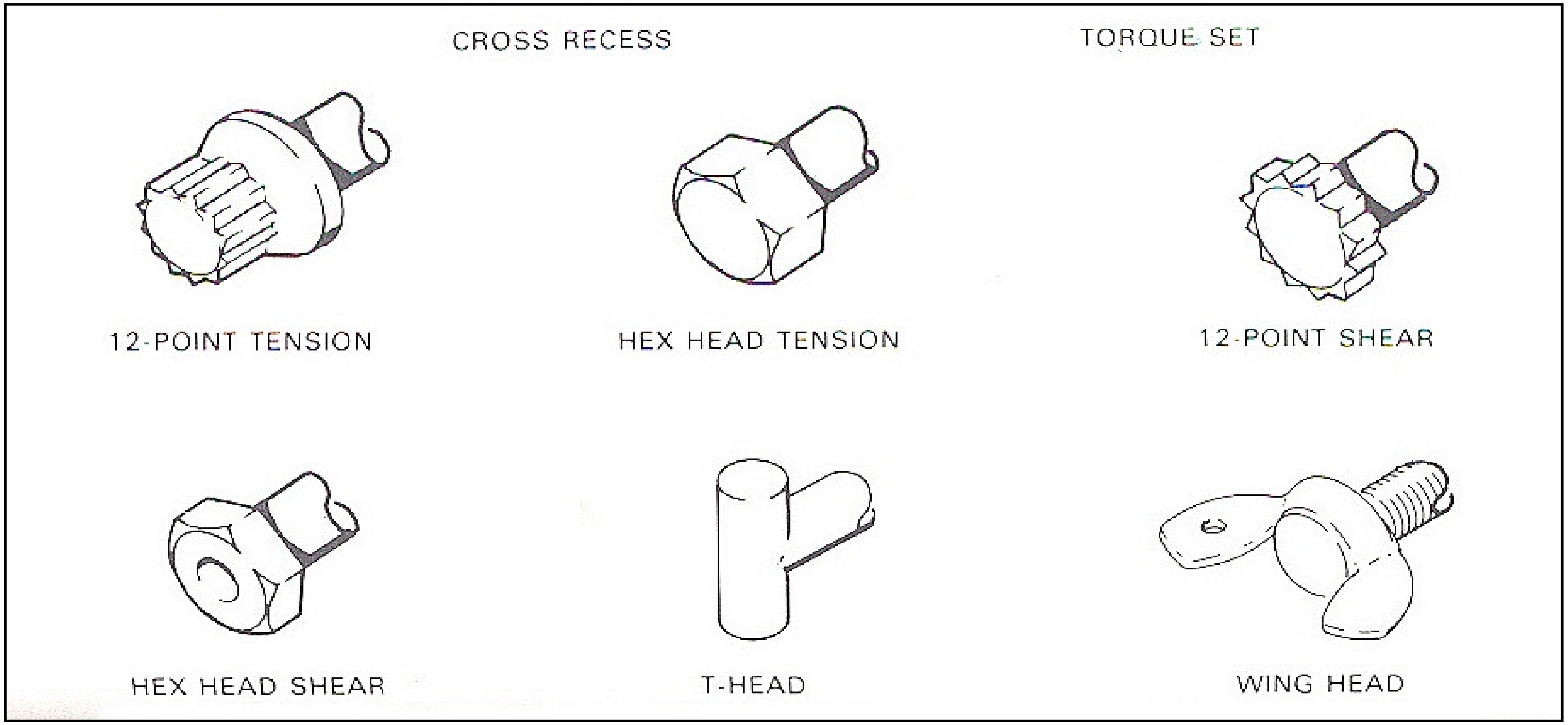




Aerospace Materials & Fasteners

Non- Permanent Fasteners

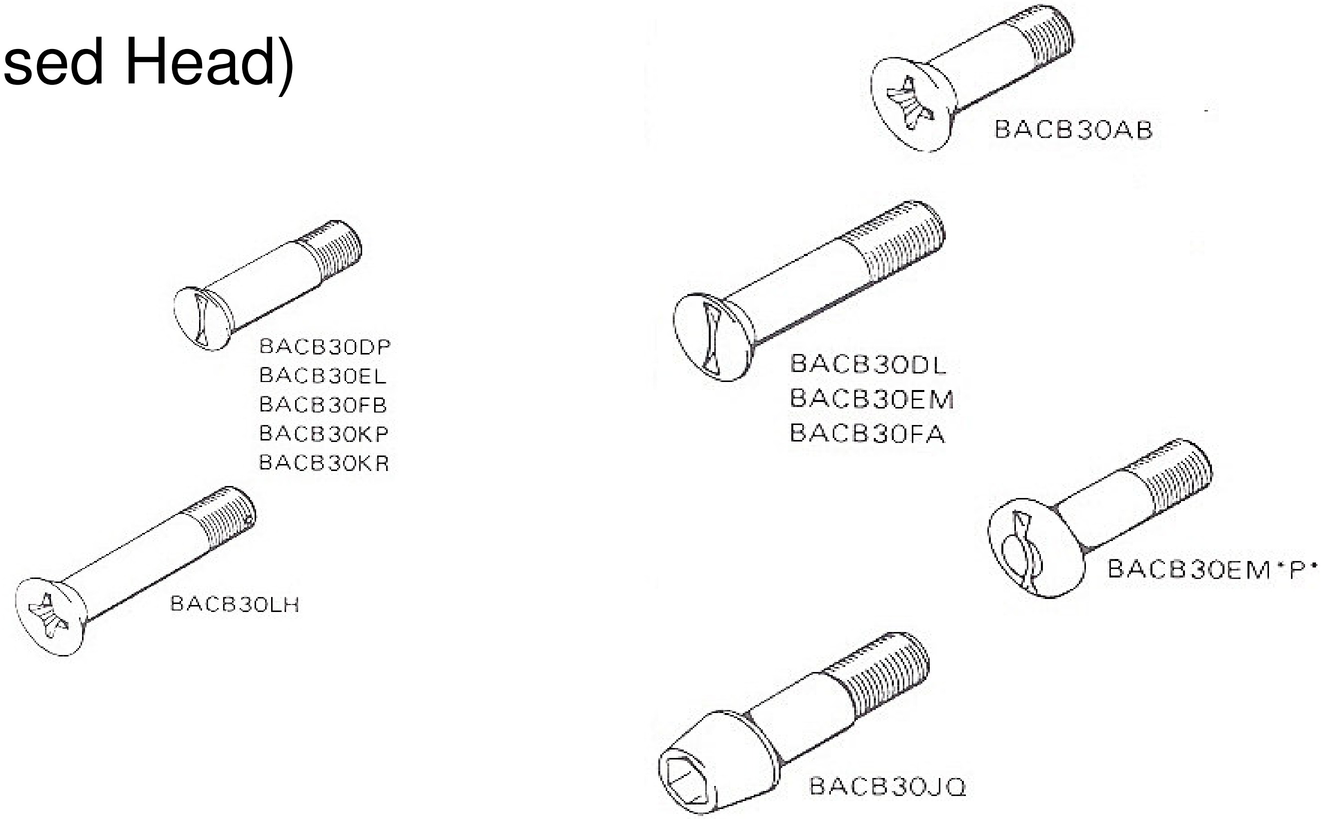
(Protruding Head)



Aerospace Materials & Fasteners

Non- Permanent Fasteners

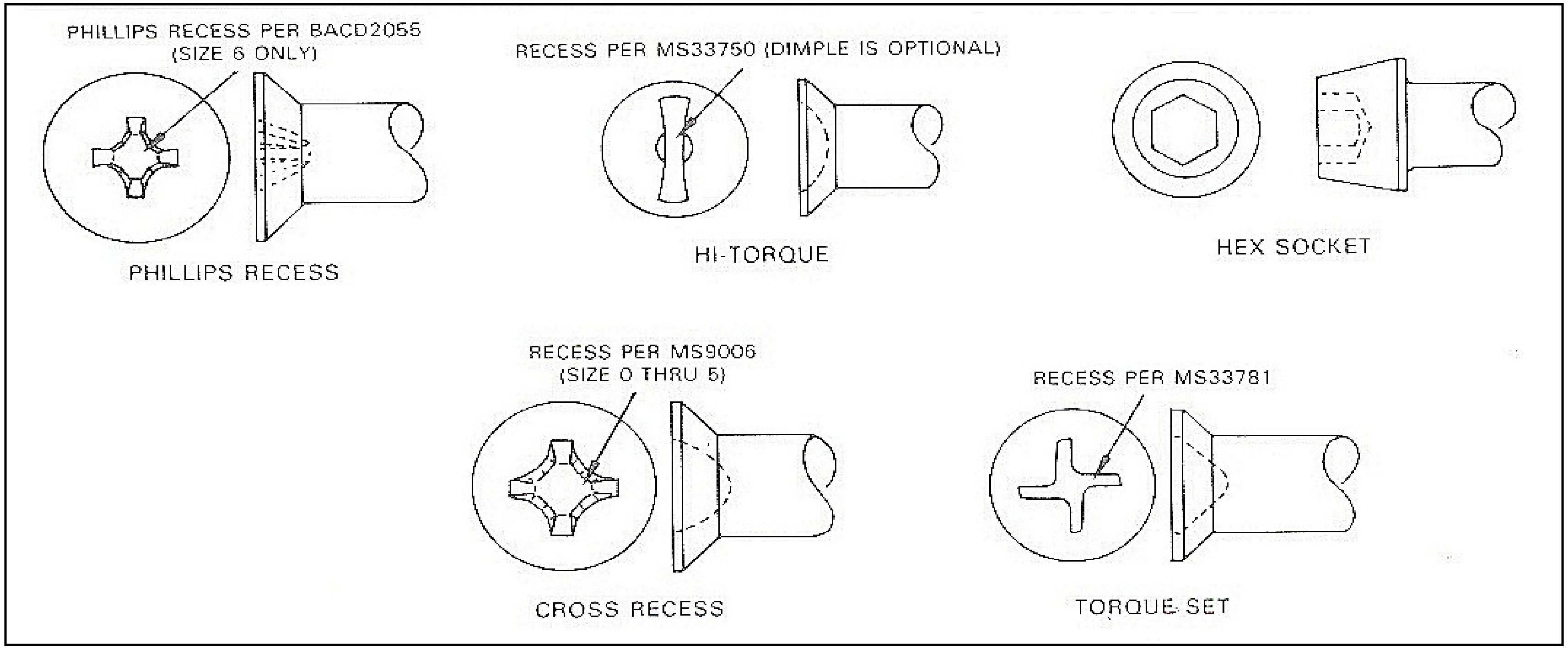
(Recessed Head)



Aerospace Materials & Fasteners

Non- Permanent Fasteners

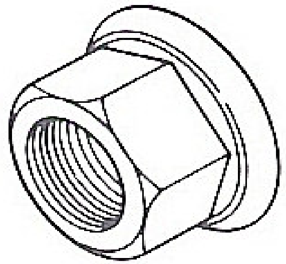
(Recessed Head)



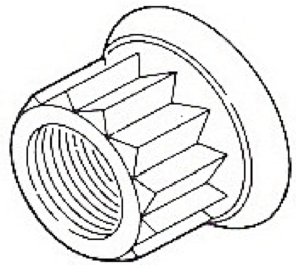
Aerospace Materials & Fasteners

Non- Permanent Fasteners

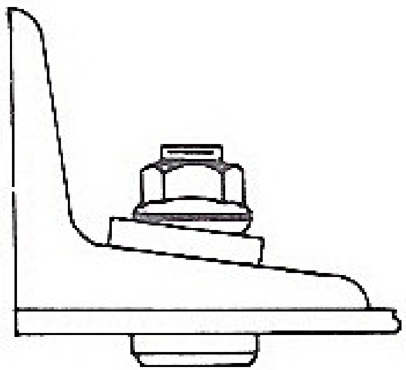
(Nuts)



PICAL HEX NUT
ITH CAPTIVE WASHER



TYPICAL 12 POINT NUT
WITH CAPTIVE WASHER



TYPICAL
INSTALLATION

(Note self aligning captive washer feature at left)

Aerospace Materials & Fasteners

Permanent Fasteners

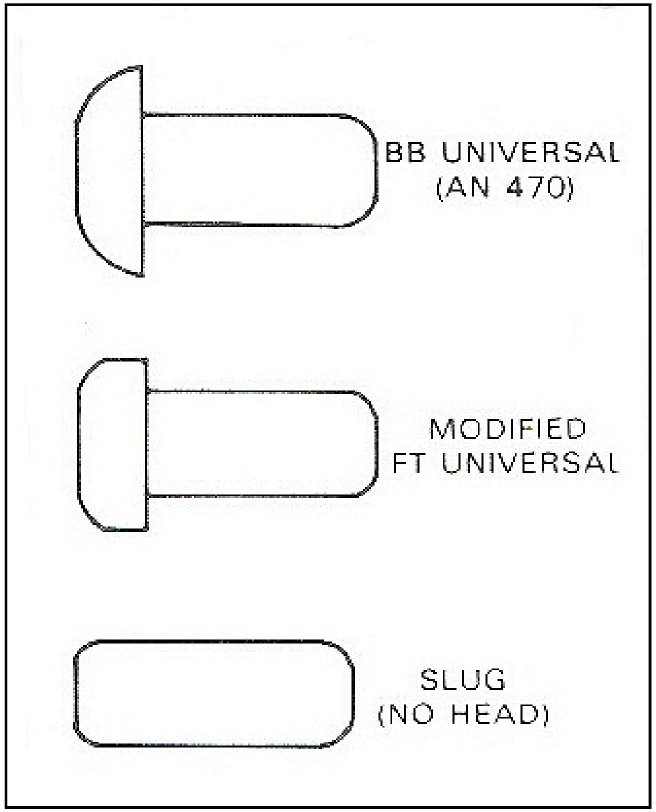
Three broad categories:

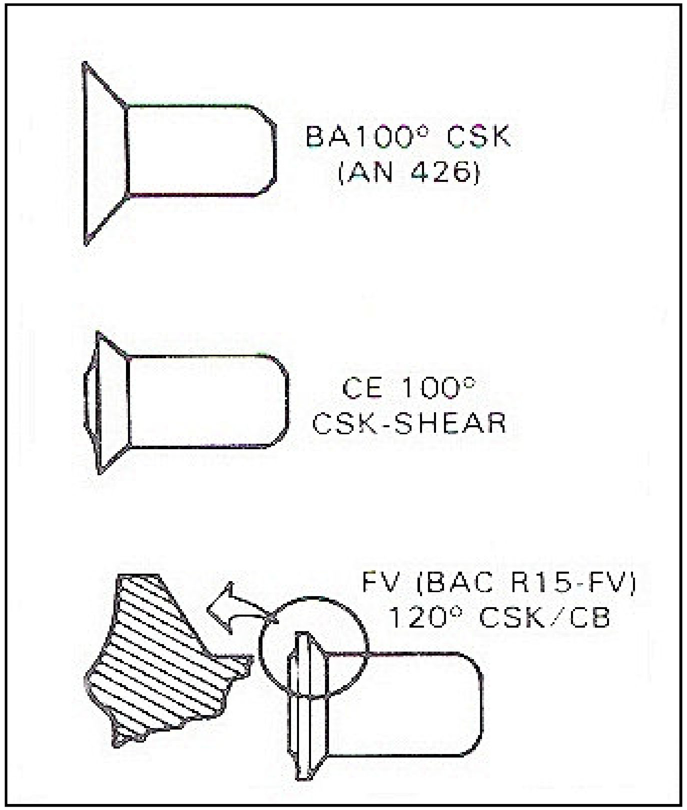
- Rivets
- Locking
- Blind (access only required from one side to install)

Aerospace Materials & Fasteners

Permanent Fasteners

(Rivets)



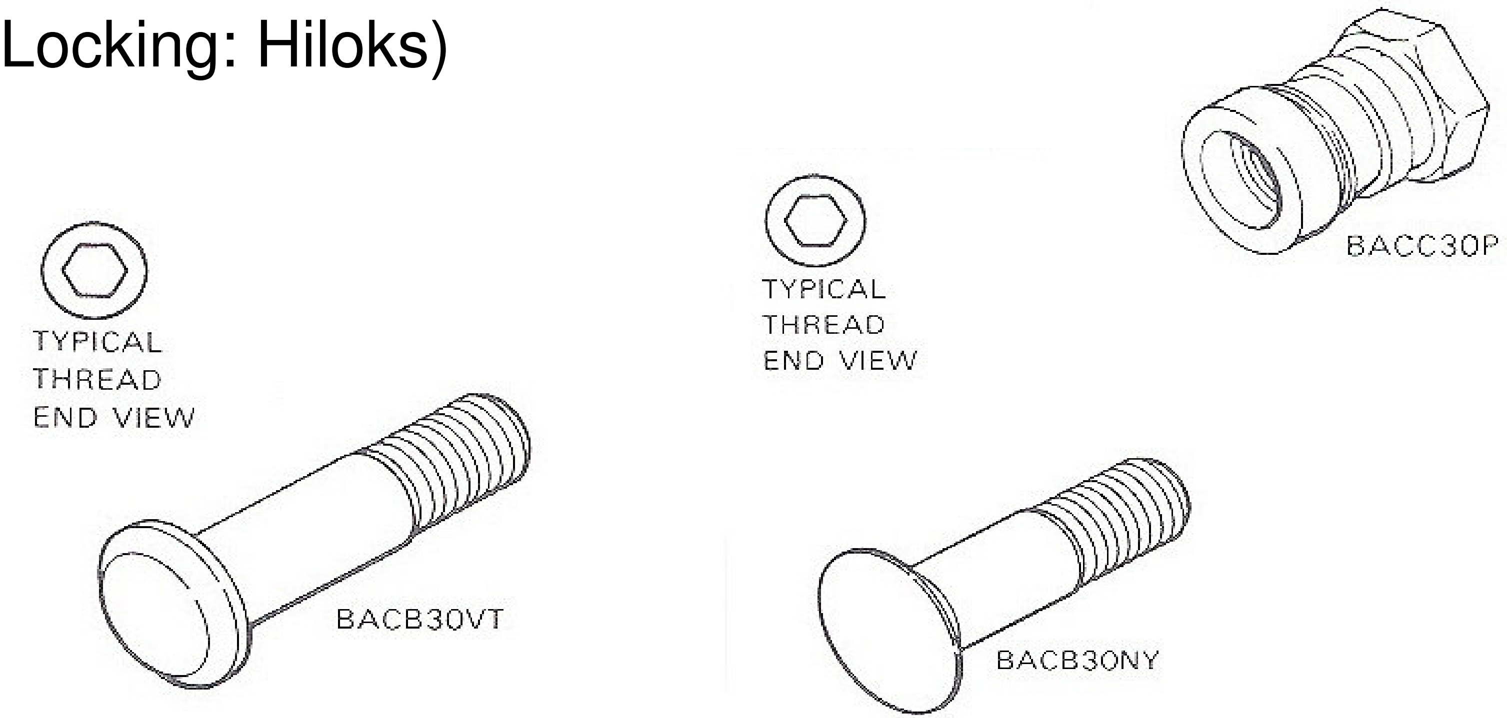


DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

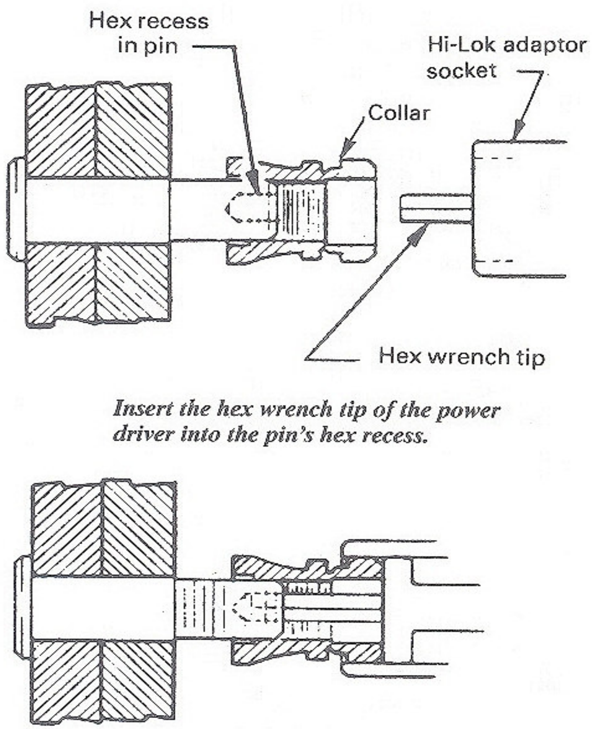
Aerospace Materials & Fasteners

Permanent Fasteners

(Locking: Hiloks)



Aerospace Materials & Fasteners

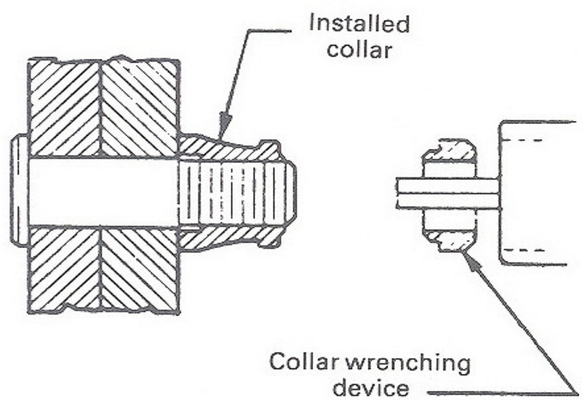


Insert the hex wrench tip of the power driver into the pin's hex recess.

Firmly press the power driver against the collar, operate the power driver until the collar's wrenching device has been torqued off.

Permanent Fasteners

(Locking: Hiloks)

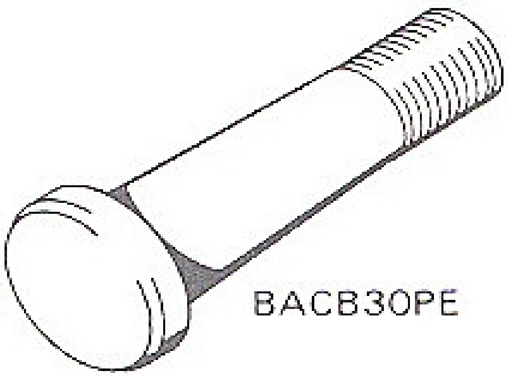


This completes the installation of the Hi-Lok fastener assembly.

Aerospace Materials & Fasteners

Permanent Fasteners

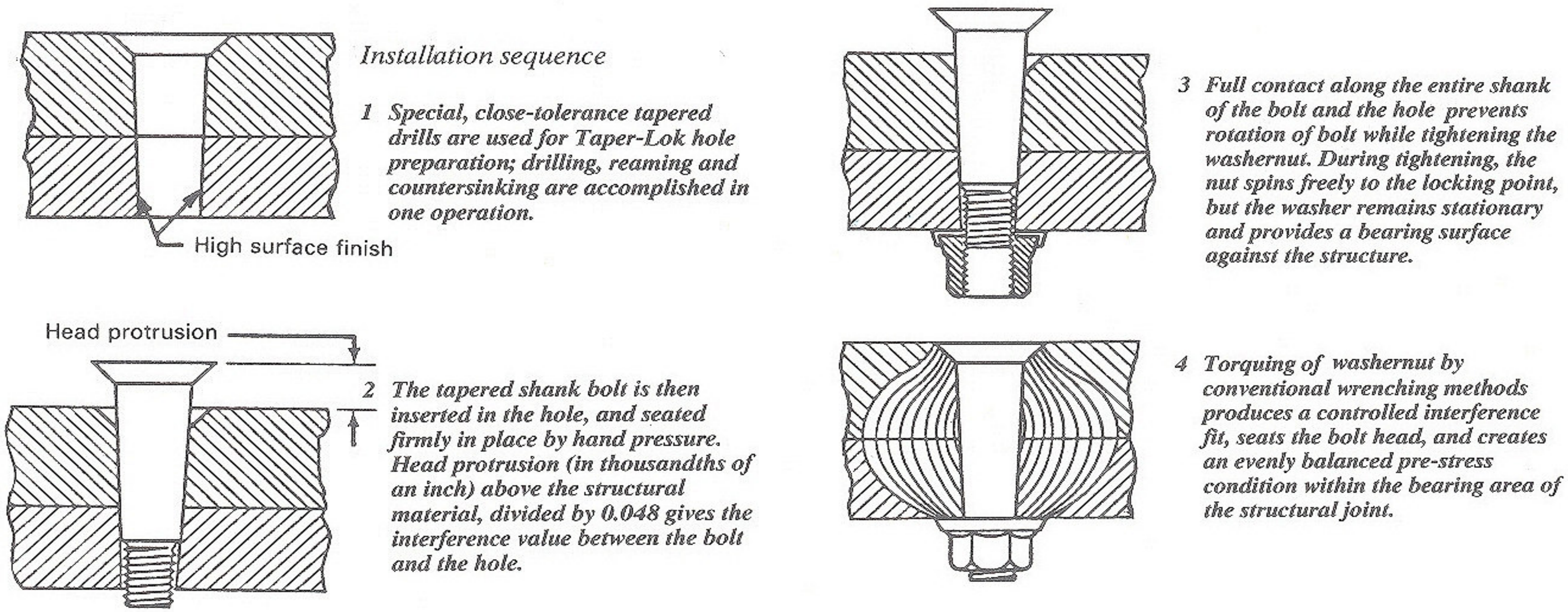
(Locking: Taperloks)



Aerospace Materials & Fasteners

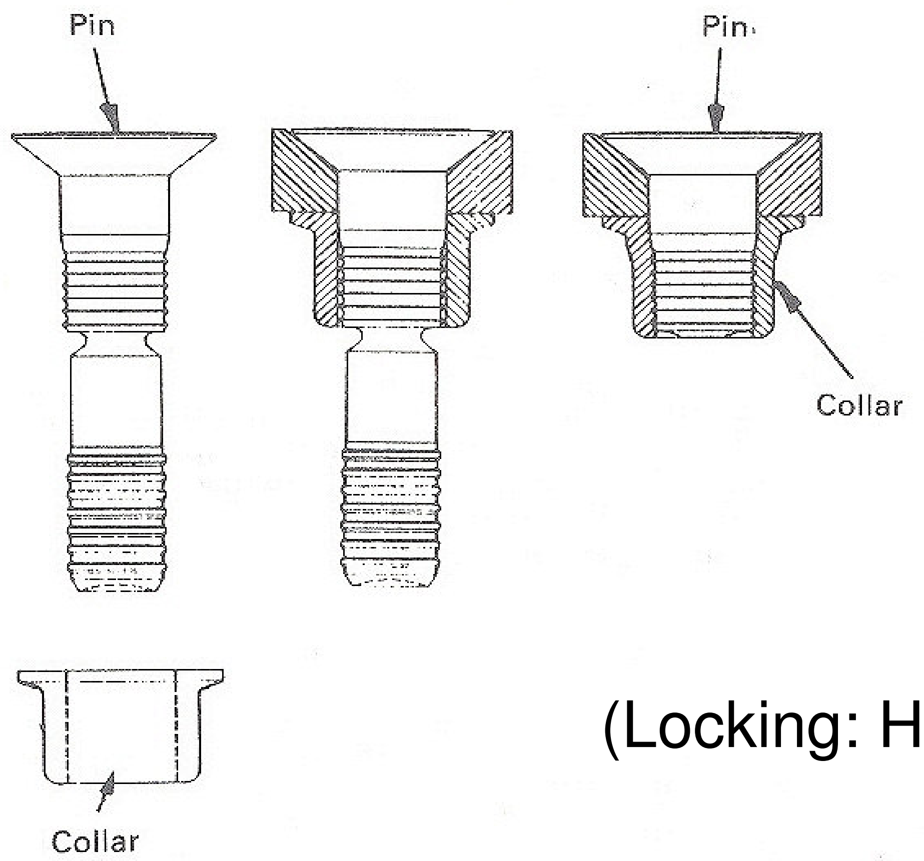
Permanent Fasteners

(Locking: Taperloks)



Aerospace Materials & Fasteners

Permanent Fasteners

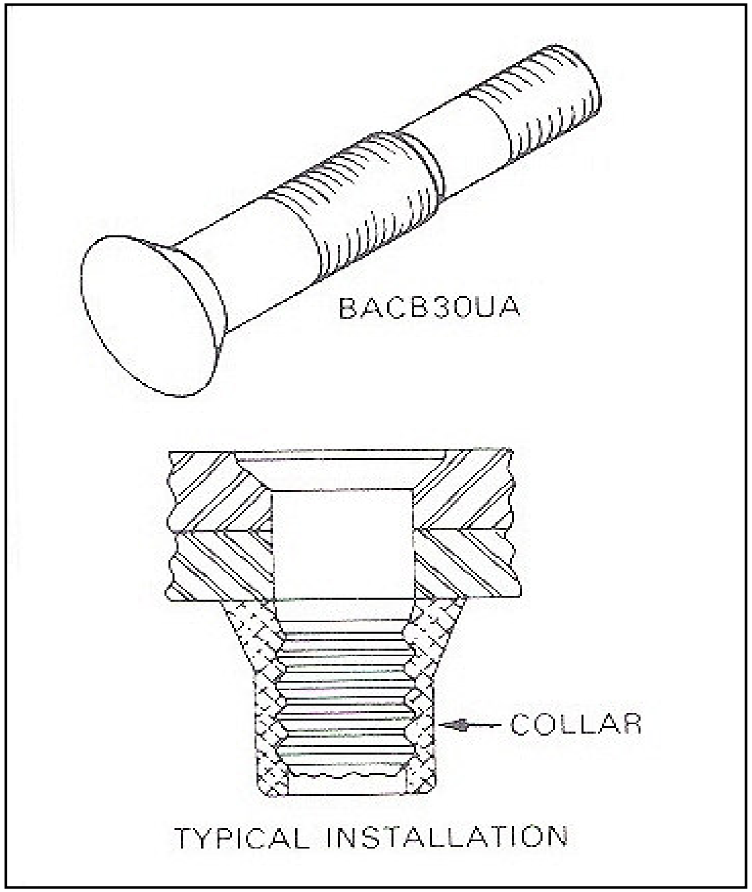


(Locking: Huck)

Aerospace Materials & Fasteners

Permanent Fasteners

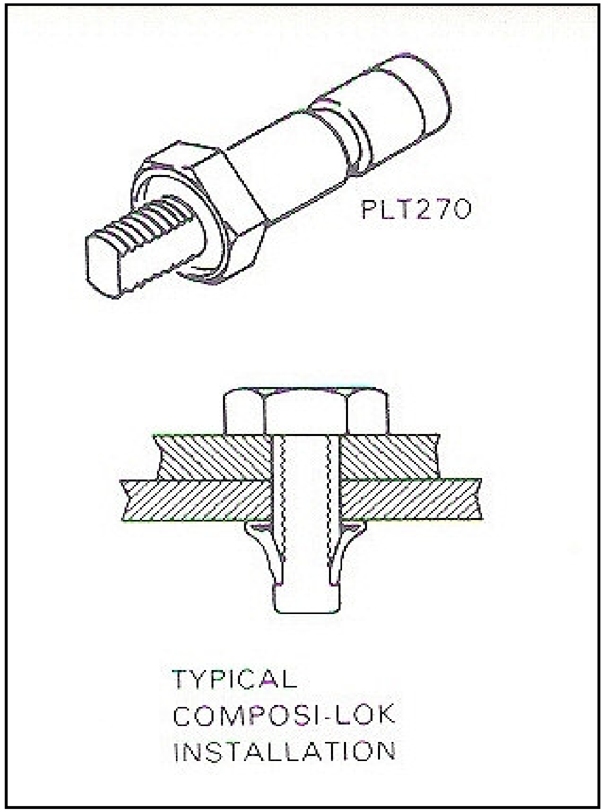
(Locking: Lokbolt)

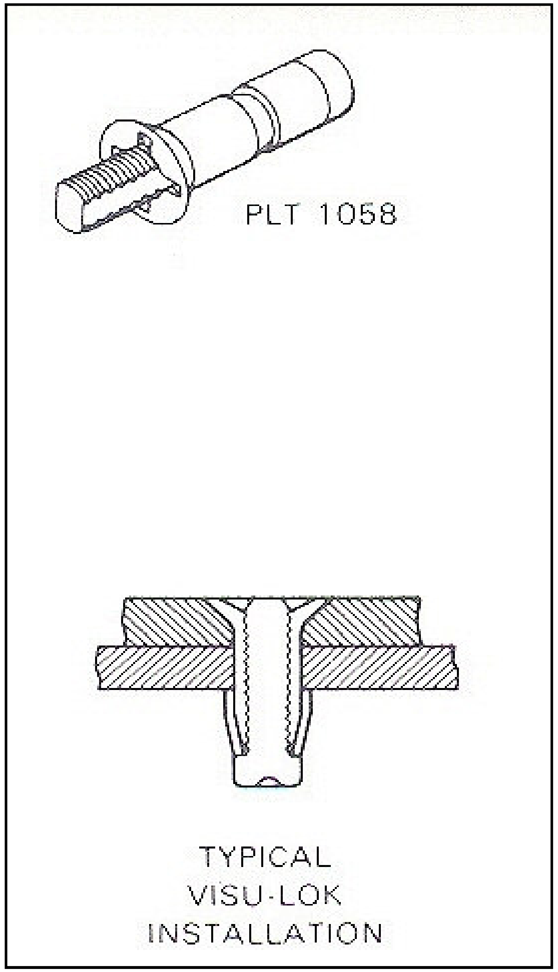


Aerospace Materials & Fasteners

Permanent Fasteners

(Blinds)





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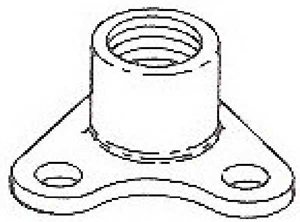
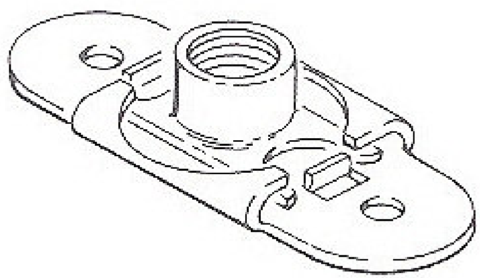
Aerospace Materials & Fasteners

Permanent Fasteners

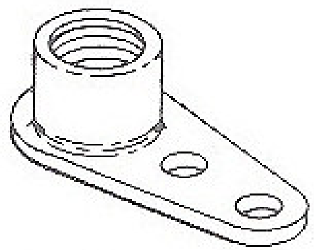
(Nutplates)



NUTPLATE
CORNER TYPE



TYPICAL TWO-LUG
SELF-LOCKING FLOATING

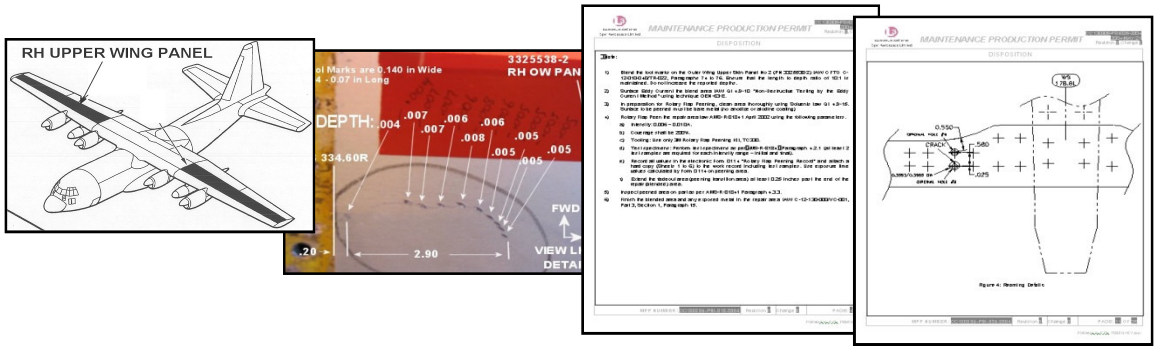


NUTPLATE TYPICAL
ONE-LUG STYLE

Overview

In-service structures will become damaged and will need to be fixed. The following will need to be accomplished:

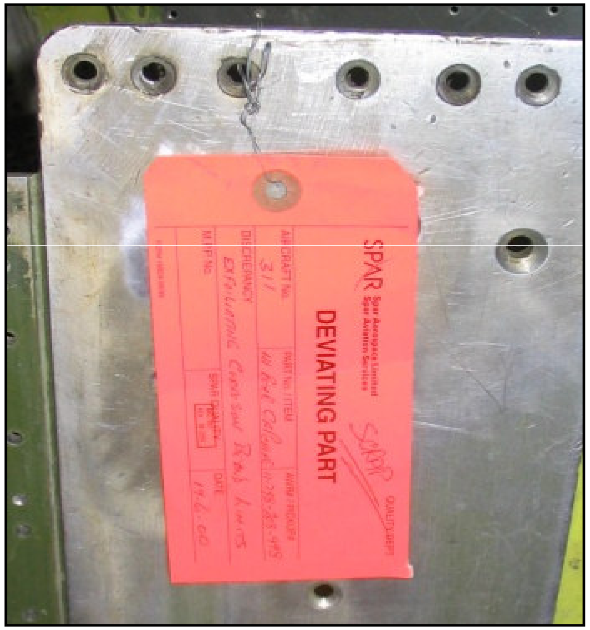
- Damage will need to be assessed
- Damage will need to be cleaned up
- A repair will need to be designed that is adequately strong and durable



Discrepancies

What is a discrepancy?

A discrepancy is any problem which arises on the Aircraft that requires further attention. Some discrepancies may be minor and will require very little work to correct, other discrepancies may require large repairs.



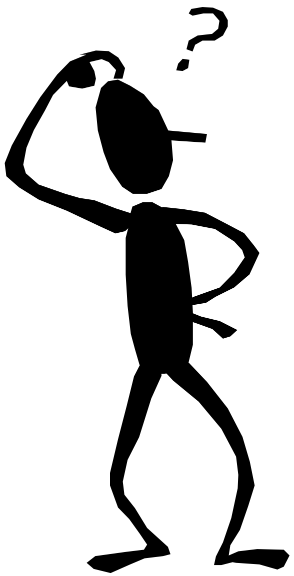
When do discrepancies arise?

The majority of discrepancies are found during inspections which are designed to look at known problem areas using special, proven techniques. However a discrepancy does not necessarily arise from an inspection, at any time when the Aircraft is on the ground problems can be found which require attention.

Where can a discrepancy be found?

Discrepancies may be found at any location on the interior or exterior of the Aircraft. A discrepancy can be of a structural, electrical or Aircraft systems nature.

Discrepancies



When do discrepancies require further attention?

When a discrepancy is discovered and further action is required an investigation is undertaken into standard repairs and approaches to correct the problem. If there are no standard repairs then further action is required.

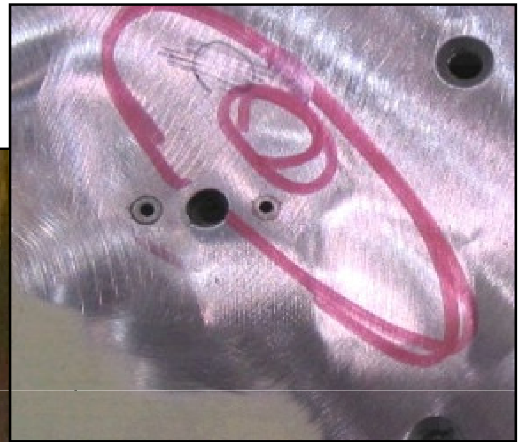
What 'further action' is acceptable?

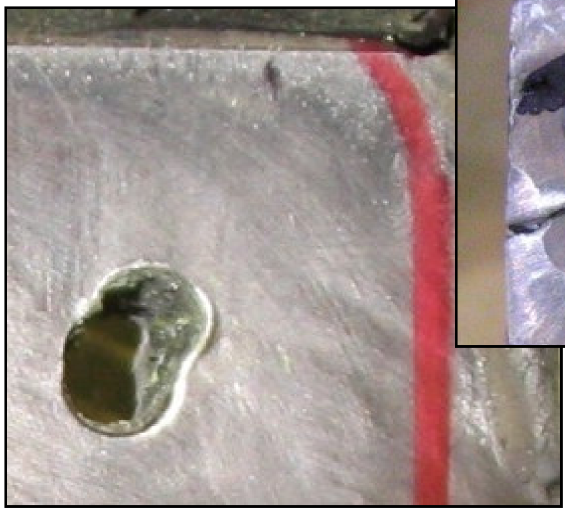
'Further action' does not necessarily mean a repair. Acceptable action includes things such as parts replacement, fastener substitution, minor or major material removal etc. The 'further action' may even be that no further action is required.

Common Discrepancies

Commonly found Structural Discrepancies

Although a discrepancy may take on many forms there a several commonly encountered problems.





Some very common problems that are often discovered are shown. These include mechanical discrepancies caused by poorly installed components; cracks and gouges, dents and scratches. These are not the only discrepancies that occur but they do cover a large proportion.

Know your Aims

Who is it for?

Remember when putting together a discrepancy data package who the audience it. A problem may be approached differently depending on its final destination. Where is the person located? How much experience do they have with the C130 airframe?

Have they seen the discrepancy?

Is the package being put together for a person who has already seen it. In such cases it may not be necessary to go into a great deal of depth.

What is the information to be used for?

The use of information when assessing a discrepancy does vary. Documentation of damage may be used merely as a log for future reference or it may be used to produce a repair. Always work to the worse case scenario but understand what is required.

Will the problem be accessible at a later date?

If any further information is required will the area still be accessible. This may include things such as moving scaffolding or taking the Aircraft to paint. If access may be a problem then try to ensure that every base is covered.

What Information is Needed

You can never have too much information. Type of information needed varies depending of the type of discrepancy. Though damage may vary the following is a guide as to what type of information may be required. Remember to include enough information to fulfill requirements, try to envision the repair.

Where is the damage?
What is the damage?
What caused the damage?
How big is the damaged area?
What envelope is available for any repair?
What physical boundaries must I work within (material type, thickness etc)?
Are there any fasteners or special factors that may affect any repair?

What Information is Needed

Where is the damage?

Give the discrepant part number(s) (including thickness & material type). Often a part will be stamped with a Lockheed part number, the material and a material specification.

Give a general location of the discrepant area (BL, WL & FS). Use known Aircraft datums from which to measure. For example, ring segments along the fuselage are on a 10 inch spacing. There are other notable main bulkheads and stations. Look for stations stamped on surrounding structure.

Damage details?

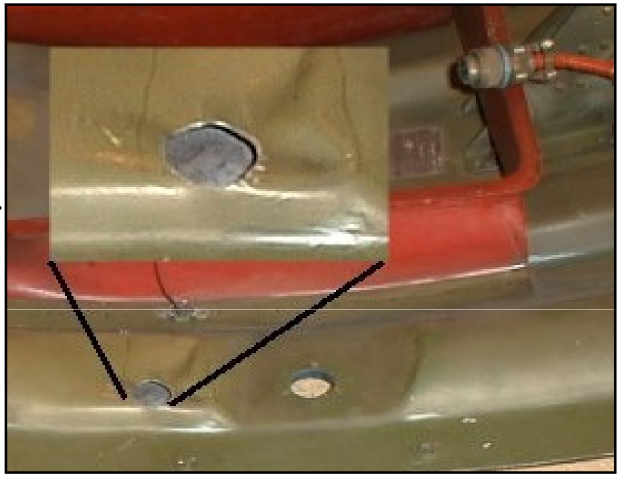
Take photos of the damage and surrounding area.

Give a complete description of any damage. Record types and location of all damage. For blendouts beyond allowed limits, note sizes and depths of each blendout. For cracks, scratches, gouges and dents beyond allowed limits note sizes/lengths and depths for each case.

What Information is Needed

What caused the damage?

In some cases, part of the repair is also prevention. The cause of the problem often comes down to age or environmental factors. However some thought into preventing the problem from occuring should be given. Here a hole was worn into a GTC door by a tube assembly which had been repaired by doublers which had also worn through.



What envelope is available for any repair (surrounding structure)?

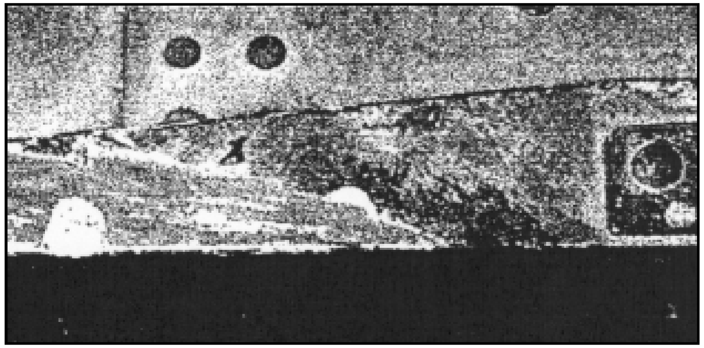
Give any available information on the location and orientation of adjacent structure. This can also include structure that may affect the maximum height of any repair. This kind of information is also very useful since it is common that a repair will require some alteration of surrounding structure.

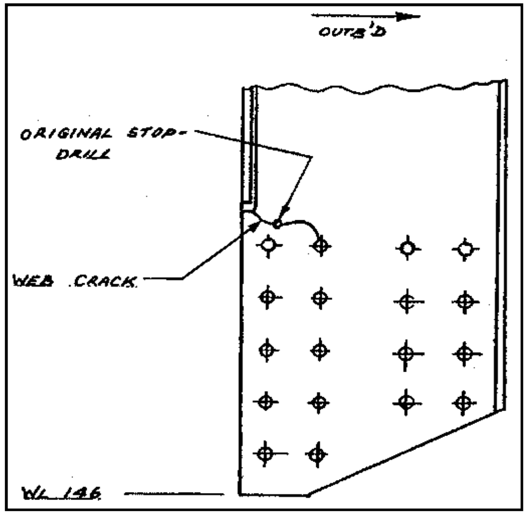
Try to envision what the likely repair is and ensure enough measurements are taken which may be necessary. For example, a damaged web may require a new portion of web be spliced in. Where may this take place?

Methods for Recording Damage

There are 3 primary methods for recording data...

- **Photographs**
- **Aircraft Rubbings**
- **Drawings/Sketches**



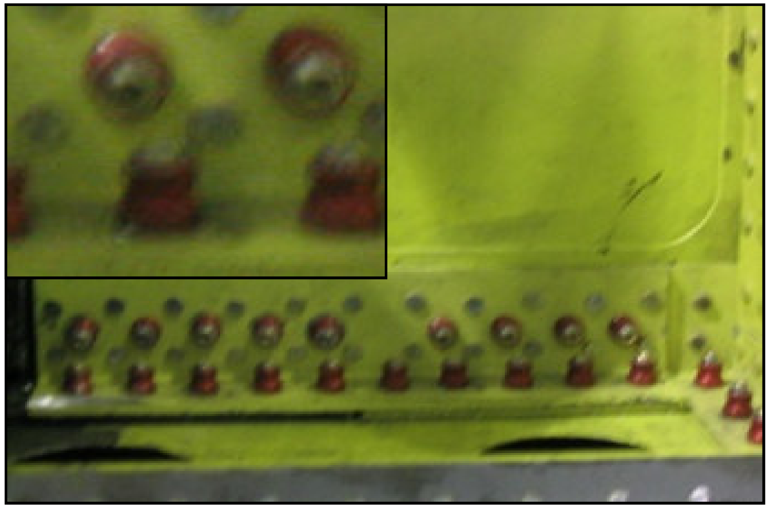


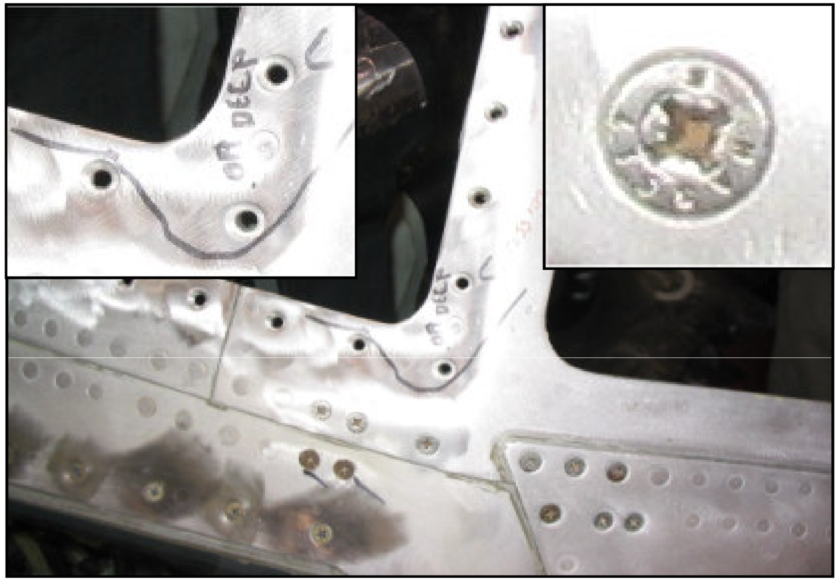
Tips on Photos…

Try to use as high a resolution as possible. This may prove valuable should you need to see an area in more detail (Even reading codes on fastener heads). Scale pictures in documents to reduce filesizes.

Don't be afraid to mark the Aircraft (drawing circles around corrosion, write fuse stations, blendout depths etc)

Remember that you may only get one chance to record damage and relevant info.



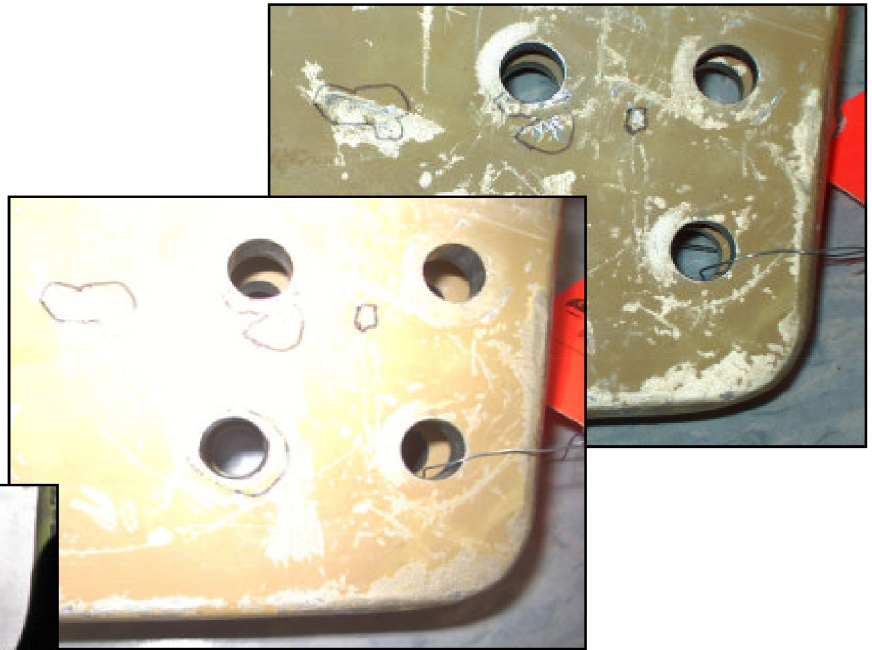


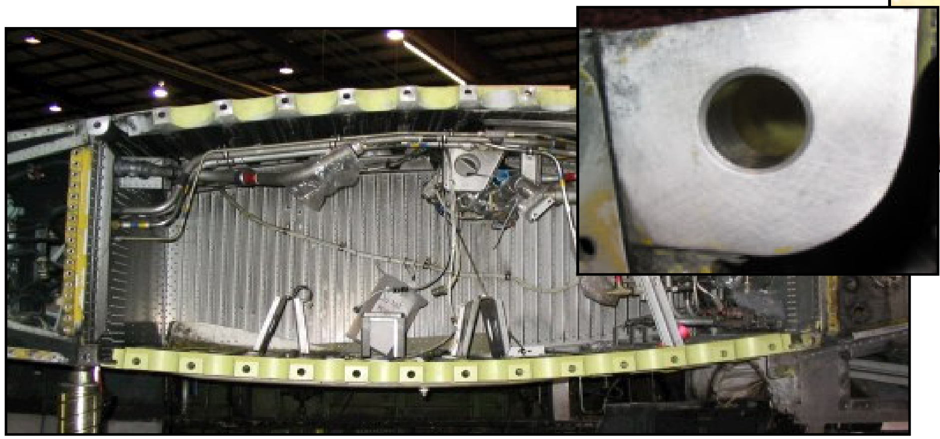
Ensure the camera is on the correct setting. Sometimes the preview on the LCD seems good but it may be out of focus or blurred if the setup is not right. Download and check photos as soon as possible to ensure they are what you want.

Tips on Photos…

Photos are free! Take photos from close up and from a distance away and from differing angles showing differing levels of detail. Sometimes surrounding structure can assist with working out loads and materials.

Try to take a top view and side view to give an idea of size and depth.





When taking a photo, beware of flashback which can distort or hide a lot of detail.

Take photos of any part numbers written on parts around the area.

Tips on Aircraft Rubbings…

Although photographs give the ability to visualize and see detail around an area it does not give any idea of size. An Aircraft rubbing gives something physical that can be scaled.

You will need as large a piece of paper as necessary, a sharp pencil, eraser, tape and a tape measure.

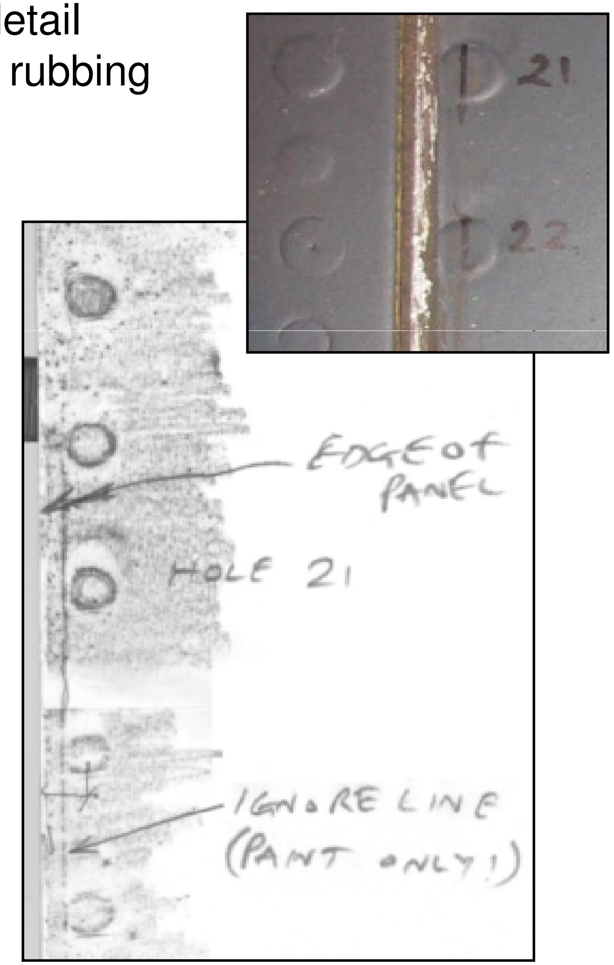
Ensure areas is clean (ie a line of old sealant may end up looking like the edge of the skin)

Secure the paper well with tape. Try to overlap a significant datum (such as a skin splice) to give something to work to. Sometimes when working with skin panels the edge of the paper can be lined up with the edge of a skin.

Mark on inbd/fwd etc to give an orientation and add some reference dimensions (edge distances, removal depths, label parts etc).

Label fasteners as a cross reference with any photos (mark fasteners on photo too!).

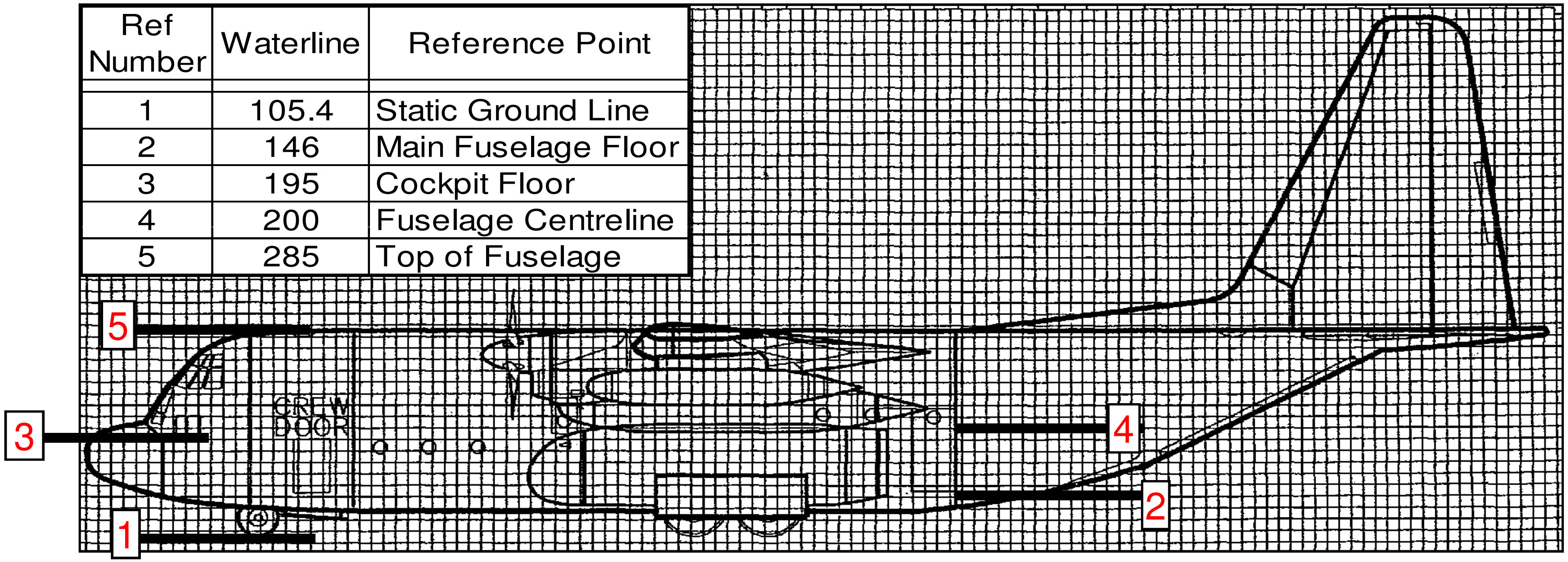
If anything strange appears when rubbing, find out what it is and label it to avoid any confusion ("edge of panel", "paint only" etc).



Reference Points

There are certain datums that can be used for the purpose of determining a location for a discrepancy. In many places on the C130 certain stations have a constant spacing and some are labeled. This is especially true of Fuselage Stations.

Ref Number	Waterline	Reference Point
1	105.4	Static Ground Line
2	146	Main Fuselage Floor
3	195	Cockpit Floor
4	200	Fuselage Centreline
5	285	Top of Fuselage

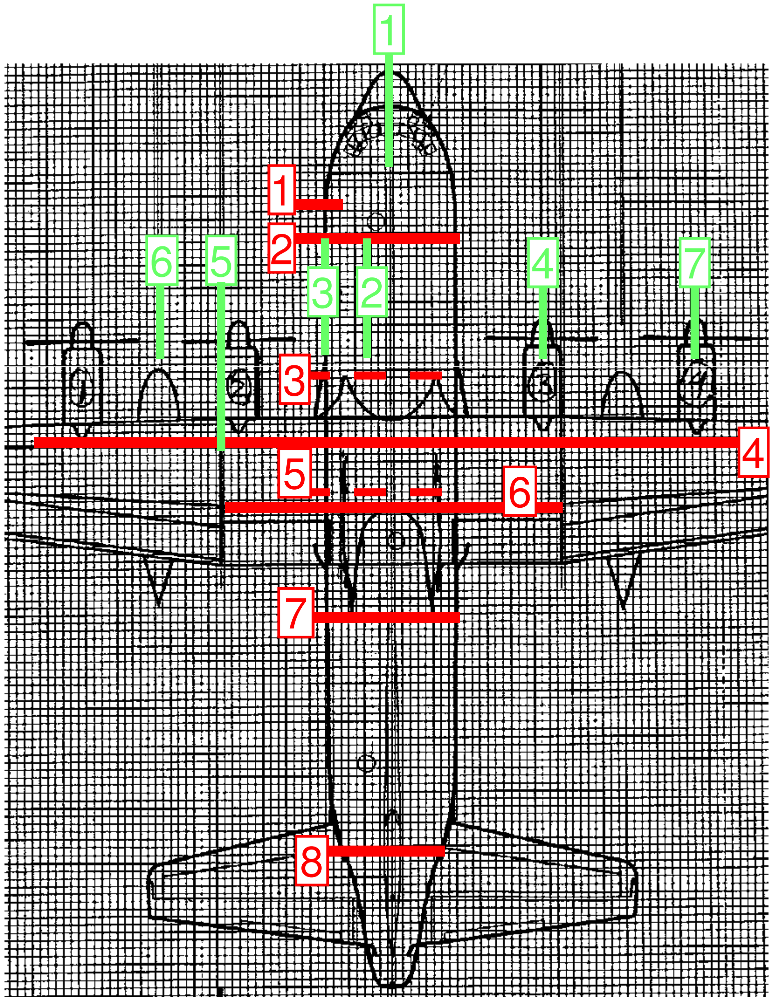


Spacings to note:

Centre Fuselage Floor main bulkheads are on a 20 inch spacing (277,297,317 etc) with a stiffener located at the mid-point (287, 307 etc).

Centre Fuselage Ring segments are on a 20 inch spacing (277,297,317 etc) with two further Ring Segments equi-spaced in between (284, 290 etc).

Reference Points



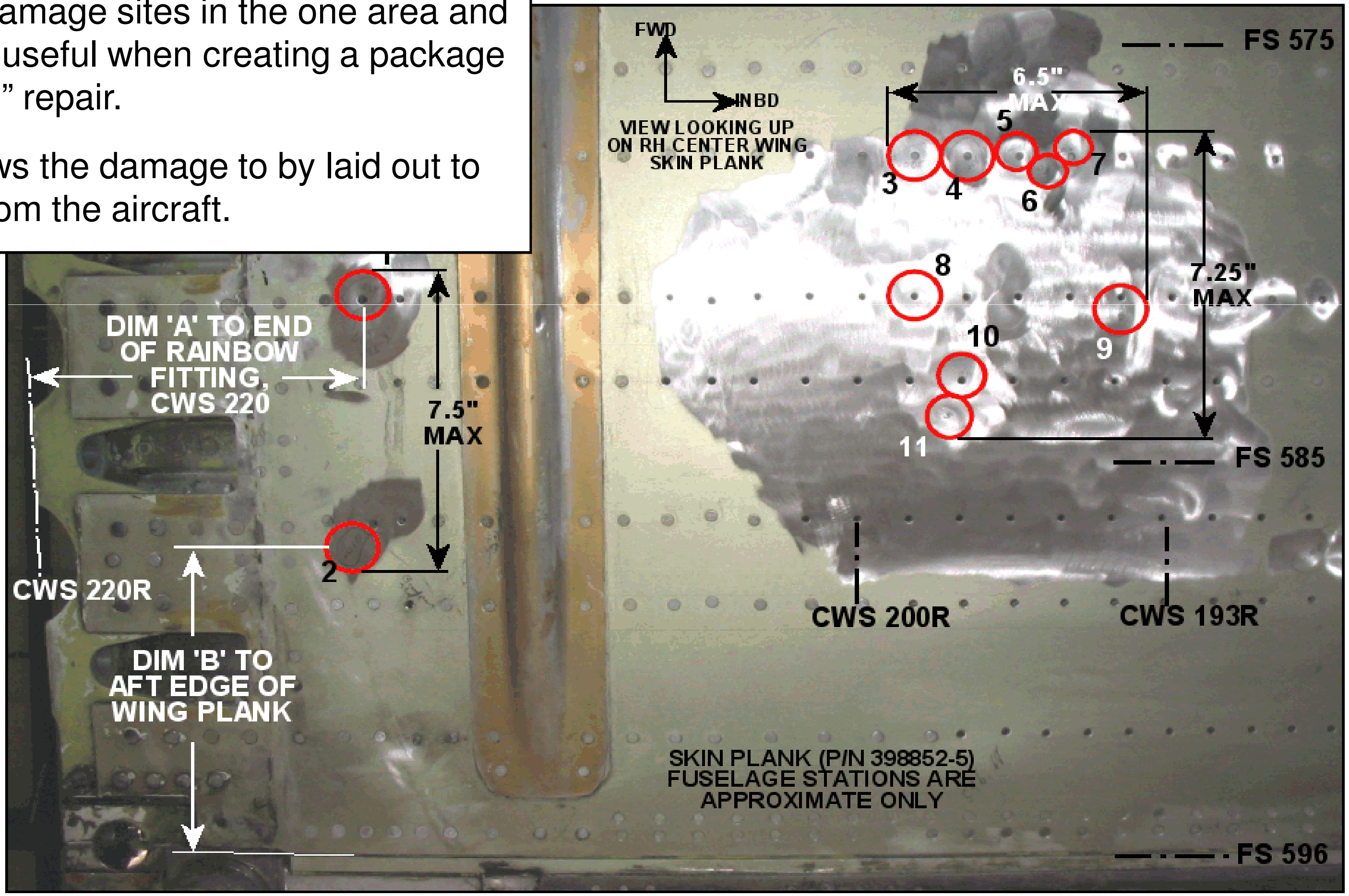
Ref Number	Fuse Station	Reference Point
1	204	Forward Post of Crew Door
2	245	Main Forward Bulkhead
3	417	Floorboard Joint
4	517	Forward Wing Beam Web
5	577	Floorboard Joint
6	596.68	Aft Wing Beam Web
7	737	Centre Fuse Aft Bulkhead
8	1041	Aft Fuse Bulkhead

Ref Number	Butt Line	Reference Point
1	0	Centreline of Aircraft
2	20L/R	Upper Fuselage Longeron
3	61.62L/R	MLG Wheel well web Main Fuse Longeron
4	180L/R	Engine 2/3 Centreline
5	220L/R	Wing Joint
6	301L/R	Pylon Centreline
7	400L/R	Engine 2/3 Centreline

Damage Mapping

Damage mapping is necessary when there are multiple damage sites in the one area and is particularly useful when creating a package for an "off site" repair.

Mapping allows the damage to by laid out to scale away from the aircraft.



Damage Mapping

Aircraft XXXX - RH Center Wing Corrosion

Locations and Depths of Damage on RH Lower Aft Plank, Center Wing

DAMAGE AREA REFERENCE NUMBER	DISTANCE FROM EDGE OF RAINBOW FITTING, FS 220 DIM 'A' (INCHES)	DISTANCE FROM AFT EDGE OF SKIN PLANK, DIM 'B' (INCHES)	Material Removed
1	8.5	15	0.024
2	8	8.5	0.010
3	21.5	18.25	0.005
4	22.75	18.25	0.014
5	23.75	18.25	0.012
6	24.25	18	0.013
7	25	18.25	0.014
8	21.25	14.75	0.010
9	26.25	14.5	0.010
10	22.5	12.75	0.014
11	22.25	11.75	0.015

Tips for Damage Mapping:

- Get official measurements (mark on the Aircraft for clarity).
- Take photos of the damaged area with “below limits”damage highlighted and measurements shown.
- Label each discrepant zone.
- Take co-ordinate measurements from know datums to each labeled zone (accuracy is not critical).
- Measure any areas of grouped damage which may likely be covered by one repair.
- Generate a damage table such as the one shown and label the photo with all necessary data, including an orientation.

Discrepancy Example

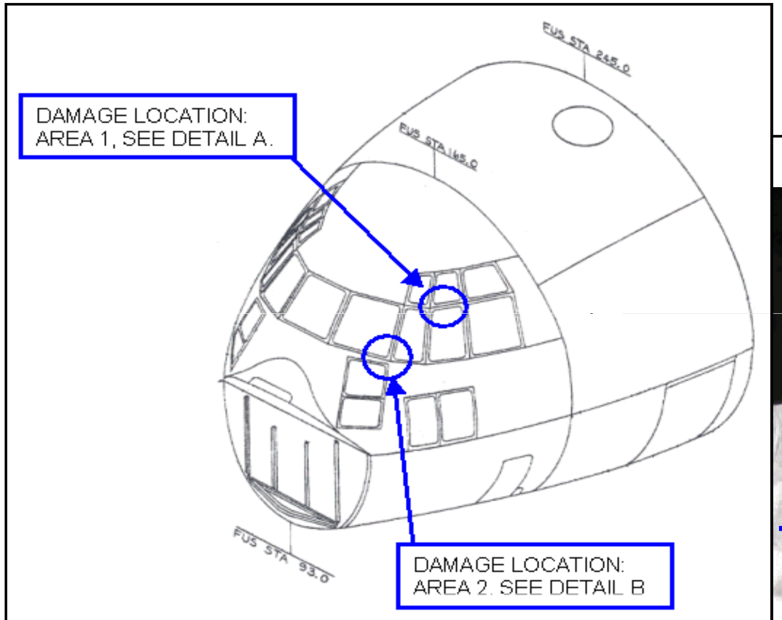


Figure 1 (Sheet 1 of 3): Damage Location

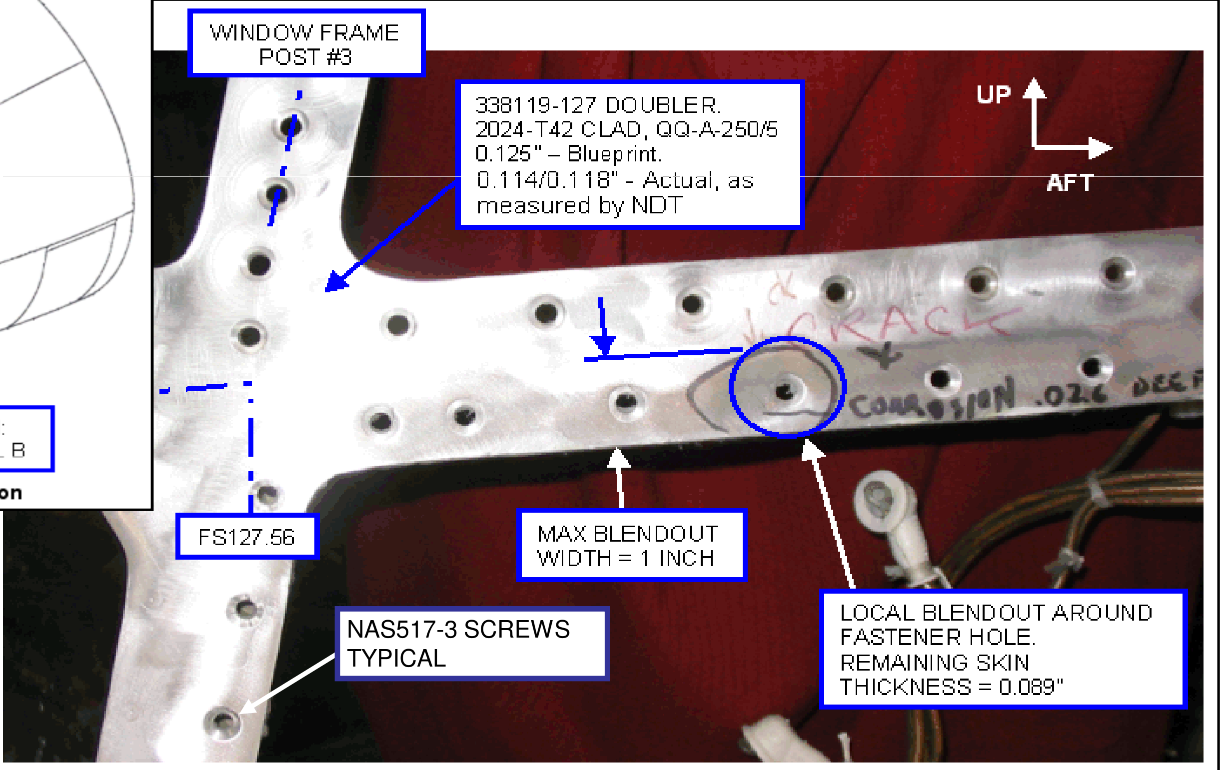


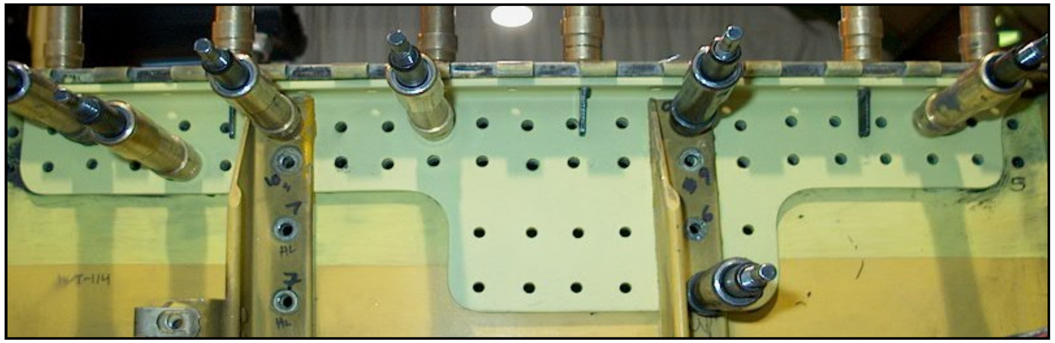
Figure 1 (Sheet 2 of 3): Damage Location
Area 1 - Detail A

Repair Manual

The 'Repair Manual' one book that contains typical metal repairs which are based on ultimate strength of materials.

The following general rules apply to typical repairs:

- General repairs should not be used to repair damage for which a specific repair has been issued.
- Do not use general repairs in restricted areas.
- Do not use general repairs for highly loaded members in primary structure; main spars, longerons, frames in fuselage openings, heavy extruded stringers, structural members supporting fittings and hinges. These sorts of components will require specific repairs.



Restricted area definition:

The areas in the vicinity of hinge fittings and their attachments, major component attachments and reinforced cutouts, eg entrance doors, cargo doors, inspection doors and access apertures are classified as restricted areas.

The stress and/or alignment tolerances preclude the use of typical repairs in these areas.

Damage & Inspection

Although it may not directly affect any repair design, the information given on damage investigation and inspection is interesting reading and may help when interpreting the cause and importance of damage. Damage and inspection looks at:

When to Inspect.

An inspection isn't only carried out when you're stood by the Aircraft. Inspection should begin as soon as the Aircraft is within eyesight. "Misalignment, asymmetrical shape, effect of light reflection on a buckled surface and other discrepancies may be seen at a distance and yet be quite unnoticed at close range".

What to look for.

Typical damage (corrosion, fatigue, fire etc) and what the tell-tale signs are to indicate such damage (loose rivets etc).

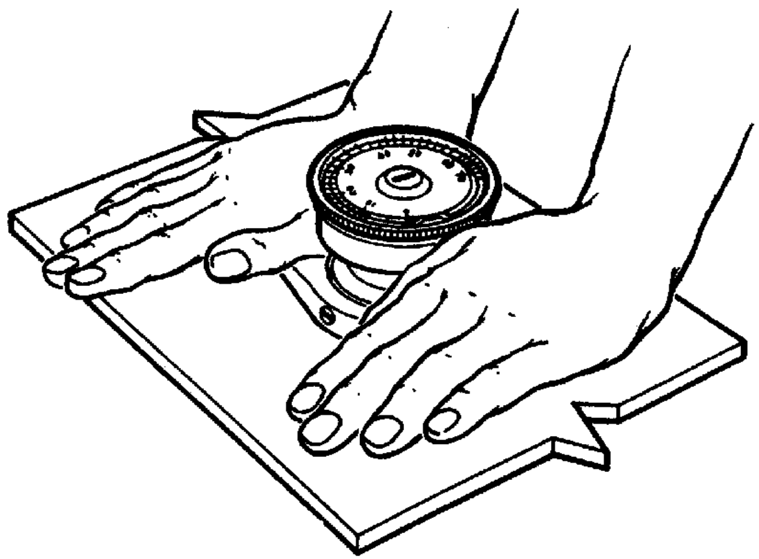
Damage & Inspection

Damage Relevance

Damage may appear the same but its severity may alter depending on its location. A hole in the fuel tank will have more severe consequences than a hole in a wing fairing. Also, damage which appears insignificant, such as a loose rivet or wrinkled skin may be the result of a more severe problem.

Types of Testing

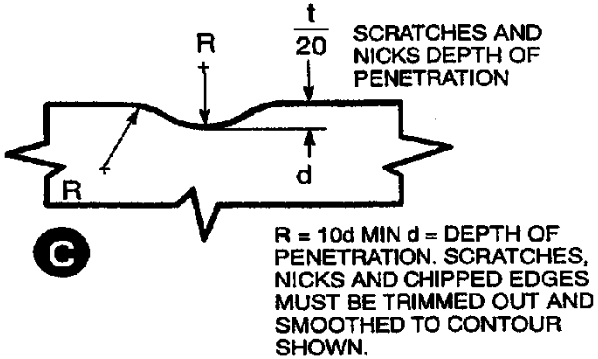
Many tools are available to assist when gathering data. The Repair Manual shows methods and applications for varying types of inspection and Hardness testing as well as test methods to find breaks in cladding and plating.



DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

Treatment of Negligible Damage

The Repair Manual gives simple definitions to the treatment of scratches, dents and other negligible damage. Not only are damage limits given but some of the reasoning behind them is given. When repairing a damaged area it is important to know how the type of damage affects the structure.

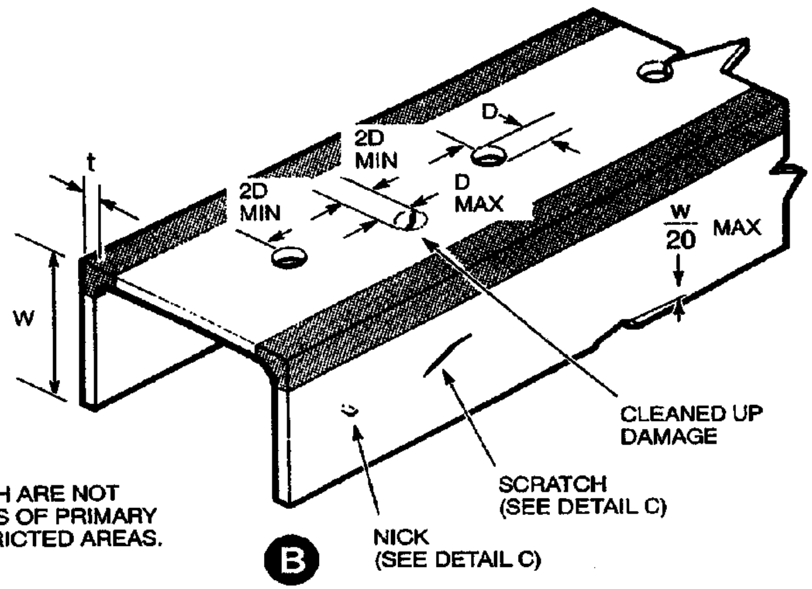


STRESS CONCENTRATION BEFORE BLENDING

STRESS CONCENTRATION RELIEVED BY BLENDING

LIMITATION

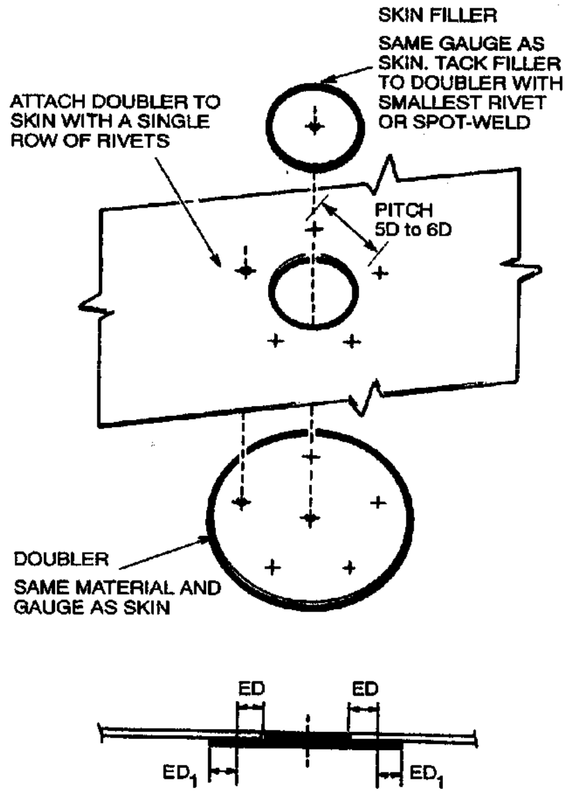
CRACKS OF ANY LENGTH ARE NOT PERMITTED IN MEMBERS OF PRIMARY STRUCTURE AND RESTRICTED AREAS.



Treatment of Negligible Damage

The Repair Manual lay out how damage should be treated from a repair perspective.:

- Scratches that exceed negligible damage limits must be considered as cracks.
- Nicks are similar to scratches except that the direction of failure has not been established. A nick has an effect similar to the cross-sectional loss of a bolt or rivet hole.
- Dents are merely displaced material but are more a cause for concern under compression loads.
- Cracks always require rework since they terminate at a point of zero radius. The longer they get the worse the stress concentration.
- Holes reduce cross sectional area but are often acceptable based on surrounding geometry in the part.

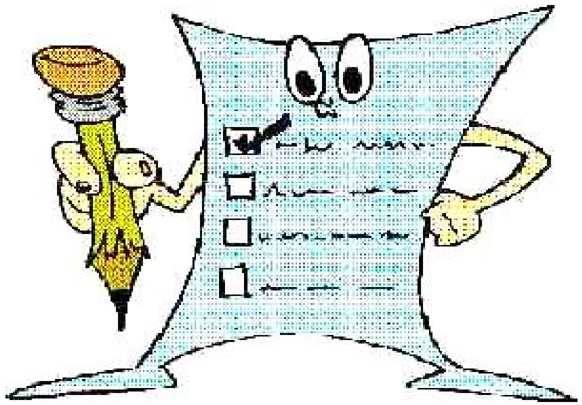


Various Instructions are given to plug a hole that is within limits.

Repair Instructions

Requirements of a Repair:

- The repaired structure must be equal to, or greater in strength than the original.
- The repaired structure must continue to perform its particular function.
- The repair must maintain aerodynamic performance as closely as possible.
- It must not interfere with the operation of any moving part.
- Normal precautions against corrosion must be taken.

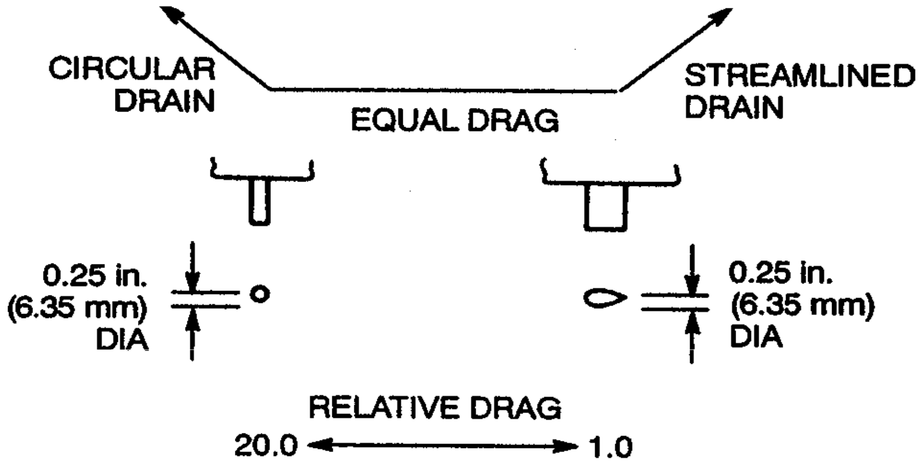


Basic instructions regarding the correct procedures for the installation of a repair are given (eg ensuring required areas are sufficiently supported, sealing etc). The Repair Manual gives a very basic outline but the information is useful as a guide as to which steps should be followed.

DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

Repair Instructions

Useful information on the weight of repairs and 'Drag' and the effects that protrusions and shapes make to the aerodynamics. Figures show how to optimise designs to minimise the effects of drag. There are also figures and instructions on how to perform a balance check of flight control surfaces.

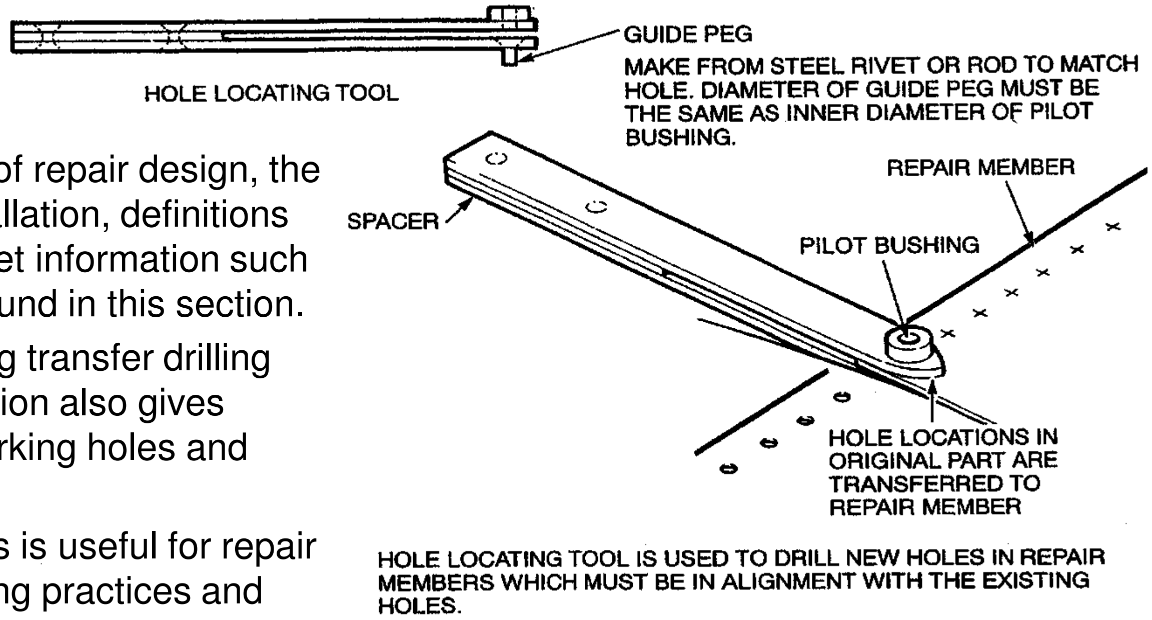


COMPARATIVE DRAG OF VARIOUS TYPES OF DRAIN PIPES

The 'repair materials' section has some details of heat treats and tempers but is not really relevant to repair design.

RELATIVE DRAG IN VARIOUS TYPES OF SKIN REPAIRS

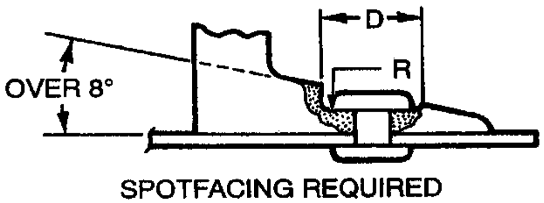
Rivet and Bolt Information



Since fasteners are a critical aspect of repair design, the RM gives plenty of detail on the installation, definitions and selection of fasteners. Useful rivet information such as materials and their benefits are found in this section.

Standard drilling procedures including transfer drilling and spot-facing are shown. This section also gives information for match drilling and marking holes and standard spot-facing dimensions.

Instructions for riveting are given, this is useful for repair design as the instructions give working practices and rules to follow.



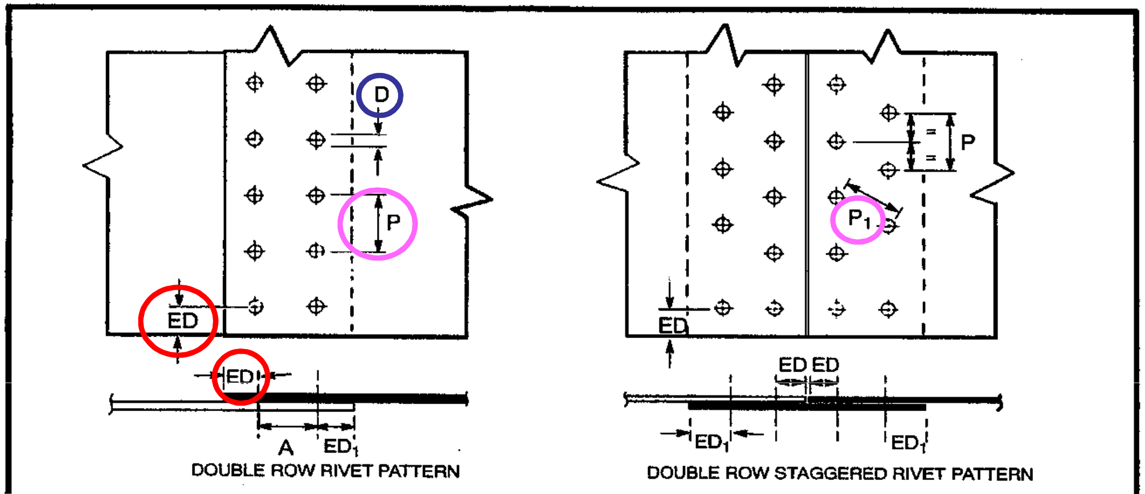
There are sections on bolts and screws and blind rivets. These sections go into detail about standard working practices and their uses and limitations.

Rivet Tables - Using the ‘Edge Distance and Spacing’ Table

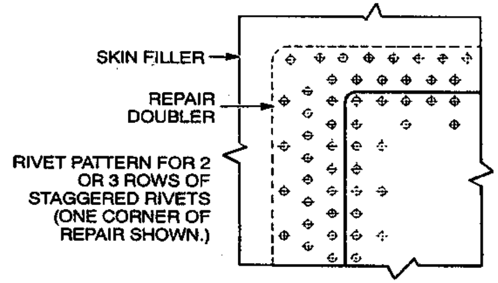
RIVET DIAMETER

EDGE DISTANCE

RIVET PITCH (SPACING)



One of the most useful parts in the RM are the ‘Edge Distance and Rivet Spacing’ tables. Protruding head fasteners still adhere to the 2D edge distance/4D spacing rule. These tables give an easy way to calculate rivet spacing and acceptable edge distances for countersunk rivets when designing a repair.

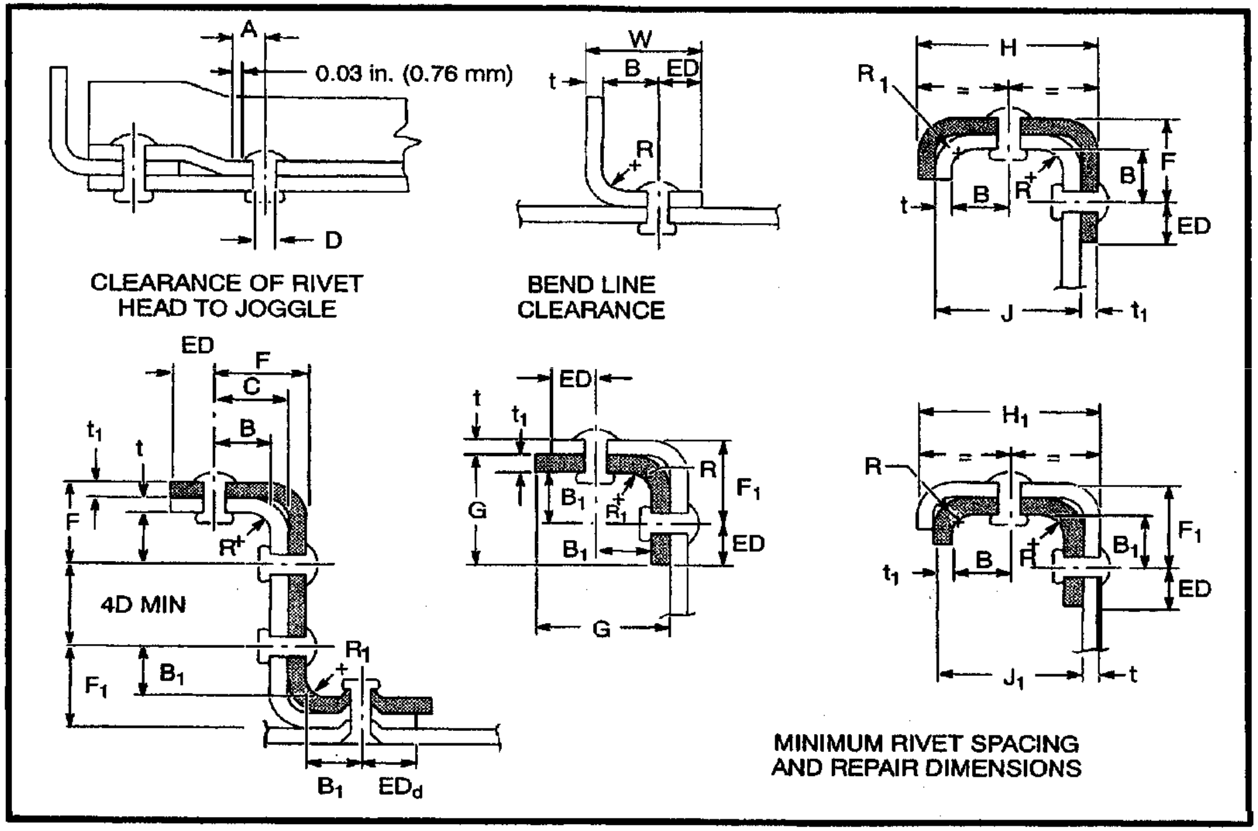


Thickness is not a determining factor when working out rivet spacing.

Standard Edge Distance and Spacing for Countersunk Rivet Holes

Rivet Diameter	Minimum Edge Distance (See Note 2)	Spacing Minimum	Spacing Maximum
3/32 in. (2.38 mm)	0.25 in. (6.35 mm)	0.43 in. (11.11 mm)	1.50 in. (38.10 mm)
1/8 in. (3.18 mm)	0.31 in. (7.94 mm)	0.56 in. (14.29 mm)	1.50 in. (38.10 mm)
5/32 in. (3.97 mm)	0.38 in. (9.53 mm)	0.72 in. (18.26 mm)	1.50 in. (38.10 mm)
3/16 in. (4.76 mm)	0.43 in. (11.11 mm)	0.84 in. (21.43 mm)	1.50 in. (38.10 mm)
7/32 in. (5.56 mm)	0.50 in. (12.70 mm)	1 in. (25.40 mm)	1.50 in. (38.10 mm)
1/4 in. (6.35 mm)	0.56 in. (14.29 mm)	1.13 in. (28.58 mm)	1.50 in. (38.10 mm)

Using the 'Edge Distance and Spacing' Table



The 'Edge Distance and Spacing' Table includes extrusions which gives dimensions and spacing in relation to the extrusion and repair member geometry.

DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

Rivet and Bolt Information

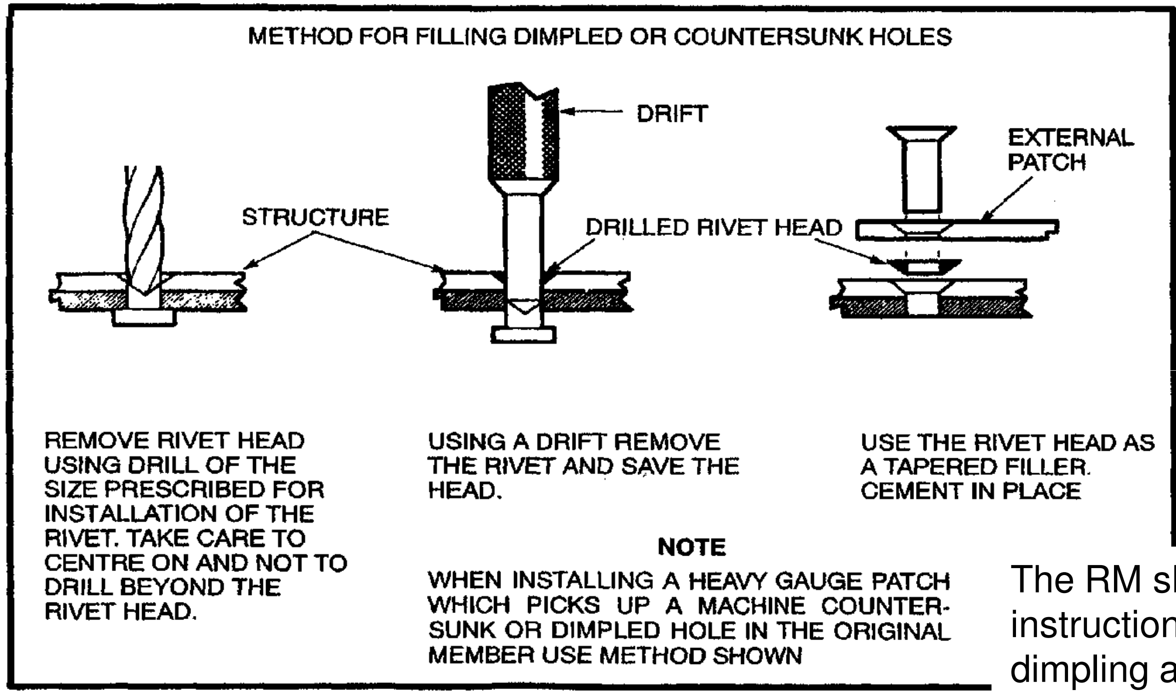
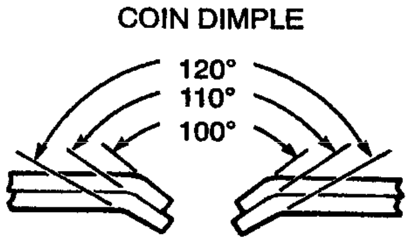


Figure 29 Filling Dimpled or Countersunk Holes



The RM shows many types of dimpling, installation instructions and any limitations. Tables required for dimpling are provided although dimpling is not very common in repair design.

Although standard practices for some of the subjects addressed in the TR are 'officially' covered in other manuals, the TR often gives a much simpler, cleaner definition.

A useful diagram to show how to fill a dimpled or countersunk hole is given in the RM. This is a very common practice when designing a repair since repair doublers and angles are often located over existing countersinks which cannot be left 'as is'.

Typical Repair Procedure

Tables to assist in the calculation of the number of rivets to use for repair of damage in members made from sheet metal and for extruded members are provided in the RM. For sheet metal repairs, tension and shear conditions have been given and for extruded members only tension and compression conditions are shown. The rivet tables are very good for quickly constructing a repair solution without having to venture into any analysis.

The RM also offers some useful rules-of-thumb to help in the selection of rivets and the rivet pattern layout as well as selection of cutout shapes to use for damage repair.

NOTE: The number of rivets given in the tables is for one side of the joint only.

Using the Quantity Calculation Table (Fig 30 & 31)

These tables can be used to calculate the required amount of rivets on each side of the damaged area dependant on materials, rivet type and size and application:

Material Thickness		Type and Diameter of Rivet	Number of Rivets per Inch (25.4 mm) of Damage for One Side of Damage Only			
			2024		2014 and 7075	
Skin or Web	Doubler		Tension	Shear	Tension	Shear
0.025 in. (0.64 mm)	0.032 in. (0.81 mm)	MS20470AD3	7.0	4.5	8.3	5.0
		MS20470AD4	5.0	3.3	5.0	3.0
		MS20600AD4	6.4	4.1	7.5	4.5
0.028 in. (0.71 mm)	0.036 in. (0.91 mm)	MS20470AD3	7.8	5.0	9.2	5.6
		MS20470AD4	5.0	3.3	5.4	3.3
		MS20600AD4	6.6	4.3	7.8	4.7
0.032 in. (0.81 mm)	0.040 in. (1.02 mm)	MS20470AD4	5.1	3.3	6.0	3.6
		MS20470D4	4.0	2.6	4.7	2.8
		MS20600AD4	6.9	4.4	8.1	4.9
		MS20600AD5	5.2	3.3	6.1	3.7
0.036 in. (0.91 mm)	0.045 in. (1.14 mm)	MS20470AD4	5.6	3.6	6.7	4.0
		MS20470D4	5.1	3.3	6.0	3.6
		MS20470AD5	4.1	2.6	4.5	2.7
		MS20600AD4	7.1	4.6	8.5	5.1
		MS20600AD5	5.4	3.5	6.4	3.9

Figure 30 (Sheet 1 of 16) Rivet Table - Protruding head in 2024, 2014 and 7075 Material

Steps for using the tables:

1. Select thickness of repaired sheet and doubler.
2. Select type of rivet to be used to attach doubler.
3. Decide whether the rivet is transferring a shear or tension load. Use the tension case if you're not sure.
4. Read down the appropriate column for the repair material selected to find the number of rivets required **on each side of the damage**.

Tables for various types of rivets (countersunk and protruding heads) and material (including extruded sections) are given.

Skin and Web Repairs

This section covers the design of the actual repair doublers and fillers for various repairs regarding size and thickness and gives some help and guidelines to assist the repair design.

There is some very good information and rules to assist in the design of a skin splice.

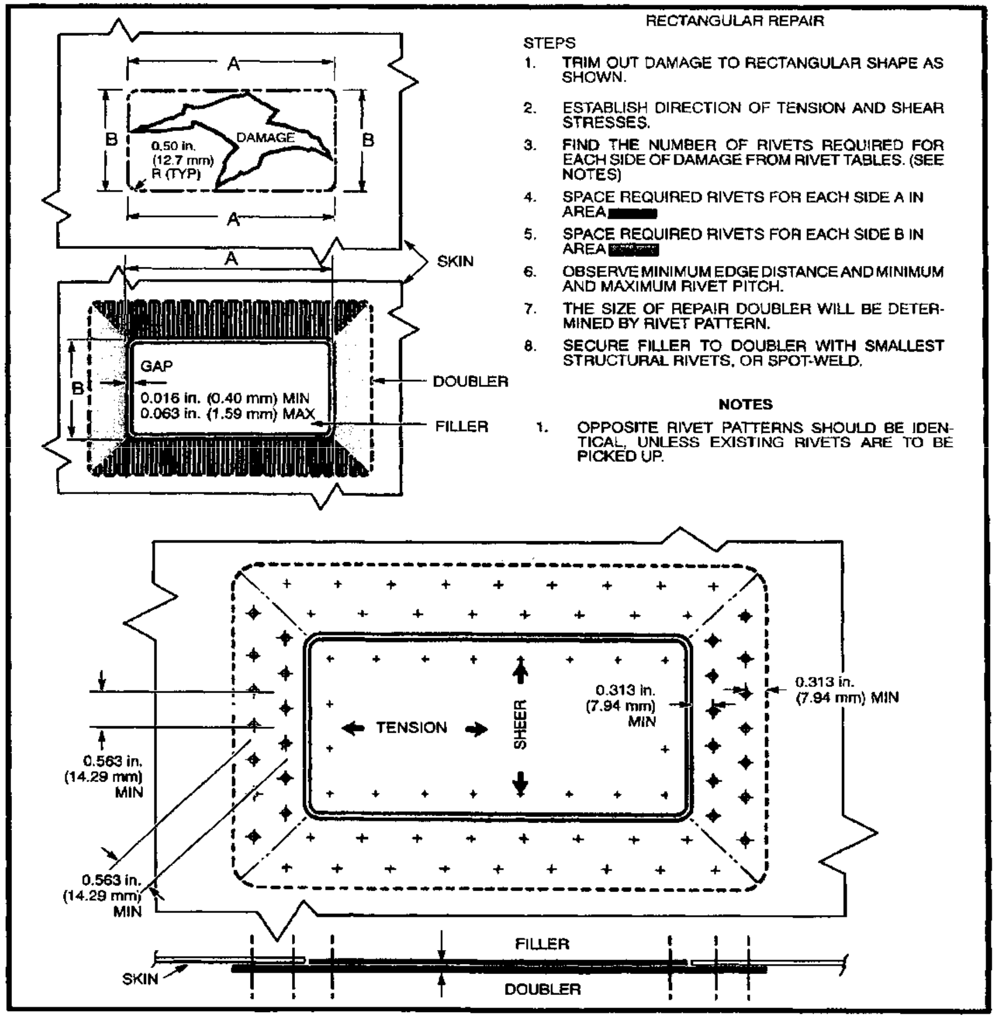


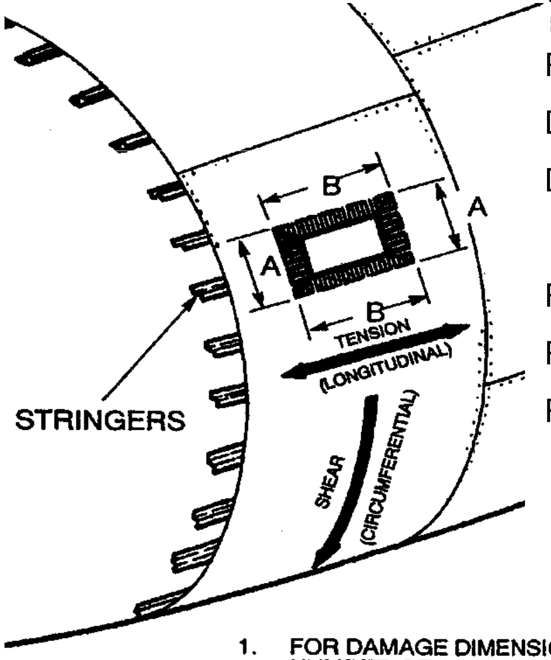
Figure 34 (Sheet 1 of 6) Rivet Distribution Pattern – Rectangular Repair

DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

Repair Example

Material Thickness		Type and Diameter of Rivet	Number of Rivets per Inch (25.4 mm) of Damage for One Side of Damage Only			
			2024		2014 and 7075	
Skin or Web	Doubler		Tension	Shear	Tension	Shear
0.025 in. (0.64 mm)	0.032 in. (0.81 mm)	MS20426AD3	6.3	4.1	7.5	4.5
		MS20426AD4	4.1	2.7	4.6	2.8
		MS20601AD4	7.7	4.9	9.0	5.4
		MS20601AD5	6.5	4.2	7.6	4.6

Figure 30 (Sheet 6 of 16) Countersunk in 2024, 2014 and 7075 Material



Repair Example:

Damaged Skin: 0.025in CLAD 2024-T4

Dimensions of Damage: ‘A’- In Shear: 6in

‘B’- In Tension: 3in

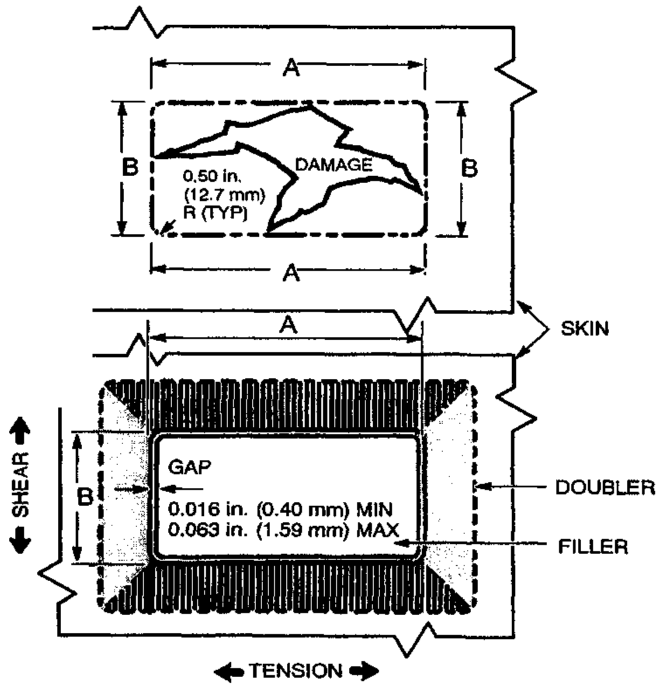
Rivet Chosen: MS20426AD4 (dimpled holes)

Repair Doubler: 0.028in CLAD 2024

Rivets required (from rivet tables):

In Shear: 6in x 2.7 rivets/in = 17 Rivets

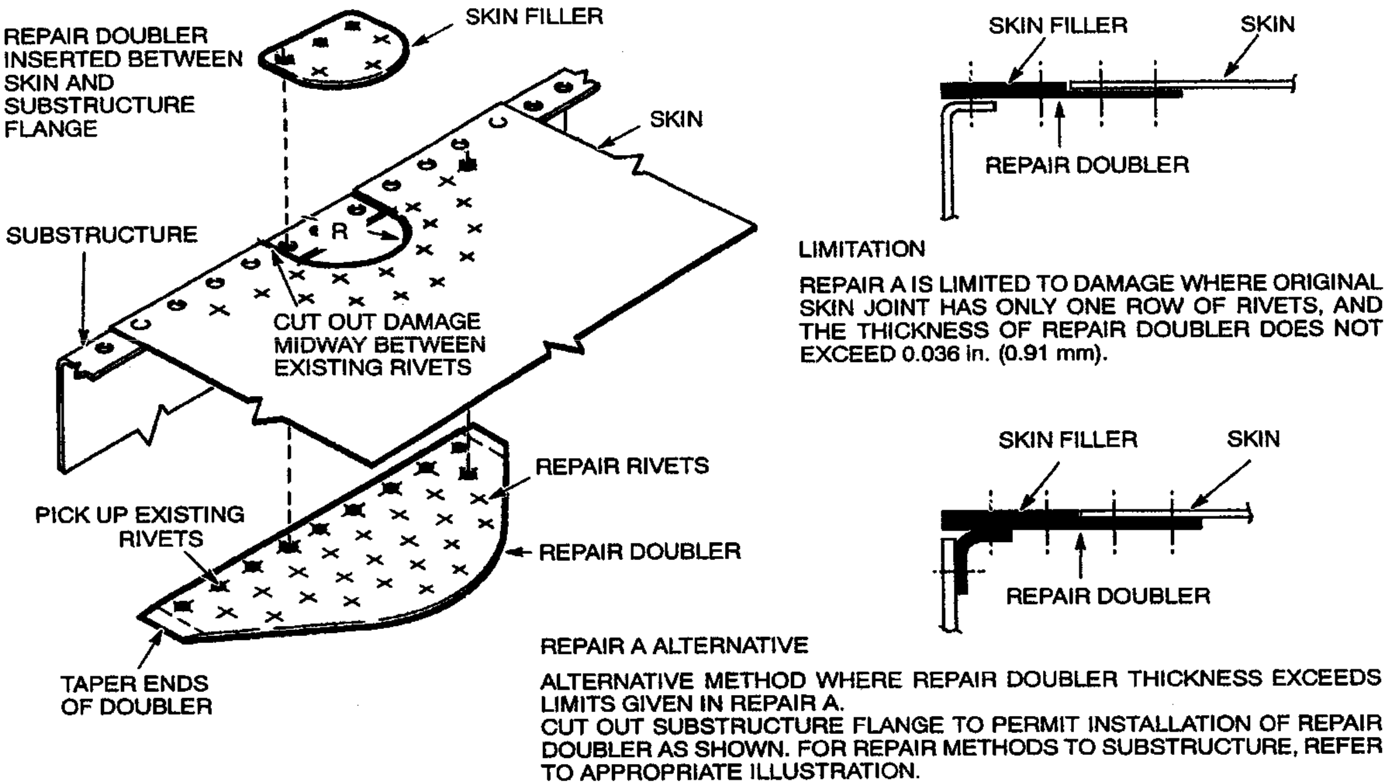
In Tension: 3in x 4.1 rivets/in = 13 Rivets



NOTES

1. FOR DAMAGE DIMENSIONS MARKED A, USE REQUIRED NUMBER OF RIVETS FROM TENSION COLUMN IN RIVET TABLES AND DISTRIBUTE THEM IN CROSS-HATCHED AREA A.
2. FOR DAMAGE DIMENSIONS MARKED B, USE REQUIRED NUMBER OF RIVETS FROM SHEAR COLUMN IN RIVET TABLES AND DISTRIBUTE THEM IN CROSS-HATCHED AREA B.

Skin and Web Repairs

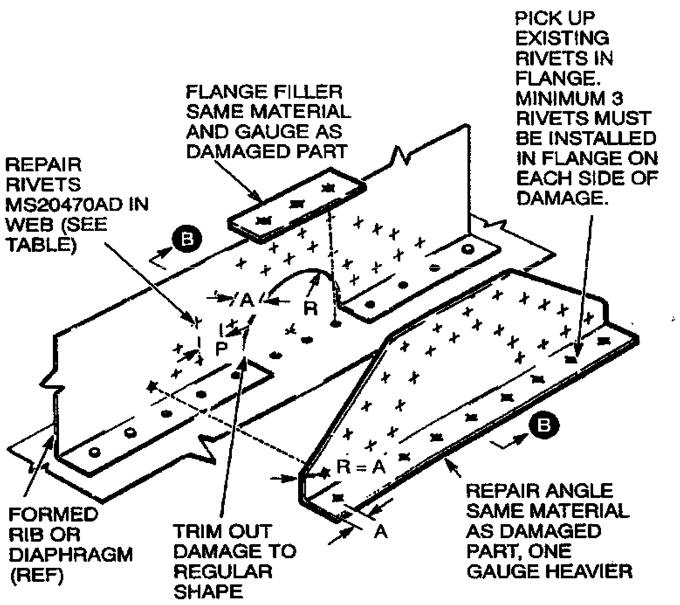


Typical Skin Repair (detailed in the RM)

Rib and Frame Repairs

There are several figures in the RM showing repairs to Ribs, Flanges and Webs. Although the figures shown may not replicate the problem at hand the general principles behind the repair figures can still be used.

Considerations and figures for splicing ribs , diaphragms and intermediate frames are given.



REPAIR A

APPLICABLE TO DAMAGE IN ATTACH FLANGE OF FORMED RIBS AND DIAPHRAGMS NOT EXCEEDING LIMITS GIVEN.

LIMITATION

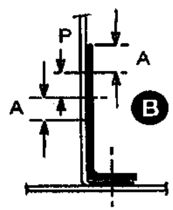
DAMAGE NOT TO PENETRATE FARTHER THAN THE END OF BEND RADIUS IN THE WEB. MAXIMUM LENGTH OF CRACK 1.5 in. (3.81 cm) OR 1/10 OF THE TOTAL LENGTH, WHICHEVER IS THE SMALLER. ONLY ONE SUCH REPAIR PER RIB OR DIAPHRAGM.

REPAIR B

APPLICABLE TO DAMAGE IN ATTACH FLANGE AND WEB OF FORMED RIBS AND DIAPHRAGMS NOT EXCEEDING LIMITS GIVEN.

LIMITATION

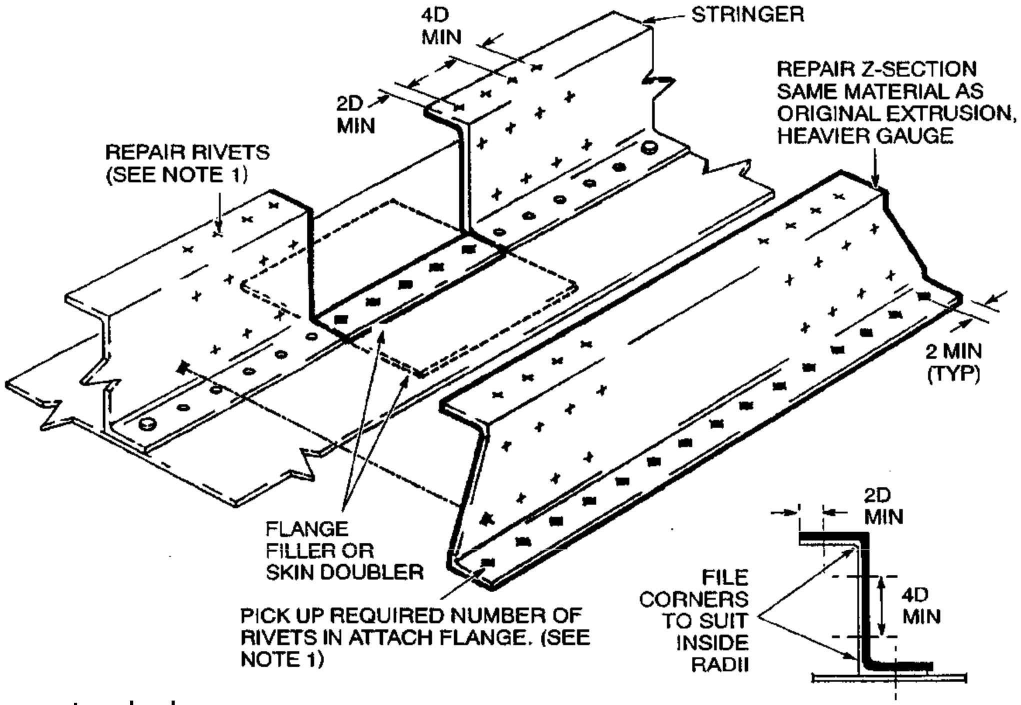
MAXIMUM LENGTH OF DAMAGE 3 in. (7.62 cm). MAXIMUM PENETRATION INTO WEB 1/3 OF WEB HEIGHT. ONLY ONE SUCH REPAIR PER RIB OR DIAPHRAGM.



Part Thickness	Rivets	Dimensions		
		A	Pitch (P) Min	Pitch (P) Max
0.018 to 0.020 in. (0.46 to 0.51 mm)	AD3	0.25 in. (6.35 mm)	0.50 in. (12.70 mm)	0.70 in. (17.78 mm)
0.022 to 0.036 in. (0.56 to 0.91 mm)	AD4	0.30 in. (7.62 mm)	0.60 in. (15.24 mm)	0.75 in. (19.05 mm)
0.040 to 0.063 in. (1.02 to 1.60 mm)	AD5	0.40 in. (10.16 mm)	0.70 in. (17.78 mm)	0.90 in. (22.86 mm)

Figure 55 (Sheet 1 of 2) Rib or Frame Flange and Web – Repair

Formed and Extruded Standard Sections



NOTES

1. FOR SELECTION OF REPAIR MATERIAL, NUMBER OF RIVETS REQUIRED FOR REPAIR AND METHOD OF RIVET DISTRIBUTION, REFER TO EXTRUDED SECTIONS REPAIRS, TYPICAL REPAIR PROCEDURE IN TEXT AND SEE APPROPRIATE ILLUSTRATIONS.
2. THIS REPAIR IS APPLICABLE TO DAMAGED PORTION OF STRINGER OR WHERE THE STRINGER MUST BE CUT OUT TO PERMIT INSERTION OF SKIN OR WEB REPAIR DOUBLER.

LIMITATION

THIS REPAIR IS NOT APPLICABLE TO RESTRICTED AREAS OR TO HEAVILY STRESSED STRINGERS IN PRIMARY STRUCTURE. REFER TO TEXT FOR DETAILED LIMITATION OR TYPICAL REPAIRS.

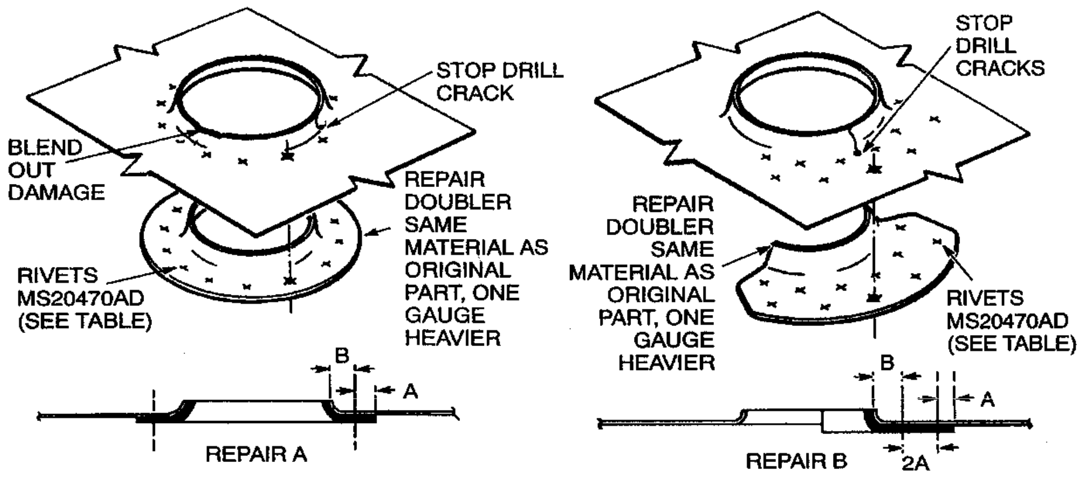
The different approaches to repair of formed or extruded sections are addressed dependant on the type and location of the damage. Considerations and suggested actions are given to repair the differing types of damage. An example for rivet calculation is included for each type.

There are fairly comprehensive guidelines to splicing various shapes of formed or extruded members. Limitations are given which apply to certain areas and these are highlighted.

Miscellaneous Repairs

In this section there are some repairs given that cover various common types of damage such as cracked dimples, damage to lightening holes, flight control tabs and honeycomb damage that is not specifically covered elsewhere.

Oil canning is comprehensively covered in this part of the RM. Definitions, likely causes, inspections, effects of oil canning, susceptible areas and repairs are all mentioned.



LIMITATION

REPAIR A IS APPLICABLE TO DAMAGE NOT PENETRATING FARTHER THAN BEND RADIUS IN THE WEB.

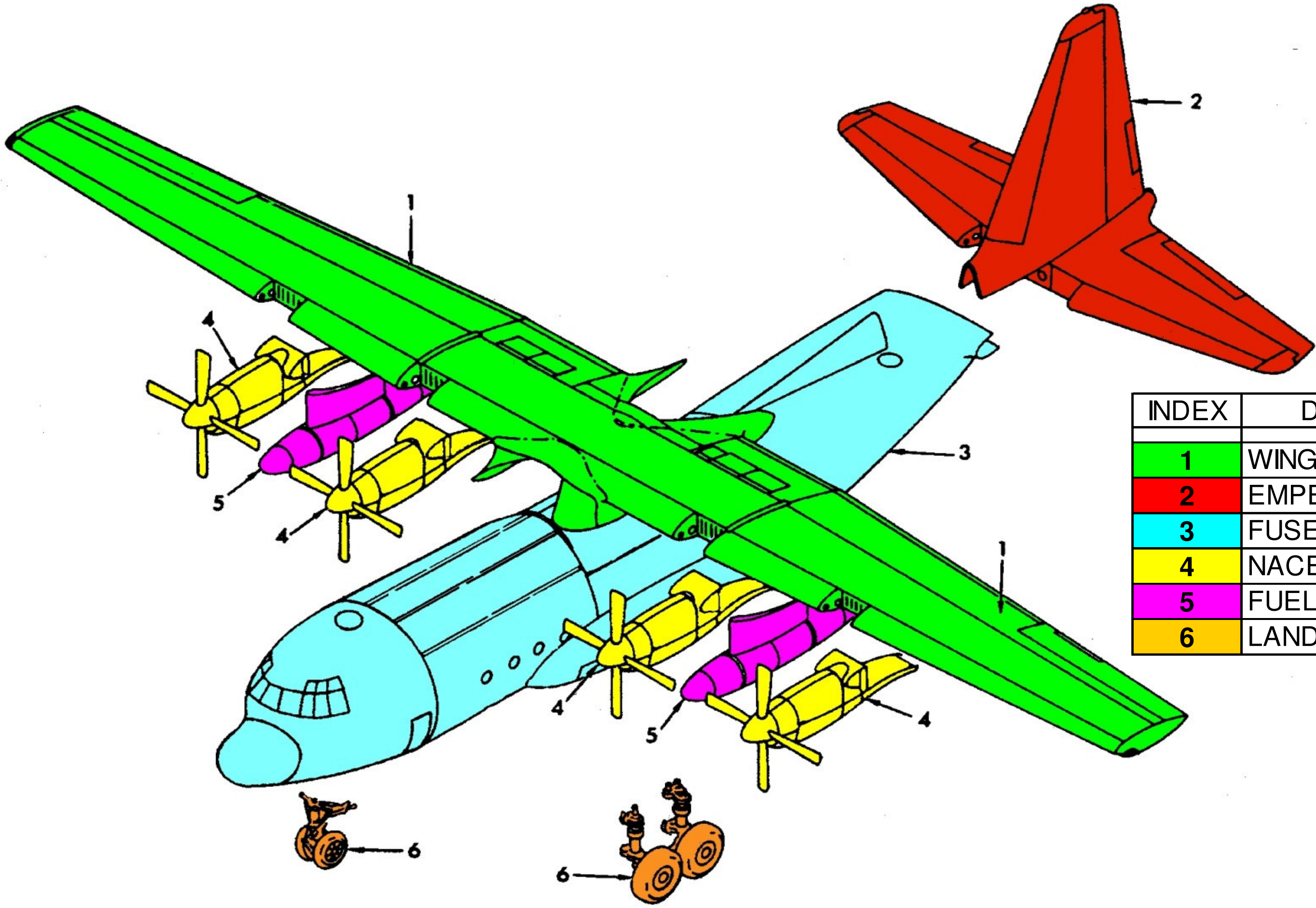
REPAIR B IS APPLICABLE TO SINGLE DAMAGE NOT PENETRATING FARTHER THAN 0.5 in. (12.7 mm) IN THE WEB.

Rivet Table

Thickness	Rivets	Dimension		
		A	B	Max Pitch
0.018 in. (0.46 mm)	MS20470AD3	0.30 in. (7.62 mm)	0.35 in. (8.89 mm)	0.65 in. (16.51 mm)
0.022 to 0.040 in. (0.56 to 1.02 mm)	MS20470AD4	0.30 in. (7.62 mm)	0.35 in. (8.89 mm)	0.75 in. (19.05 mm)
0.045 to 0.064 in. (1.14 to 1.63 mm)	MS20470AD5	0.35 in. (8.89 mm)	0.40 in. (10.16 mm)	0.90 in. (22.86 mm)

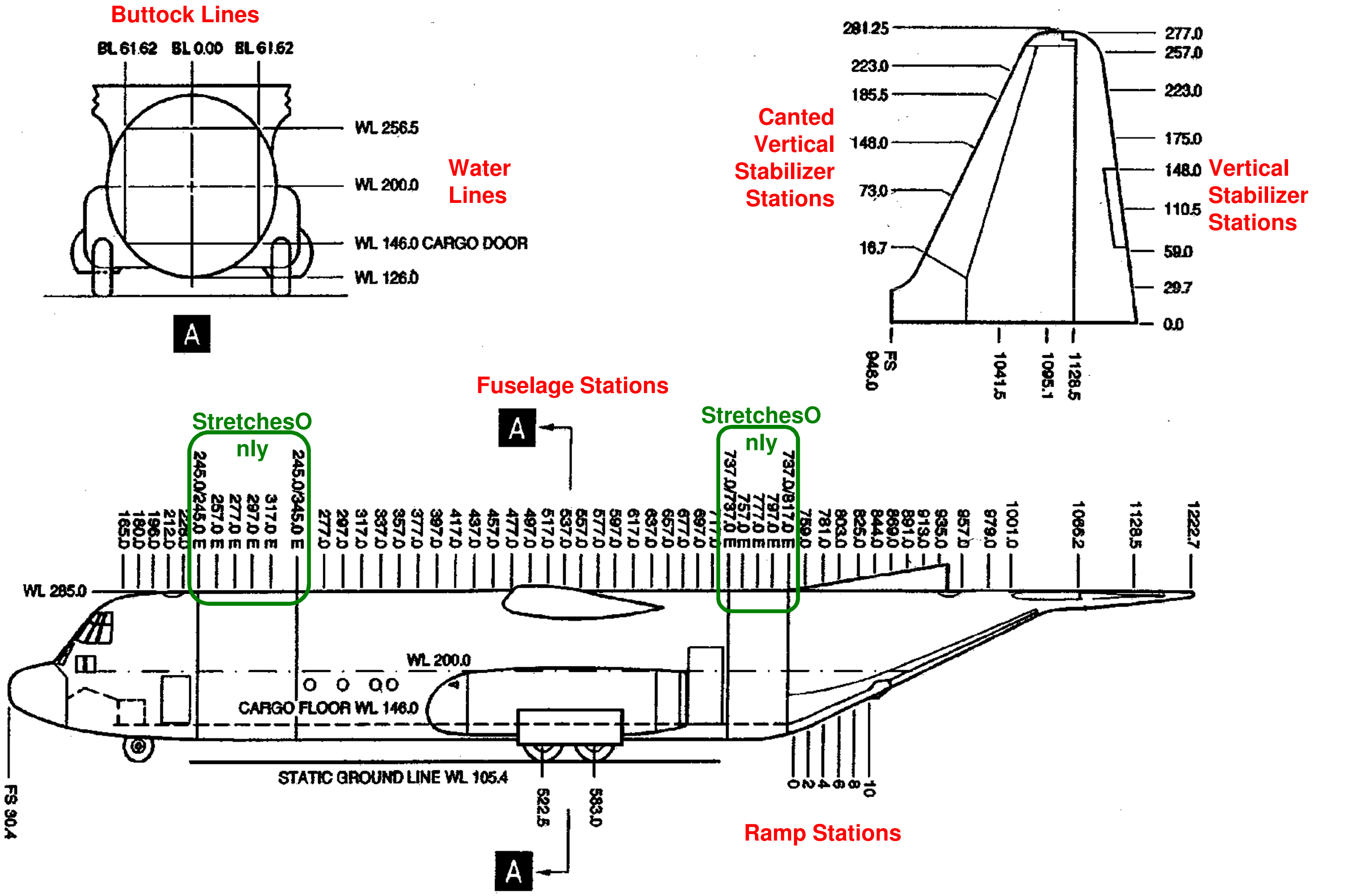
Illustrated Parts Catalogue

Major Assemblies



INDEX	DESCRIPTION	CHAPTER IN MY
1	WING GROUP	2-1-1
2	EMPENNAGE GROUP	3-1-1
3	FUSELAGE GROUP	4-1-1
4	NACELLE GROUP	6-1-1
5	FUEL TANKS	7-1-1
6	LANDING GEAR	5-1-1

Aircraft Stations

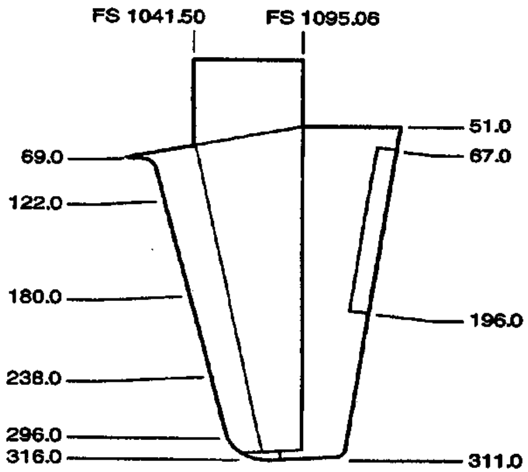


Aircraft Stations

FS	Fuselage Station
WL	Water-Line
BL	Buttock Line
RS	Ramp Station
CWS	Center Wing Station
OWS	Outer Wing Station
HSS	Horizontal Stablizer Station
VSS	Vertical Stabilizer Station
OWFS	Flap Station
AS	Aileron Station

Fuselage Stations

Horizontal Stabilizer Stations



Center Wing Stations

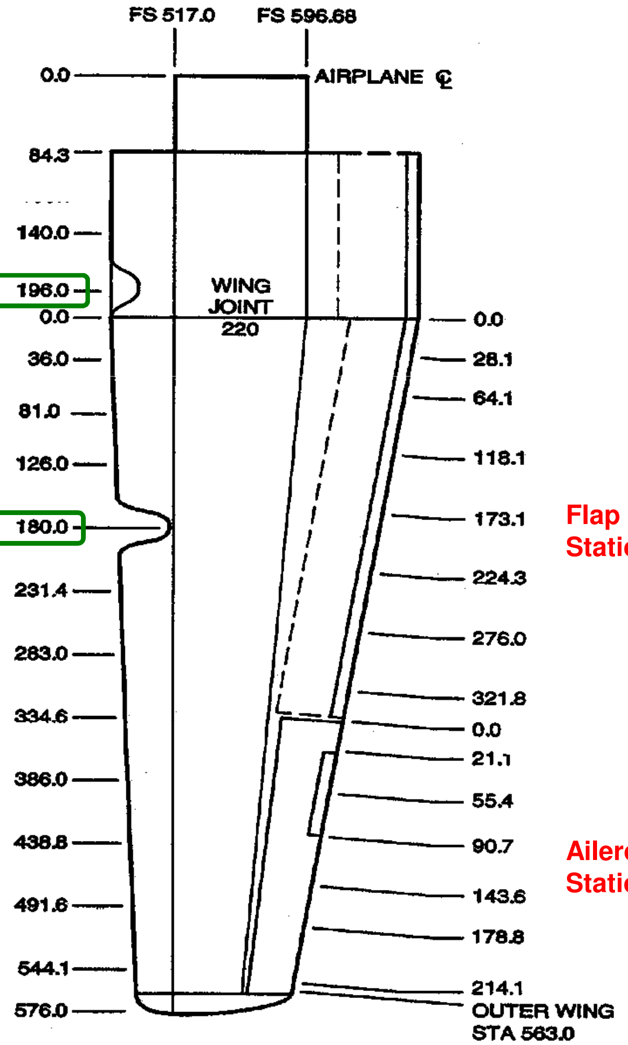
Engine #2/3 Centerline

Engine #1/4 Centerline

Outer Wing Stations

Flap Stations

Aileron Stations



DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

GROUP: FORWARD FUSELAGE STRUCTURE
GROUPE: STRUCTURE DE FUSELAGE AVANT

MAJOR ASSEMBLY: Forward Fuselage Floor and Stairway
ENSEMBLE PRINCIPAL: Plancher et escalier de fuselage avant

FIGURE AND INDEX NUMBER – FIGURE ET NUMÉRO IND.	PART NUMBER NUMÉRO DE PIÈCE	1234567 NOMENCLATURE	1234567 NOMENCLATURE	UNITS PER ASSY – QTÉ PAR ENS.	EFF
2-1-8 -1	372370-3	. Floorboard Installation - Flight-deck (NHA 388002-1 and 388002-3)	. Installation plancher - Poste de pilotage (EIS 388002-1 et 388002-3)	NP	
	373144-3	. . Panel - Floorboard, forward flight-deck, LH ;or	. . Panneau de plancher - Partie avant du poste de pilotage, GAUCHE ;ou	1	H
	373144-7	. . Panel - Floorboard, forward flight-deck, LH ;or	. . Panneau de plancher - Partie avant du poste de pilotage, GAUCHE ;ou	1	Y
	373144-4	. . Panel - Floorboard, forward flight-deck, RH ;or	. . Panneau de plancher - Partie avant du poste de pilotage, DROITE ;ou	1	H
	373144-6	. . Panel - Floorboard, forward flight-deck, RH ;or	. . Panneau de plancher - Partie avant du poste de pilotage, DROITE ;ou	1	Q
	373144-8	. . Panel - Floorboard, forward	. . Panneau de plancher - Partie	1	Y

Effectivity Code	Aircraft
A	130305 to 130320
B	130305 to 130326
C	130305 to 130326, 130334 and 130335
D	130305 to 130328, 130334, 130335 and 130338 to 130342
E	130305 to 130328 and 130334 to 130342
F	130305 to 130328 and 130338 to 130342
G	130305 to 130333
H	130305 to 130333, 130336 and 130337
J	130305 to 130333 and 130336 to 130342
K	130305 to 130333 and 130338 to 130342
M	130305 to 130337
N	130321 to 130342
P	130332 and 130333
Q	130332, 130333,
R	130332, 130333 and 130336 to 130342
S	130332 to 130335
T	130332 to 130335 and 130338 to 130342
U	130332 to 130337
V	130332 to 130342
W	130334 and 130335
X	130334 and 130335, 130338 and 130339
Y	130334 and 130335, 130338 to 130342

- ✈ Provides an illustrated breakdown of parts of the A/C.
- ✈ Parts for all aircraft effectivities are provided as a pullout.

Layout

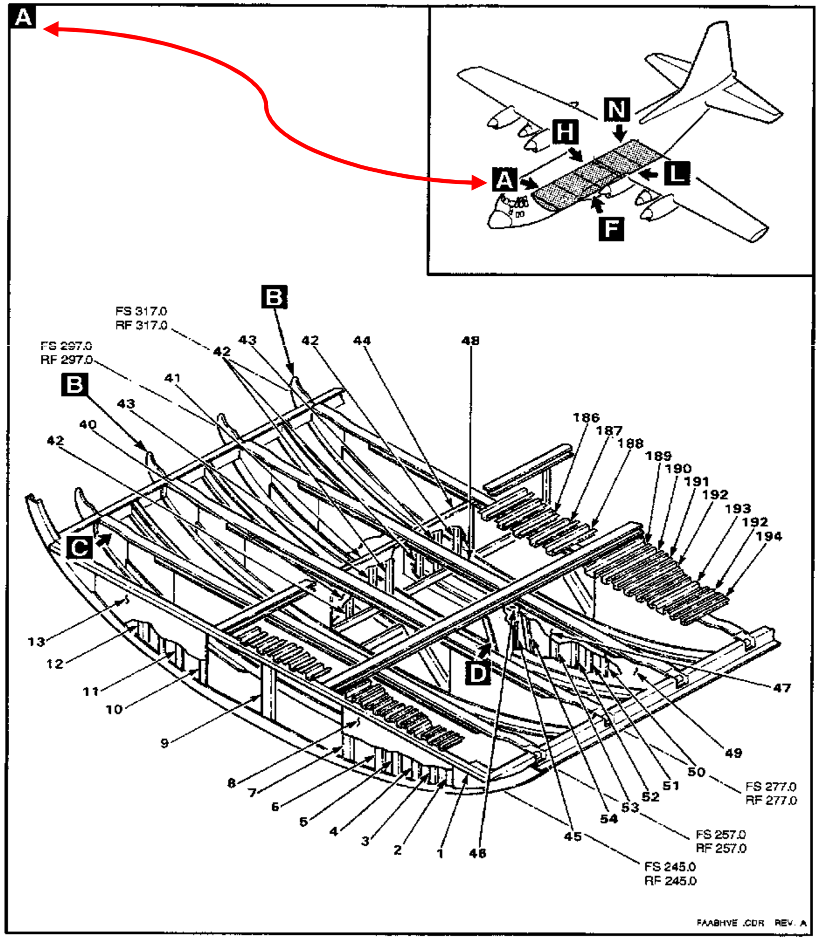
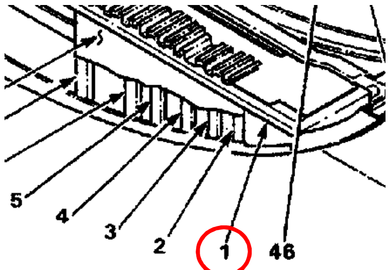


Figure 2-2-5 (Sheet 1 of 7) Centre Fuselage Lower Interior Structure (E, H, H(84) and H-30)
Figure 2-2-5 (feuille 1 de 7) Structure intérieure inférieure de fuselage central (E, H, H(84) et H-30)

- Illustrations are the main guide.
- Navigated by 'starting big and going smaller'.
- Parts are labelled in the illustration.

C-12-130-0A0/MY-001



GROUP: FORWARD FUSELAGE STRUCTURE
GROUPE: STRUCTURE DE FUSELAGE AVANT

MAJOR ASSEMBLY: Forward Fuselage Floor and Stairway
ENSEMBLE PRINCIPAL: Plancher et escalier de fuselage avant

FIGURE AND INDEX NUMBER – FIGURE ET NUMÉRO IND.	PART NUMBER NUMÉRO DE PIÈCE	1234567 NOMENCLATURE	1234567 NOMENCLATURE	UNITS PER ASSY – QTÉ PAR ENS.	EFF
2-1-8 -1	372370-3	. Floorboard Installation - Flight-deck (NHA 388002-1 and 388002-3)	. Installation plancher - Poste de pilotage (EIS 388002-1 et 388002-3)	NP	
	373144-3	. . Panel - Floorboard, forward flight-deck, LH :or	. . Panneau de plancher - Partie avant du poste de pilotage	1	H

Reference from illustration.

Lockheed Part/Assembly Number.

Description of Part/Assembly.

Quantity of Parts/Assemblies.

Effectivity.

Alphanumeric Parts List

C-12-130-0A0/MY-001

PART NUMBER NUMÉRO DE PIÈCE	FIGURE AND INDEX NUMBER - FIGURE ET NUMÉRO IND.	UNITS PER ASSY - QTÉ PAR ENS.
388005-9	2-2-2-1C	1
388005-9	2-2-3-2	REF
388005-9	2-2-7-19	1
388008-1	2-2-7-6	1
388008-11	2-2-7-53	1
388008-13	2-2-7-6	1
388008-15	2-2-7-19	1
388018-1	2-2-5-1	1
388018-1	2-2-6-1	1
388018-11	2-2-6-9	1
388018-17	2-2-5-9	1
388018-19	2-2-5-13	1
388018-21	2-2-6-13	1
[illegible]	[illegible]	1
388018-3	2-2-5-8	1
[illegible]	[illegible]	1
388018-6	2-2-5-2	1
388018-7	2-2-6-5	2
388018-9	2-2-6-4	2
388026-3	2-2-5-45	1
388026-3	2-2-6-29	1
388026-5	2-2-5-47	1
388026-6	2-2-5-47	1
388026-7	2-2-5-46	1
388026-9	2-2-5-46	1
388027-3	2-2-3-40	REF
388027-3	2-2-4-47	1
388027-3	2-2-5-1	REF
388027-3	2-2-6	1
388027-3	2-2-12-302	REF
388027-7	2-2-3-40	REF
388027-7	2-2-4-47	1
388027-7	2-2-5-1	REF
388027-7	2-2-6	1
388027-7	2-2-12-302	REF
388031-1	2-2-1-96	NP
388031-1	2-8-5-3	REF
388031-1	2-8-11-7	NP
388031-3	2-2-1-96	NP
388031-3	2-8-5-3	REF
388031-3	2-8-11-58	NP

5-191 Ch/Mod. 5 2002-09-03

- Contains a full listing of part numbers
- Refers to relevant Figure & Index Number.
- Shows quantities of parts required to make a complete Aircraft.

FIGURE ET NUMÉRO IND.	PART NUMBER NUMÉRO DE PIÈCE	
2-2-5		
	[illegible]	. . . . . Fitt[illegible]
-8	388018-3	. . . . Web - Bulkhead, FS 245.0
-9	388018-17	. . . . Stiffener - Bulkhead, FS 245.0, BL 0.0
-10	356243-8R	. . . . Stiffener - Bulkhead, FS 245.0, BL 20.0
-11	356243-7R	. . . . Stiffener - Bulkhead, FS 245.0, BL 25.
-12	389329-1	. . . . Fitting Assy - Snatch-block, FS 245.0, BL 35.5 RH
	389329-3	. . . . . Fitting - Snatch-block

2-2-109

Assembly Structure

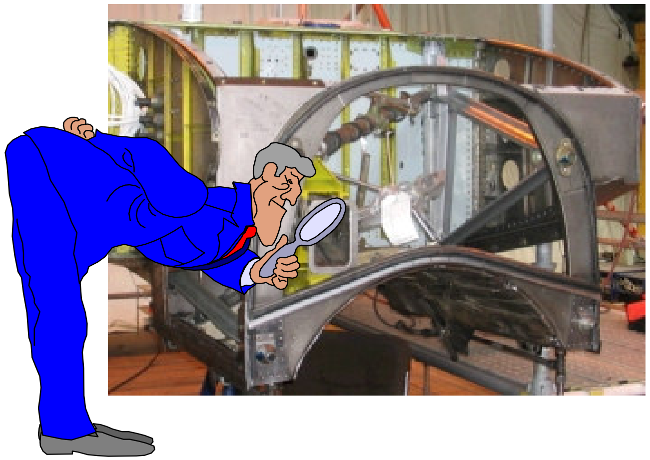
NUMERO IND.	PART NUMBER NUMÉRO DE PIECE	1234567 NOMENCLATURE
2-2-5 -1	388978-1	. Structure Assy - Centre fuselage, lower (See Figure 2-2-1) ;or
	388978-5	. Structure Assy - Centre fuselage, lower (See Figure 2-2-1)
	388027-3	. . Panel Assy - Centre fuselage, lower (See Figure 2-2-12) ;or
	3311027-1	. . Panel Assy - Centre fuselage, lower (See Figure 2-2-12)
	388018-1	. . . Bulkhead Assy - Cargo floor, FS 245.0
	389183-3	. . . . Cap - Bulkhead, upper, FS 245.0
-2	388018-5	. . . . Stiffener - Bulkhead, FS 245.0, BL 50.0 LH

- Assembly
  - • Details of Assembly
  - • Subassembly
    - • • Details of Subassembly
    - • • Sub-subassembly
      - • • • Details of Sub-subassembly
      - • • • Sub-sub-subassembly
        - • • • • Details of Sub-Sub-subassembly

Using the Parts Catalog

Two Ways to Search…

Searching using a Part Number



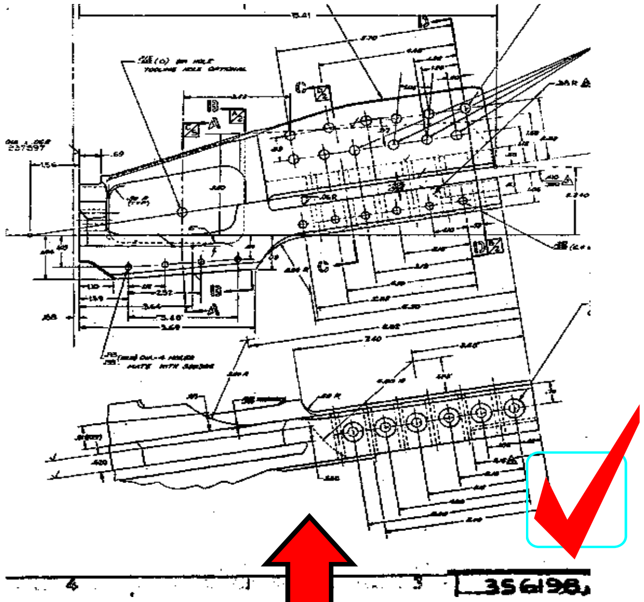
Locating from the Aircraft

DEPARTAMENTO DE CIÊNCIAS AEROESPACIAIS

Searching From a Part Number

For Aircraft 130334

PART NUMBER NUMÉRO DE PIÈCE	FIGURE AND INDEX NUMBER – FIGURE ET NUMÉRO IND.	UNITS PER ASSY – QTÉ PAR ENS.
356145-9R	2-2-5-92	1
356189-1	2-11-3-68	1
356190-1	2-11-3-68	1
356198-3	2-3-1-143	1
356198-4	2-3-1-143	1
356198-5	2-3-1-143	1
356198-5	2-3-1-143	1
356198-6	2-3-1-143	1
356198-6	2-3-1-143	1

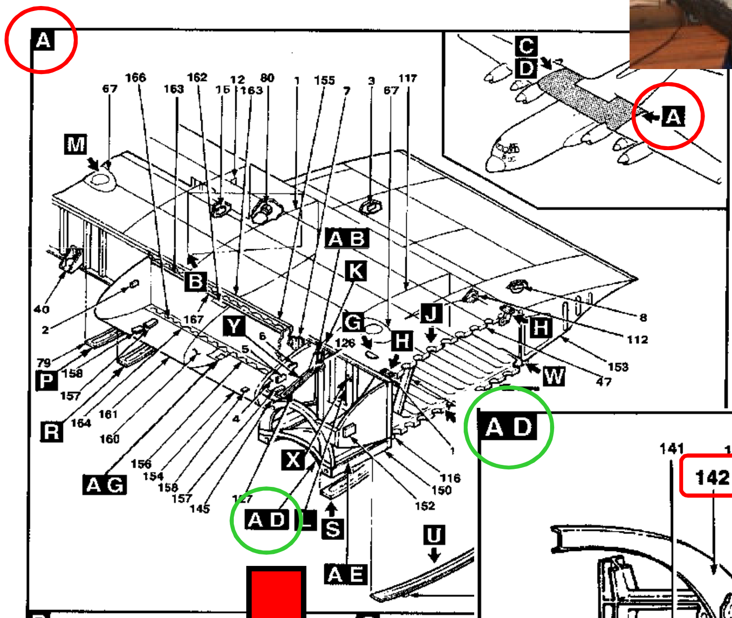


GROUP: AFT FUSELAGE STRUCTURE
GROUPE: STRUCTURE DE FUSELAGE ARRIÈRE

MAJOR ASSEMBLY: Aft Fuselage Structure
ENSEMBLE PRINCIPAL: Structure de fuselage arrière

FIGURE AND INDEX NUMBER – FIGURE ET NUMÉRO IND.	PART NUMBER NUMÉRO DE PIÈCE	1234567 NOMENCLATURE	1234567 NOMENCLATURE	UNITS PER ASSY – QTÉ PAR ENS.	EFF.
2-3-1 -143	372446-1R	. . . Longeron Assy - Lower, aft fuselage side panel (See Figure 2-7-1 or 2-3-3)	. . . Ensemble longeron inférieur - Panneau latéral de fuselage arrière (Voir figure 2-7-1 ou 2-3-3)	1	
	343755-1L	. . . . Fitting Installation - Lower longeron, FS 737.0 ;or	. . . . Installation raccord de longeron inférieur - RF 737.0 ;ou	NP	
	356198-6	. . . . . Fitting - Lower longeron, FS 737.0 RH (IAW C-12-130-000/CD-015) ;or	. . . . . Raccord de longeron inférieur - RF 737.0 DROITE (Conformément au C-12-130-000/CD-015) ;ou	1	H
	356198-6	. . . . . Fitting - Lower longeron, FS 737.0 RH	. . . . . Raccord de longeron inférieur - RF 737.0	1	W

W	130334 and 130335



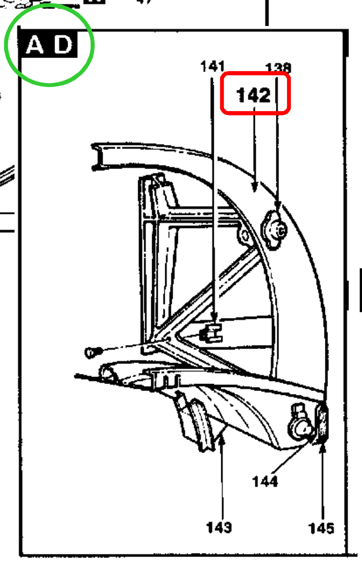


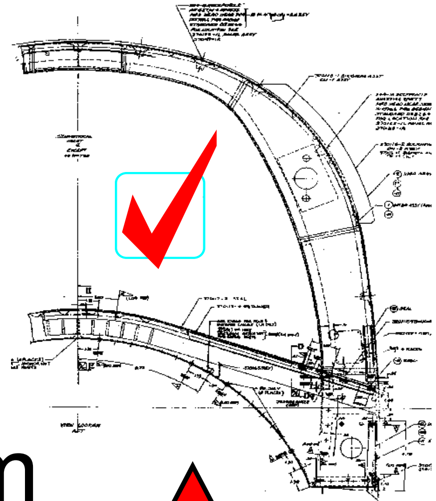
Figure 2-4-1 (Sheet 7 of 7)

GROUP: CENTRE WING STRUCTURE
GROUPE: STRUCTURE DE SECTION CENTRALE D'AILE

MAJOR ASSEMBLY: Centre Wing Assembly
ENSEMBLE PRINCIPAL: Ensemble section centrale d'aile

FIGURE AND INDEX NUMBER – FIGURE ET NUMÉRO IND.	PART NUMBER NUMÉRO DE PIÈCE	1234567 NOMENCLATURE	1234567 NOMENCLATURE	UNITS PER ASSY – QTÉ PAR ENS.	EFF
2-4-1 -131	F2452-12d	.... Barrel Nut - (72962) ;or	.... Écrou cylindrique - (72962) ;ou	1	
	NAS577B12A	.... Barrel Nut ;or	.... Écrou cylindrique ;ou	1	
	370133-2	.... Clip - Upper nacelle to fitting	.... Patte - De la partie supérieure de nacelle à la ferrure	1	V
-142	370112-2	... Nacelle Assy - Upper, inboard	... Ensemble partie supérieure de nacelle intérieur	1	
	370116-2	.... Bulkhead Assy - Upper nacelle	.... Ensemble cloison - Partie supérieure de nacelle	1	Q

Searching From the Aircraft



Repair Design

Repair Definition Requirements

- Once a repair concept has been decided on, it is necessary to adequately define the repair
- There are two primary reasons why we define a repair:
  - So a mechanic can fabricate and install it
  - Maintenance record documentation
- Repair designs are typically defined by a combination of a sketch(es) and notes

Repair Definition Requirements

- Support and Shoring
  - Identify any specific aircraft support requirements (jacking and shoring)
  - Refer to TMXXXXXX, Part 1, Section 7

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Repair Definition Requirements

- Damage Clean Up Notes
  - Specify area access requirements such as removals
  - Specify damage cleanup requirements
    - Trimming, Blending, Reaming, etc
    - Specify material removal limitations
    - Provide reference to process specifications as applicable and appropriate
  - Specify post clean-up NDI requirements as necessary to confirm complete removal of all damage
    - BHEC, ECSS, visual, etc

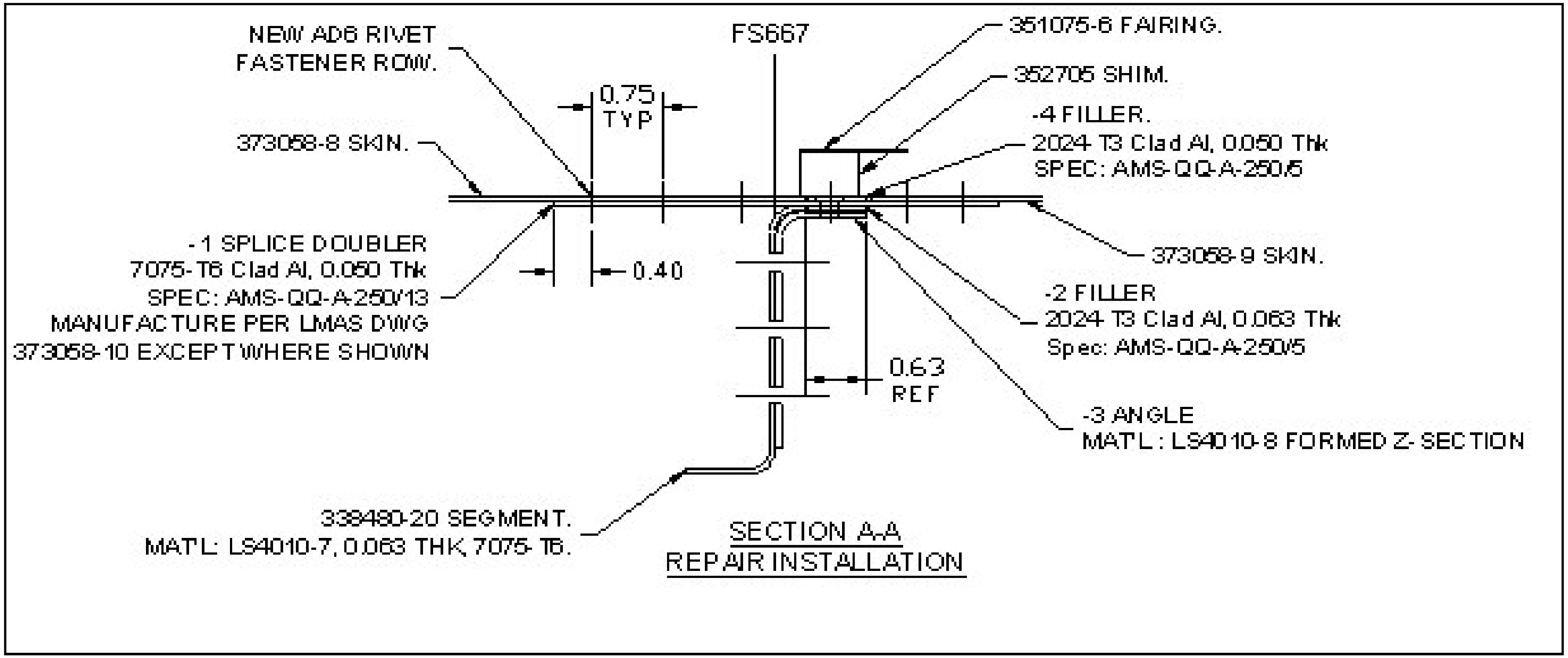
Example: "Mechanically remove corrosion IAW TMXXXXX, Part 4, Section 1, Para 5. Confirm amount of material removed using ECSS per GEN-63E (material removal not to exceed 0.030 in)."

Repair Definition Requirements

- Geometry
  - Provide all geometric information required to build and install the repair such as lengths, widths, thickness', radii and reference measurements
    - Refer to TMXXXXX,, Figures 24-28 & C-12-130-000/MN-001, Part 1, Section 3 for sheet metal minimum bend radii information
  - Hand sketches, digital sketches over damage photos, aircraft rubbings with hand sketches and CAD are all equally acceptable
  - Provide only those dimensions that are necessary

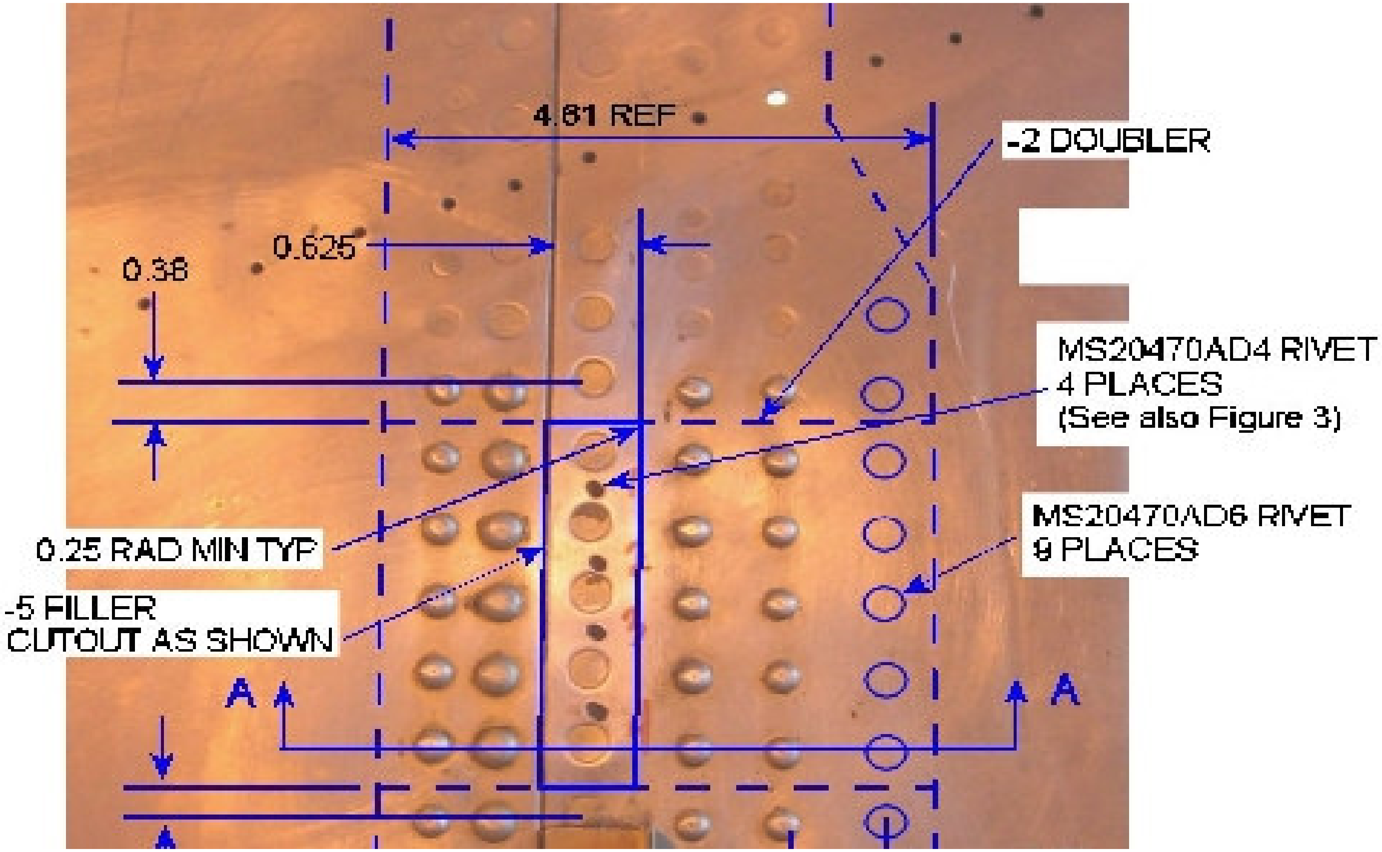
Repair Definition Requirements

- Geometry (cont'd)



Repair Definition Requirements

- Geometry (cont'd)



Repair Definition Requirements

- Material
  - Specify alloy, temper and specification of repair members

    Examples:
    - 7075-T6 sheet per AMS 4045
    - AISI 4130 sheet per AMS 6360
  - Refer to RMXXXXXX, Figure 11 for standard gauge thickness'
- Hardware
  - Specify bolt, washer nut/collar, screws, nutplates and rivets
    - Examples:
      - AN6-27 bolt, NAS1154-8 screw, MS21042-08 nut, AN960-8 washer
  - Refer to RMXXXXXX for fastener hardware

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Repair Definition Requirements

- Surface Finish
  - Surface finish requirements at fatigue critical locations need to be specified (63 in microinch RMS is typically the minimum)
  - Cold working requirements such as shot peening or rotary flap peening

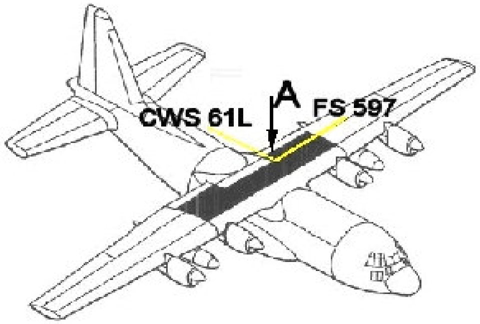
RMS (Root Mean Square) - measures the overall roughness of a surface by taking a number of surface irregularity readings and then calculating the square root of the mean of squares from those readings. Higher RMS numbers indicate rougher surfaces, while lower numbers indicate smoother surfaces

Repair Definition Requirements

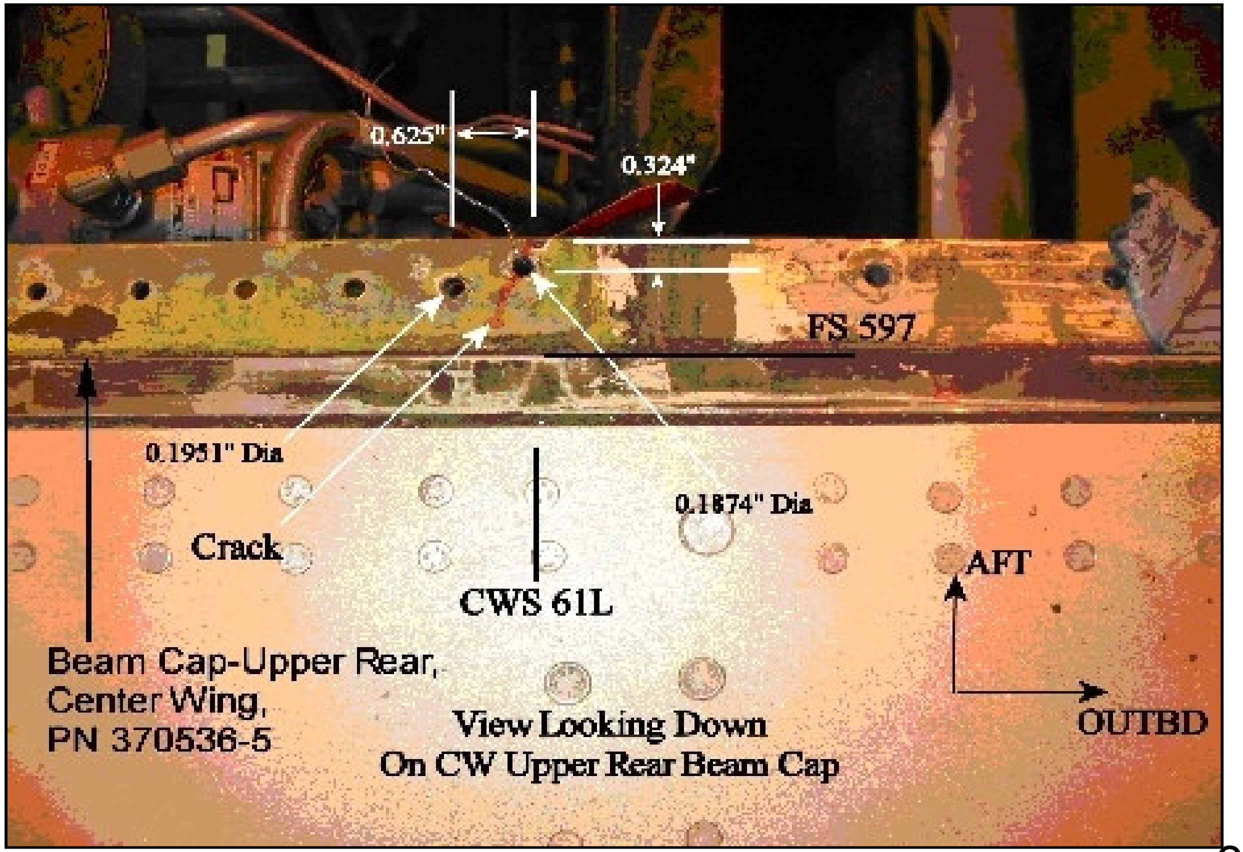
- Paint, Primer and Chemical Coatings
  - Refer to applicable Technical Manual
- Sealant
  - Choose the appropriate sealant and apply per applicable Technical Manual
- Installation Information
  - Identify all information requirements specific to the installation that are critical to achieving the design requirements
    - Critical predecessors and successors
    - Bending in ‘O’ condition, then heat treating
    - Fastener installations
- Hole preparation
  - All holes must be correctly sized to accept fasteners and meet the fit requirements
- Corrosion Preventive Compounds (CPCs)
  - Specify the type of CPC that is to be applied after repair installation

Common Repairs & Associated Design Issues

Strap

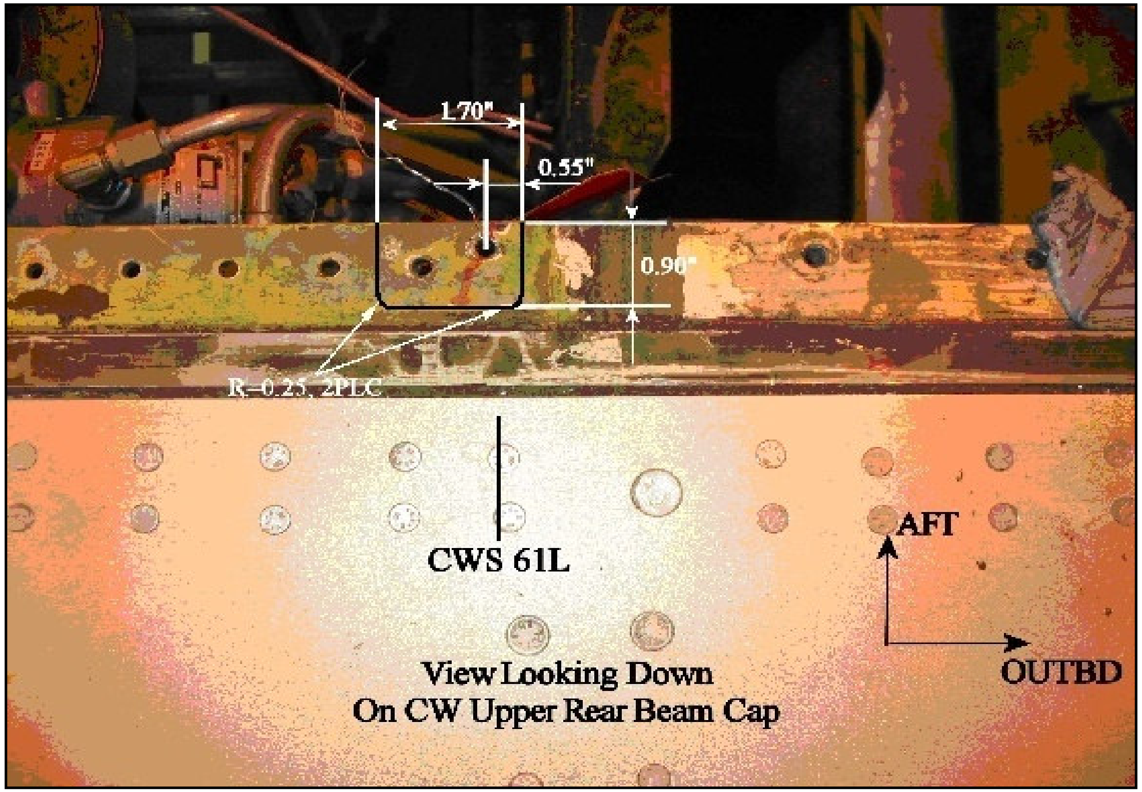


This repair addressed damage on the flange of the aft upper spar cap common to the pressure panel attachments.



Common Repairs & Associated Design Issues

Strap

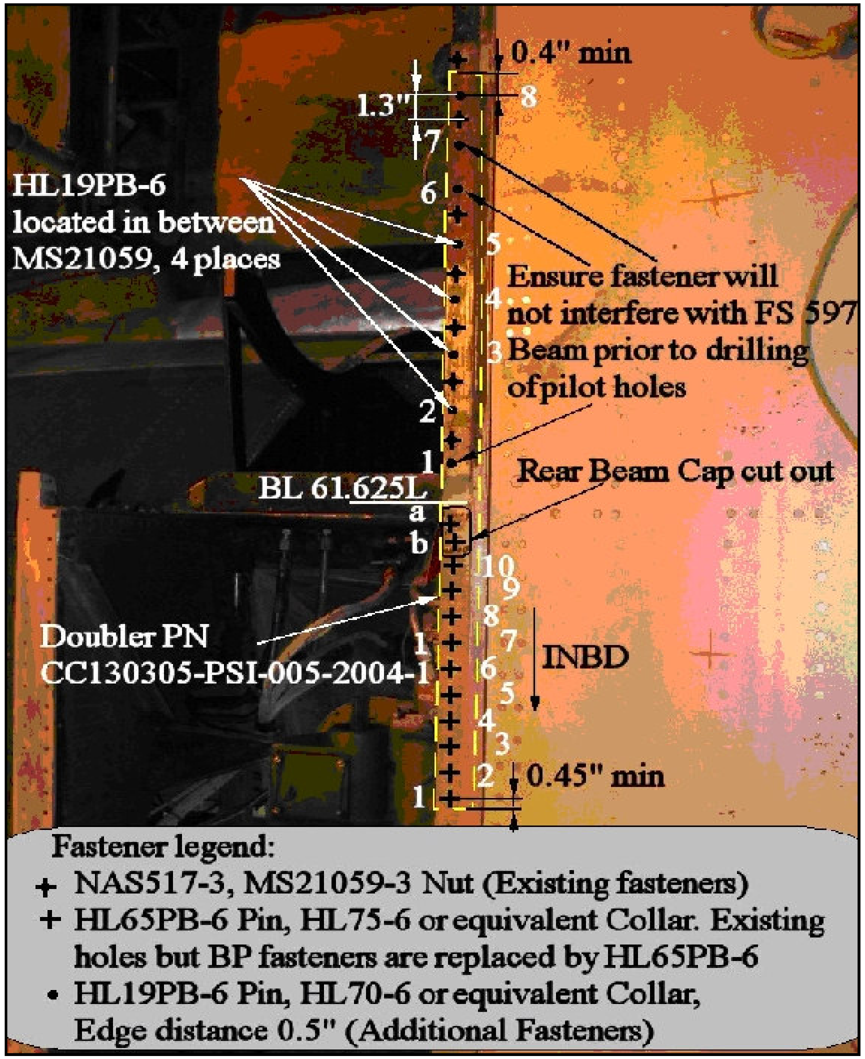


The damage is excised by trimming the spar cap flange according to the dimensions specified at left. Note the low edge distance on the fastener hole common to the crack……..

Common Repairs & Associated Design Issues

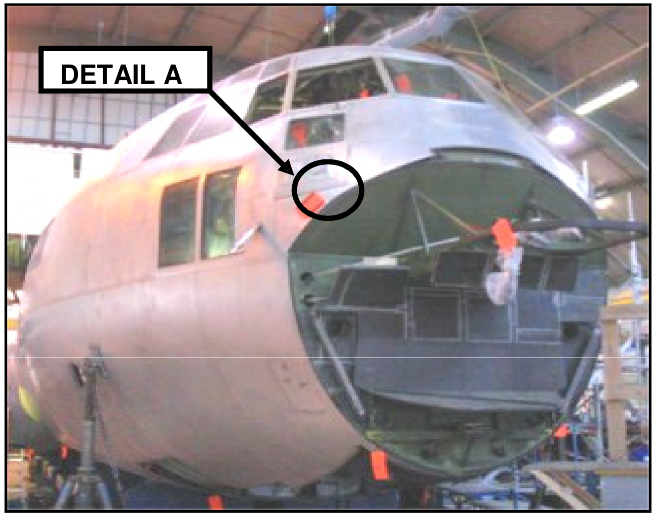
Strap

A filler is designed to fill the gap and a repair strap (shown in yellow) straddles the damage zone - the strap is tapered at the end using a 20:1 taper ratio based on strap thickness. Additional fasteners are installed to permit the strap to carry at least the load carrying capability of the cap flange in net tension. Fastener pitch is between 4 and 6D. Edge distances are specified to achieve at least 2D.

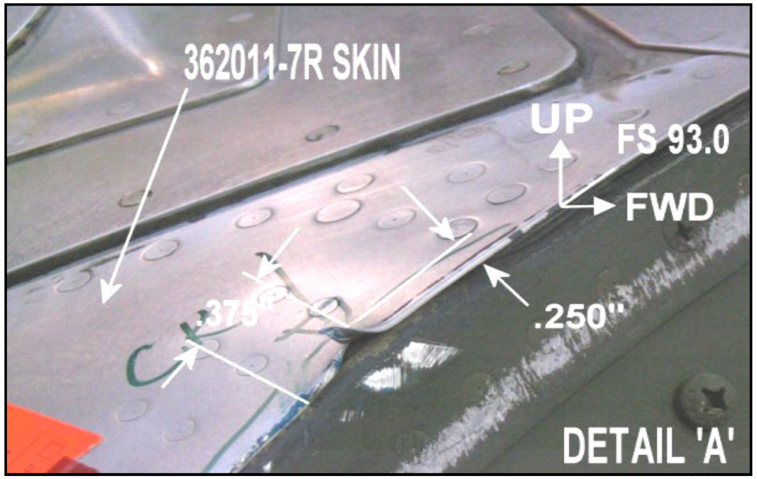


Common Repairs & Associated Design Issues

Trim



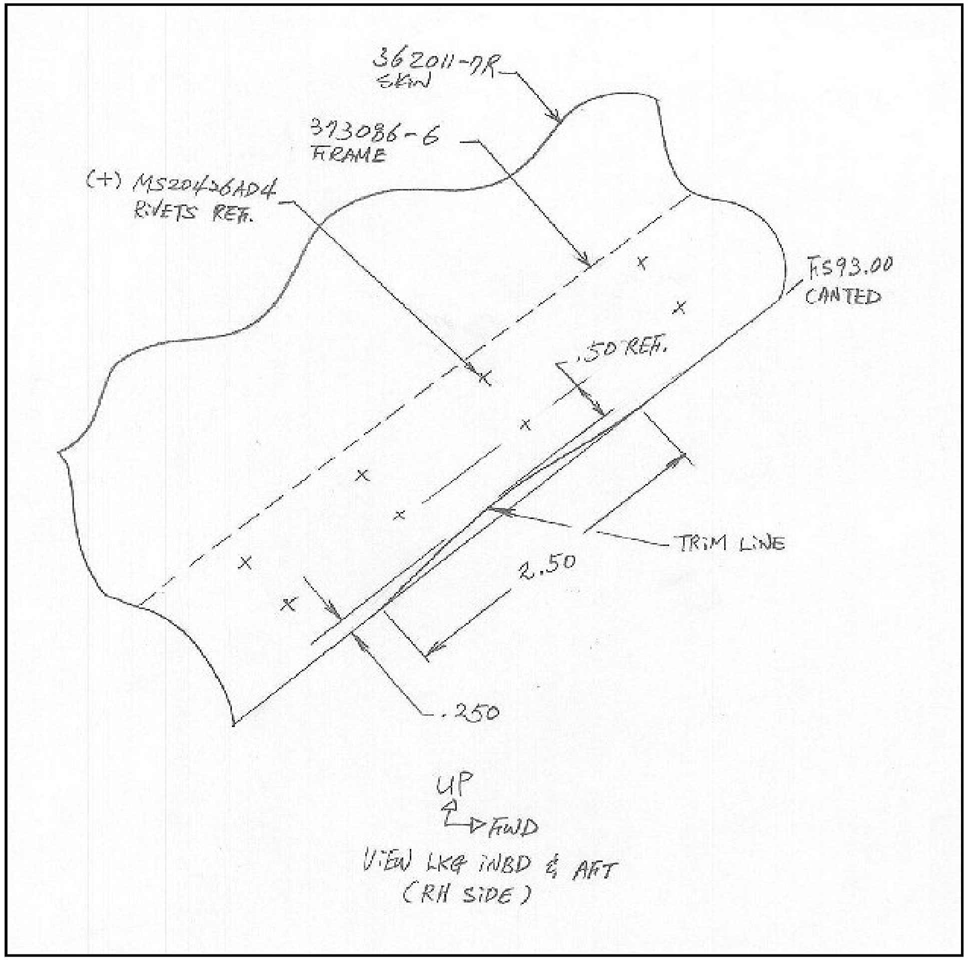
The free edge of the fuselage skin at the radome bulkhead has been gouged.



Common Repairs & Associated Design Issues

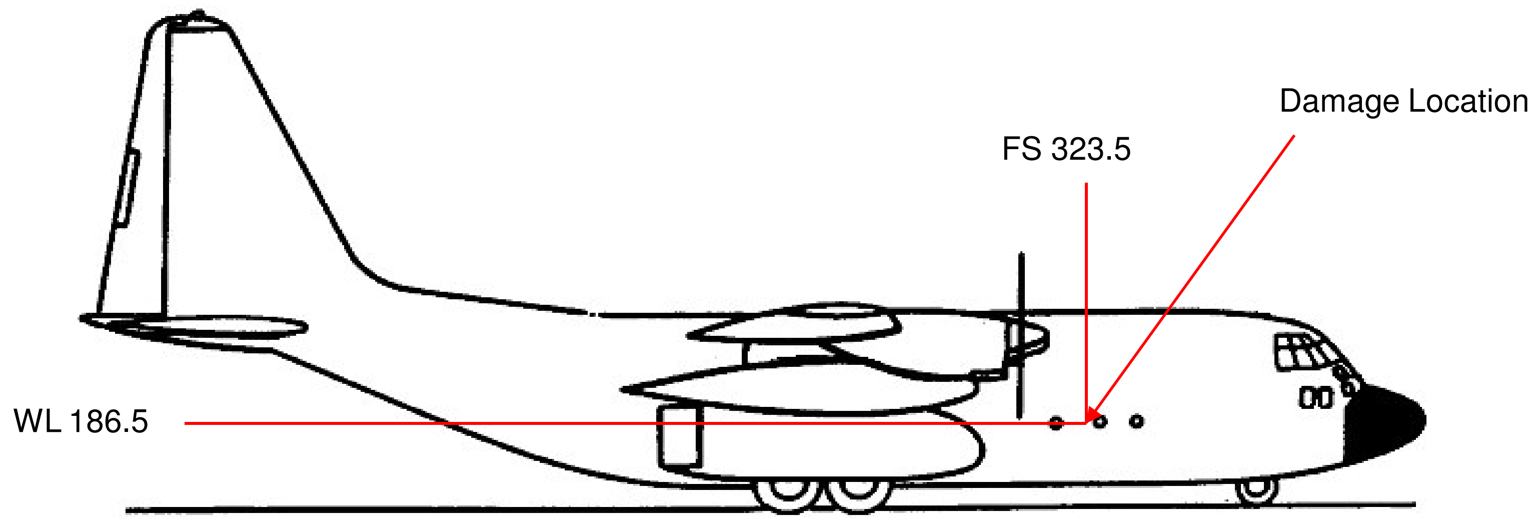
Trim

The design solution is simply to trim the damage out. The trim radius is large to avoid the creation of any stress concentrations. Edge distance between the trim line and the existing fasteners is ensured by calling up the 0.50” measurement



Common Repairs & Associated Design Issues

External Doubler



A substantial dent has been noted adjacent to the aircraft's pitot/static system - an external doubler repair has been elected.

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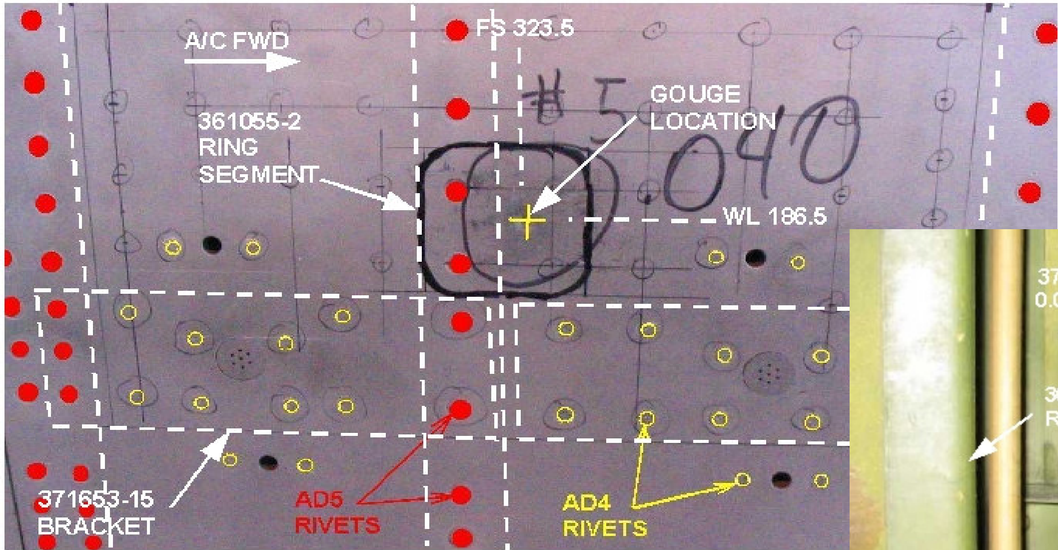
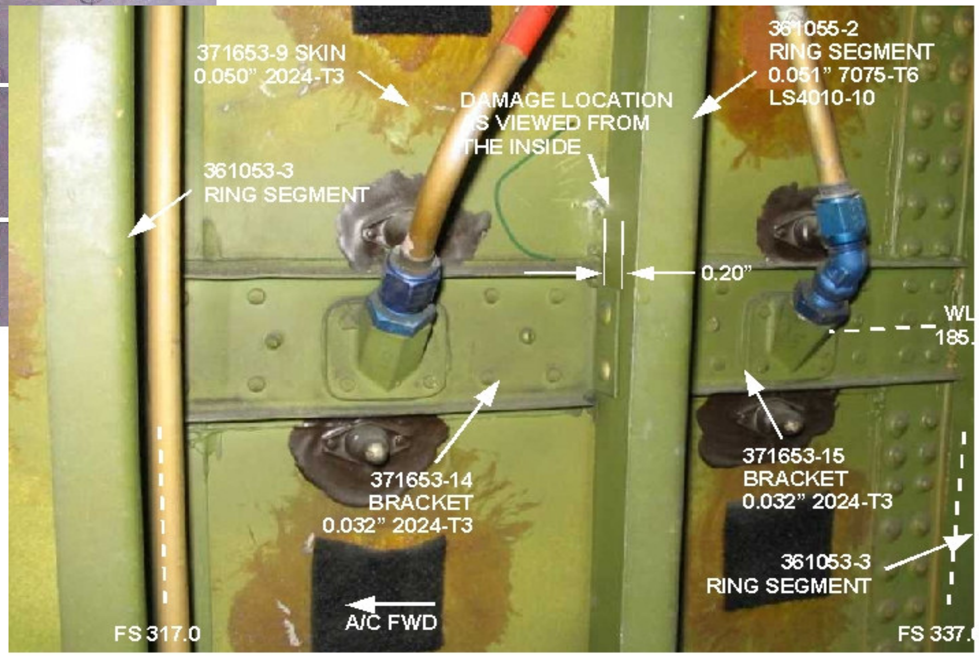
Common Repairs & Associated Design Issues

External Doubler



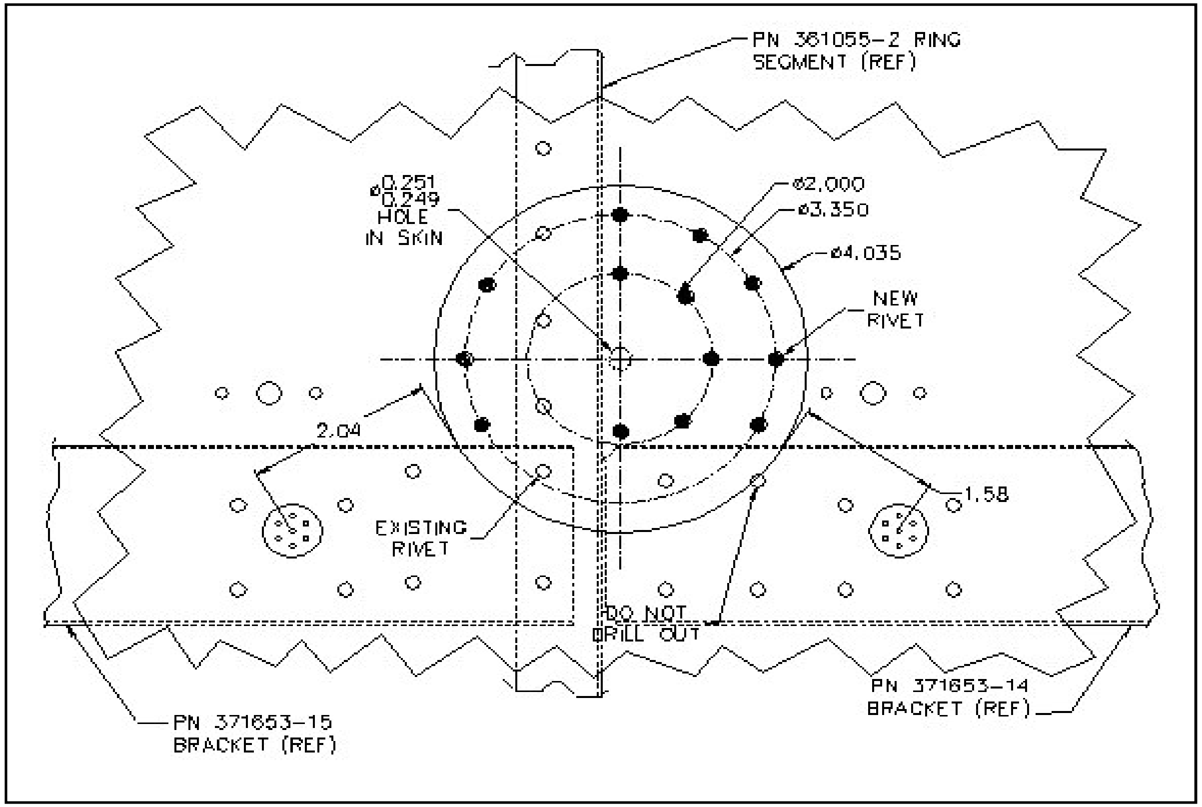


The dent is immediately adjacent to an internal fuselage frame.

Common Repairs & Associated Design Issues

External Doubler

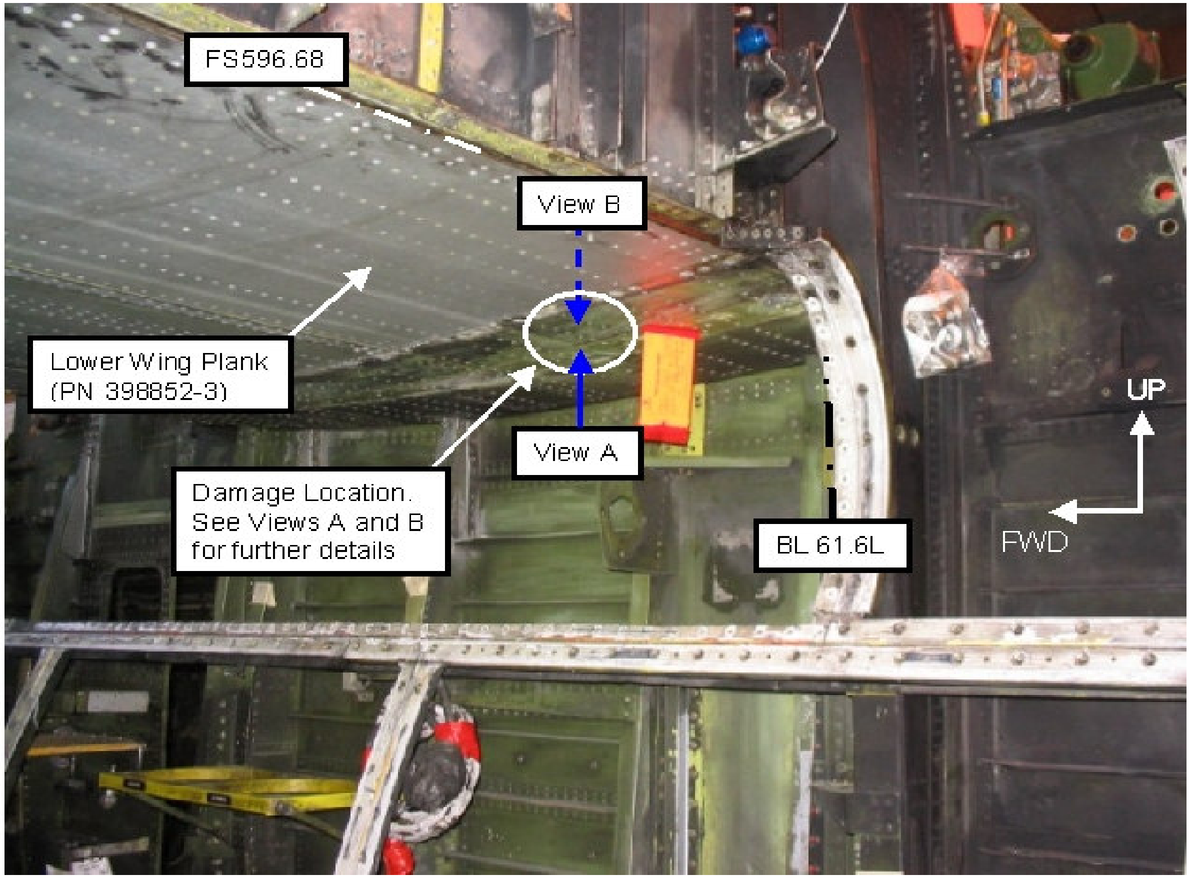
The dent was excised and an external doubler was elected - presumably to avoid disturbing the frame. However, note that the skin is now sandwiched between the frame flange and the external doubler - inspectability of the skin has been compromised. Repair designs often involve careful consideration of many competing factors; ease of installation and inspectability are only two of them. Compromises are inevitable.



Common Repairs & Associated Design Issues

Bushing

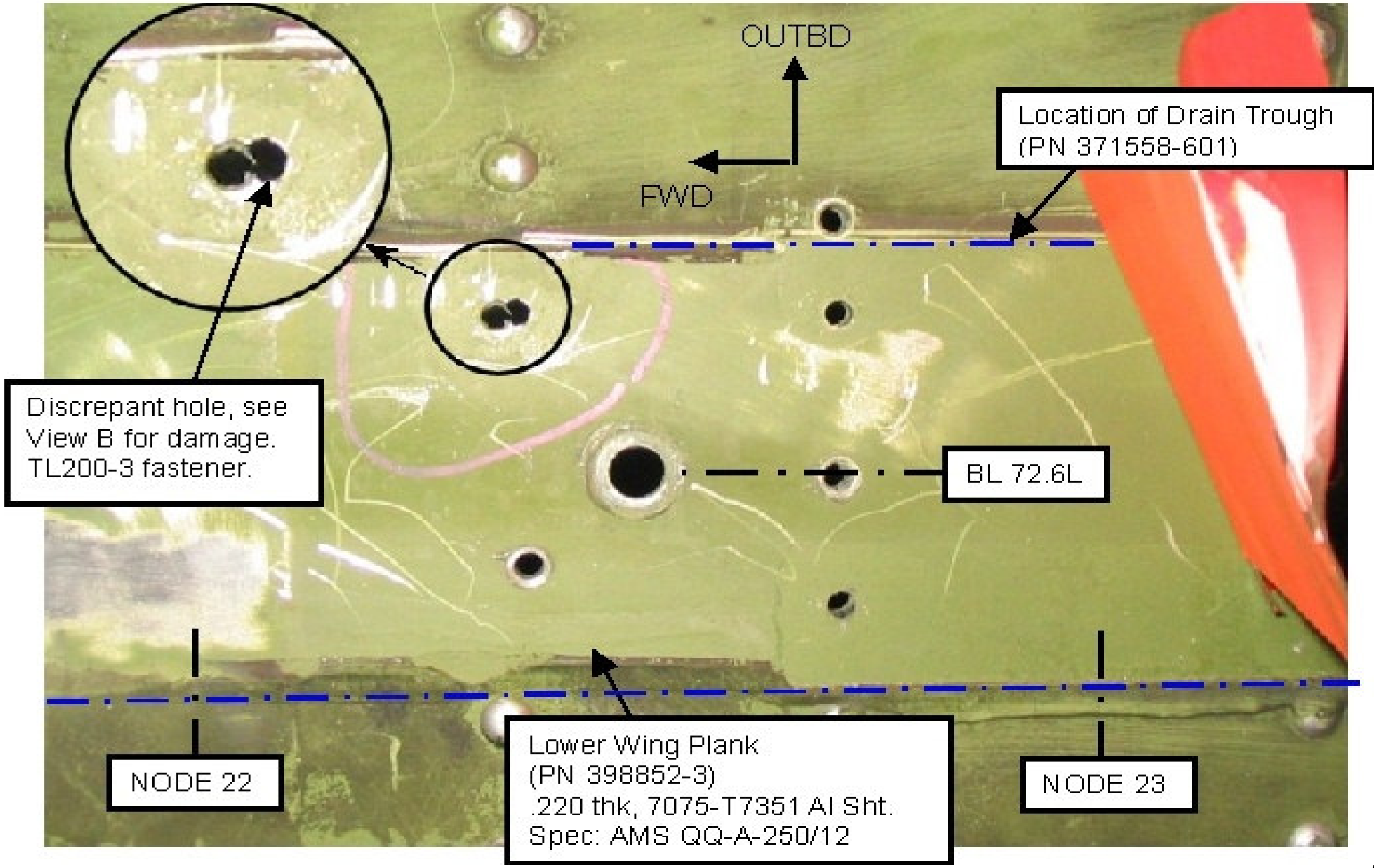
A double drilled hole was found on the lower skin plank at the left hand wing root.



Common Repairs & Associated Design Issues

Bushing

Double drilled holes are often called 'Snowman' holes - for obvious reasons….



Common Repairs & Associated Design Issues

Bushing

A freeze bushing design was selected to fix this problem. The 'snowman' hole is progressively reamed until circular. An aluminum plug is then fabricated such that its diameter is slightly larger than the holes. The plug is then submerged in liquid nitrogen (approximately 300 deg F below zero) to shrink it, followed by immediate installation. When the plug warms back up, it expands into the hole and fits with a high degree of interference.

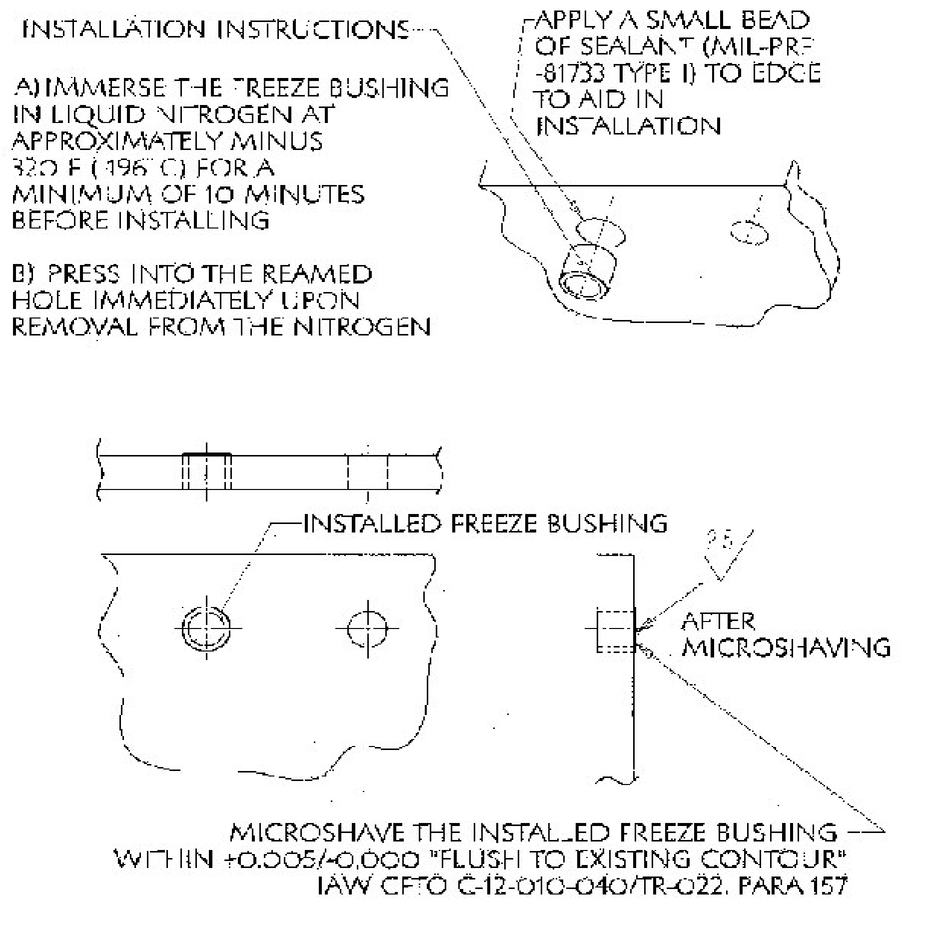
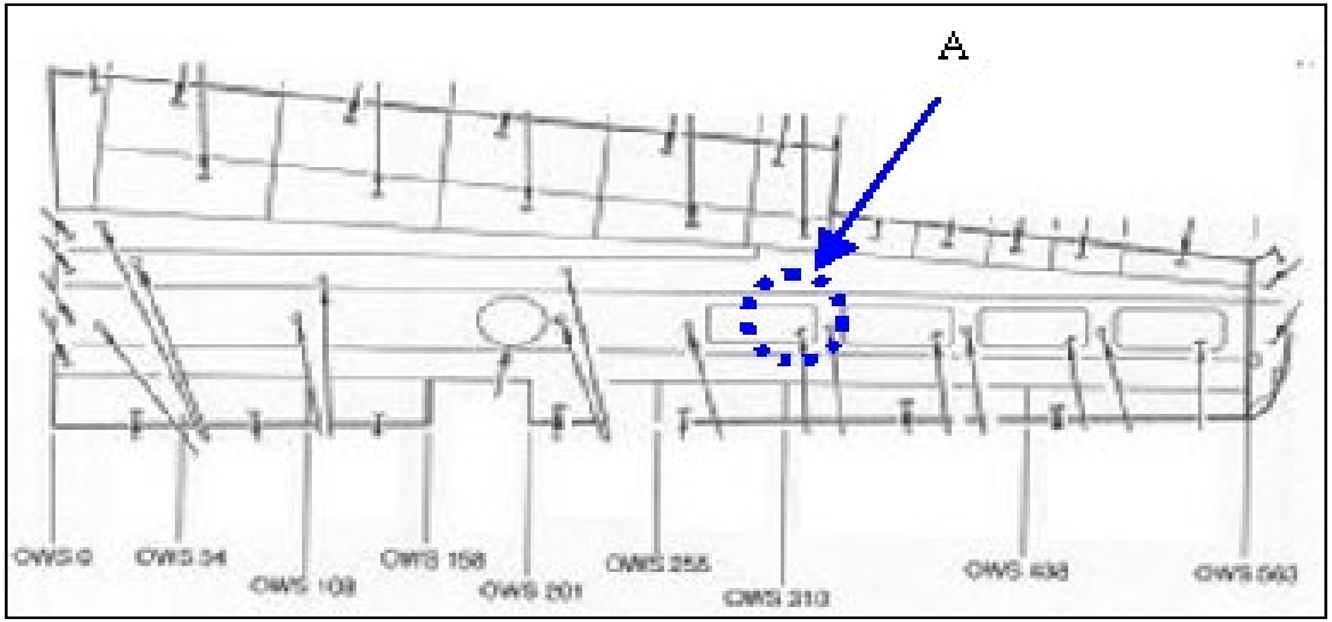


Figure 3: Freeze Bushing Fabrication and Installation (Sheet 3 of 3)

Common Repairs & Associated Design Issues

Blend

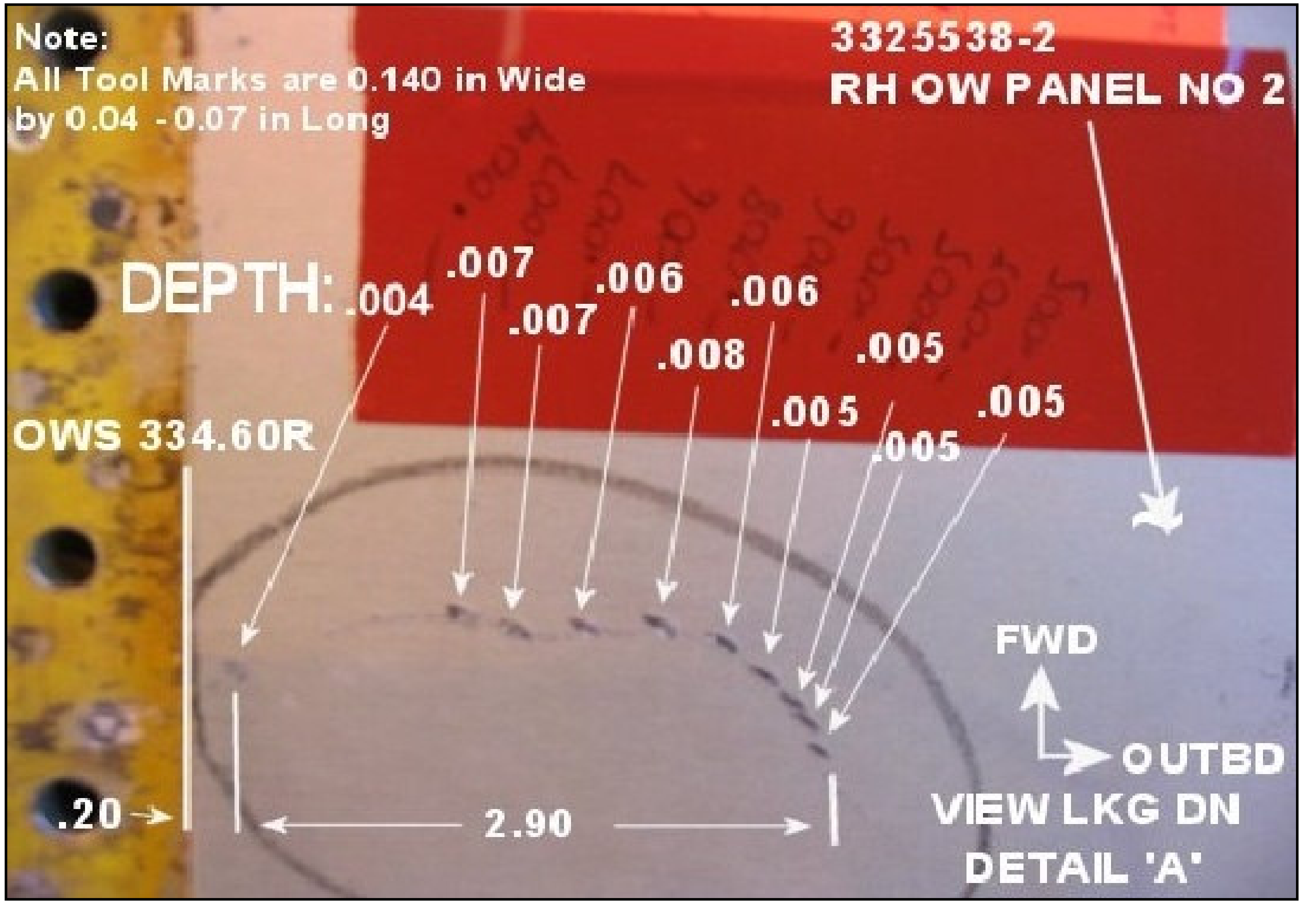
During removal of a fuel access panel on the outboard upper wing surface, the speeder wrench slipped off the fastener and gouged the skin plank.



Common Repairs & Associated Design Issues

Blend

The damage was repaired by blending, the area was after Surface Eddy Current Inspected for cracks. The area was then cold worked using shot peening followed by alodining, primer and paint.



Repair Analysis

The Principle of Equivalent Strength

- The glider tow rope above is loaded in tension
- The tension load is equivalent to the aerodynamic loads created by the glider
- The aerodynamic loads created by the glider are dependent on the glider weight, the airspeed and the aerodynamic characteristics of the glider
- If the glider rope broke due to local and isolated damage, how could we splice the two halves together and ensure that the repair splice strength is adequate?

Repair Analysis

The Principle of Equivalent Strength

There are two approaches we could use:

1. Calculate the aero-loads created by the glider and design a repair splice to carry those loads
2. Design a splice to restore the original strength of the tow system

The latter approach makes use of the principle of equivalent strength - the actual loads imparted by the glider to the rope are interesting, but irrelevant provided the rope system's original strength has been restored.

Repair Analysis

The Principle of Equivalent Strength

Restoring adequate strength involves looking at the rope system as a whole. When we do this, we are looking for the 'weak link'. Although the rope may be designed for a 3,000# load, the clevis that links the rope to the glider may only be designed for a 1,500# load. If this was the case then the rope splice needs to only be strong enough to carry a 1,500# load.

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Repair Analysis

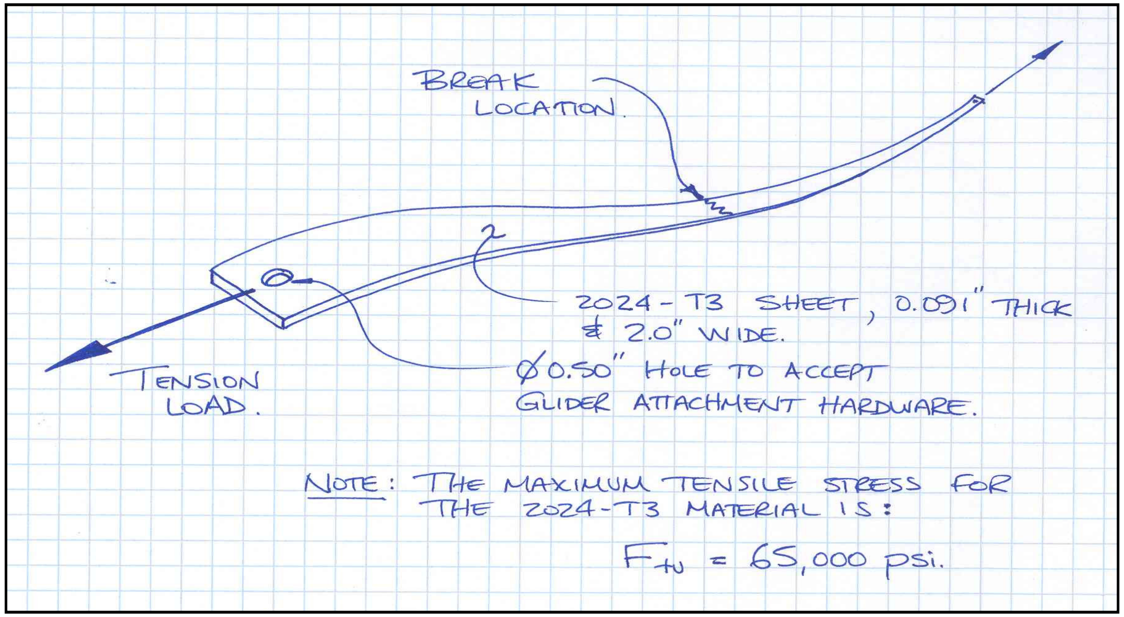
The Principle of Equivalent Strength

Let's replace the glider tow rope with a piece of long sheet aluminum shown at right.

Let's assume that our aluminum rope has broken due to fatigue cracking at a gouge location.

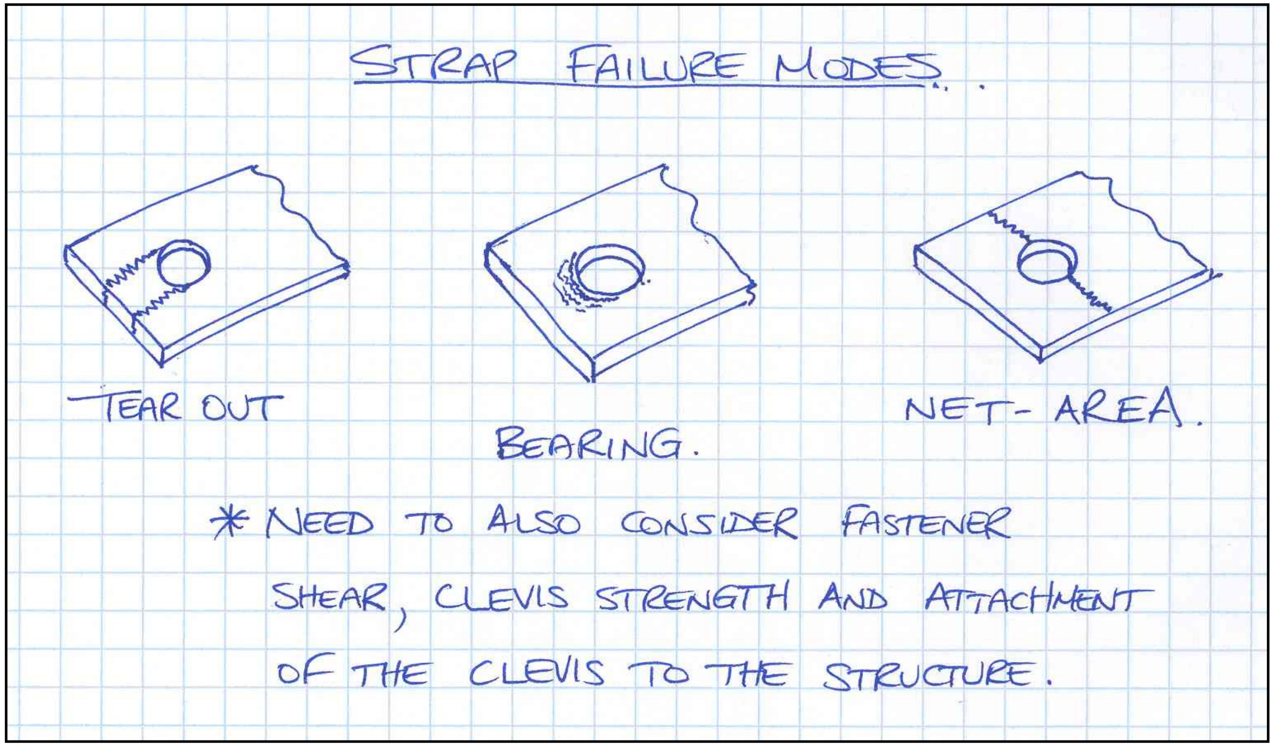
The repair we design to splice the two broken halves together must be capable of carrying the maximum load that our aluminum rope system as a whole is capable of carrying.

We need to establish the weak link load (repair design load).



Repair Analysis

The Principle of Equivalent Strength

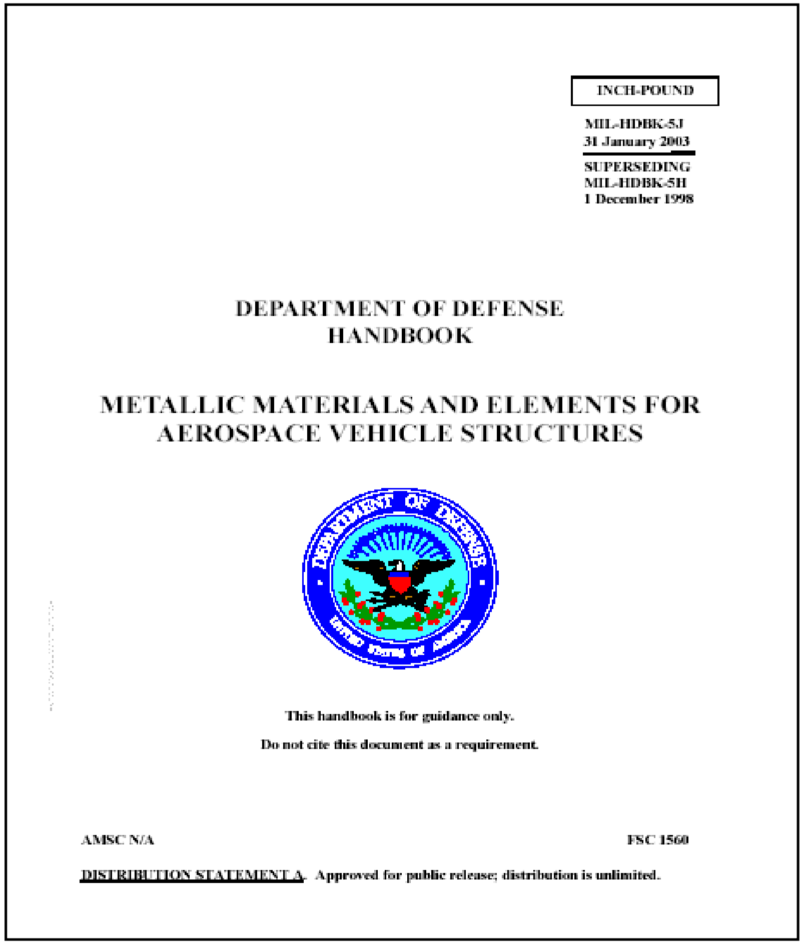


Determination of the repair design load requires assessing all possible failure modes and the associated loads at failure. Ignoring our clevis bolt, clevis and means of attachment to the aircraft, our tow rope has three primary failure modes: the clevis bolt can tear out of the strap or it can cause a local bearing failure - additionally a failure in tension across the attachment hole could occur.

Repair Analysis

The Principle of Equivalent Strength

Calculating the loads associated with these three failure modes requires a knowledge of the strength of 0.091" thick 2024-T3 sheet. We typically derive this knowledge from Mil-Hdbk-5 which addresses the vast majority of aerospace materials. Allowables (strength) data has been compiled based on extensive testing - data is typically presented in tabular form.



INCH-POUND

MIL-HDBK-5J
31 January 2003

SUPERSEDING
MIL-HDBK-5H
1 December 1998

DEPARTMENT OF DEFENSE
HANDBOOK

METALLIC MATERIALS AND ELEMENTS FOR
AEROSPACE VEHICLE STRUCTURES

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AMSC N/A FSC 1560

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Repair Analysis

The Principle of Equivalent Strength

Table 3.2.3.0(b$_1$). Design Mechanical and Physical Properties of 2024 Aluminum Alloy Sheet and Plate

Specification	AMS 4037 and AMS-QQ-A-250/4																	AMS-QQ-A-250/4		
Form	Sheet					Plate												Sheet		Plate
Temper	T3					T351												T361		
Thickness, in.	0.008-0.009	0.010-0.128		0.129-0.249		0.250-0.499		0.500-1.000		1.001-1.500		1.501-2.000		2.001-3.000		3.001-4.000		0.020-0.062	0.063-0.249	0.250-0.500
Basis	S	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	S	S	S
Mechanical Properties:																				
F_{tu}, ksi:																				
L	64	64	65	65	66	64	66	63	65	62	64	62	64	60	62	57	59	68	69	67
LT	63	63	64	64	65	64	66	63	65	62	64	62	64	60	62	57	59	67	68	66
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	52[a]	54[a]	49[a]	51[a]	...	...	...
F_{ty}, ksi:																				
L	47	47	48	47	48	48	50	48	50	47	50	47	49	46	48	43	46	56	56	54
LT	42	42	43	42	43	42	44	42	44	42	44	42	44	42	44	41	43	50	51	49
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	38[a]	40[a]	38[a]	39[a]	...	...	...
F_{cy}, ksi:																				
L	39	39	40	39	40	39	41	39	41	39	40	38	40	37	39	35	37	47	48	46
LT	45	45	46	45	46	45	47	45	47	44	46	44	46	43	45	41	43	53	54	52
ST	...	...	...	...	...	...	...	...	...	...	...	...	...	46	48	44	47	...	...	...
F_{su}, ksi	39	39	40	40	41	38	39	37	38	37	38	37	38	35	37	34	35	42	42	41
F_{bru}[b], ksi:																				
(e/D = 1.5)	104	104	106	106	107	97	100	95	98	94	97	94	97	91	94	86	89	111	112	109
(e/D = 2.0)	129	129	131	131	133	119	122	117	120	115	119	115	119	111	115	106	109	137	139	135
F_{bry}[b], ksi:																				
(e/D = 1.5)	73	73	75	73	75	72	76	72	76	72	76	72	76	72	76	70	74	82	84	81
(e/D = 2.0)	88	88	90	88	90	86	90	86	90	86	90	86	90	86	90	84	88	97	99	96
e, percent (S-basis):																				
LT	10	c	...	c	...	12	...	8	...	7	...	6	...	4	...	4	...	8	9	9[d]
E, 10^3 ksi	10.5					10.7												10.5		10.7
E_c, 10^3 ksi	10.7					10.9												10.7		10.9
G, 10^3 ksi	4.0					4.0												4.0		4.0
μ	0.33					0.33												0.33		0.33
Physical Properties:																				
ω, lb/in.^{3}	0.100																			
C, K, and α	See Figure 3.2.3.0																			

a Caution: This specific alloy, temper, and product form exhibits poor stress-corrosion cracking resistance in this grain direction. It corresponds to an SCC resistance rating of D, as indicated in Table 3.1.2.3.1(a).
b Bearing values are "dry pin" values per Section 1.4.7.1. See Table 3.1.2.1.1.
c See Table 3.2.3.0(c).
d 10% for 0.500 inch.

This is the Mil-Hdbk-5 table for 2024-T3 plate and sheet from which the relevant material properties may be extracted.

Repair Analysis

The Principle of Equivalent Strength

We see that the following properties are applicable to our 2024-T3 sheet glider to rope:

F_{tu} = 65 ksi

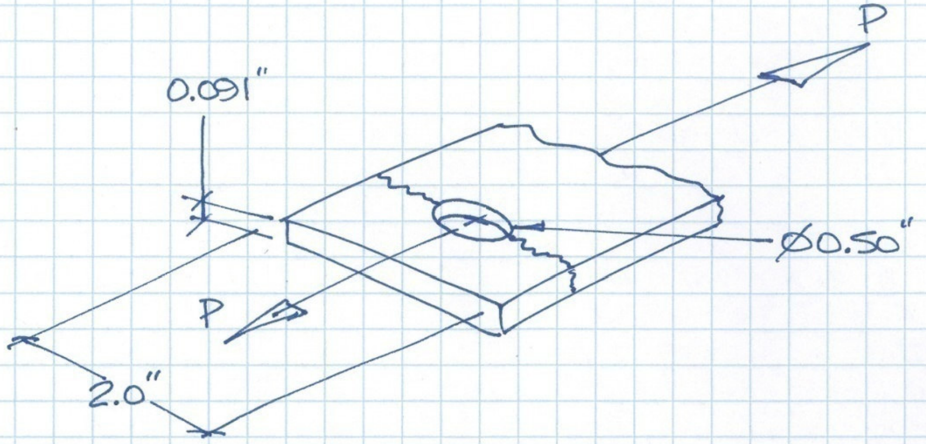
F_{su} = 40 ksi

F_{bru} = 131 ksi

Specification					
Form	Sheet				
Temper	T3				
Thickness, in.	0.008-0.009	0.010-0.128		0.129-0.249	
Basis	S	A	B	A	B
Mechanical Properties:					
F_{tu}, ksi:					
L	64	64	65	65	66
LT	63	63	64	64	65
ST	...	...	...	...	...
F_{ty}, ksi:					
L	47	47	48	47	48
LT	42	42	43	42	43
ST	...	...	...	...	...
F_{cy}, ksi:					
L	39	39	40	39	40
LT	45	45	46	45	46
ST	...	...	...	...	...
F_{su}, ksi	39	39	40	40	41
F_{bru}^{b}, ksi:					
(e/D = 1.5)	104	104	106	106	107
(e/D = 2.0)	129	129	131	131	133

Repair Analysis

The Principle of Equivalent Strength



NET TENSION AREA : $A_{NET} = (2.0 - 0.50)(0.091)$

$= 0.1365\ in^2.$

ALLOWABLE TENSION STRESS : $F_{tu} = 65\ ksi = 65{,}000\ psi.$

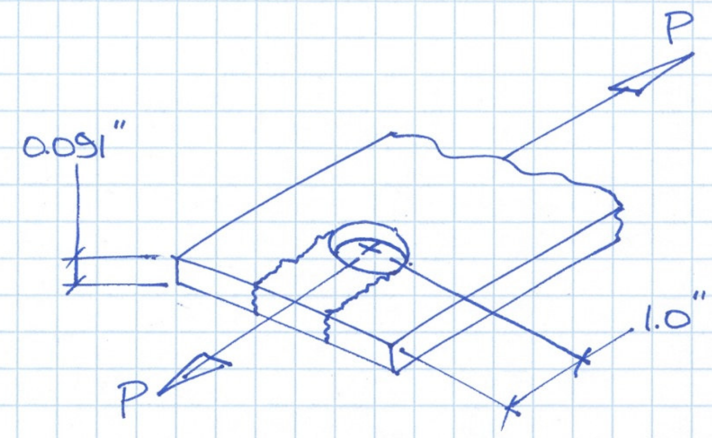
ALLOWABLE TENSION LOAD : $P_{TENS} = F_{tu} \times A_{NET}$

$= (65{,}000)(0.1365)$

$= 8870\ \#.$

Repair Analysis

The Principle of Equivalent Strength



Shear Area: $A_{SHR} = (0.091)(1.0)(2)$

$= 0.182 \text{ in}^2.$

Allowable Shear Stress: $F_{SU} = 40 \text{ ksi} = 40{,}000 \text{ psi}.$

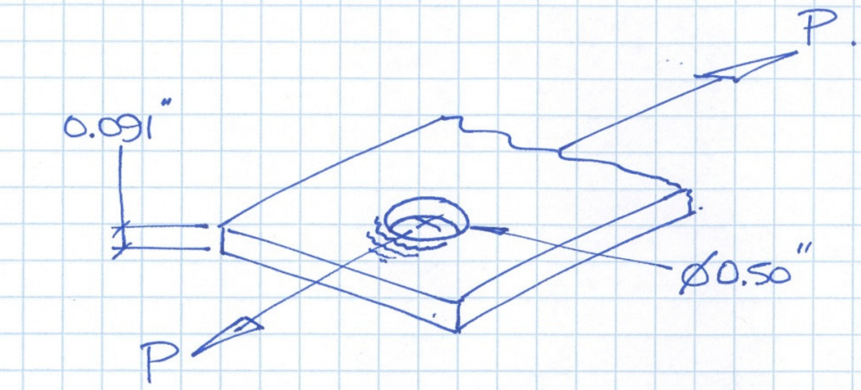
Allowable Shear Load: $P_{SHR} = F_{SU} \times A_{SHR}$

$= (40{,}000)(0.182)$

$= 7280 \#.$

Repair Analysis

The Principle of Equivalent Strength



Bearing Area: $A_{BRG} = (0.50)(0.091)$

$= 0.0455 \text{ in}^2$.

Allowable Bearing Stress: $F_{BRG} = 131 \text{ ksi} = 131{,}000 \text{ psi}$.

Allowable Bearing Load: $P_{BRG} = F_{BRG} \times A_{BRG}$.

$= (131{,}000)(0.0455)$

$= 5960 \#$.

Repair Analysis

The Principle of Equivalent Strength

Summarizing the loads at failure:

Shear Out: 7,280 #

Tension: 8,870 #

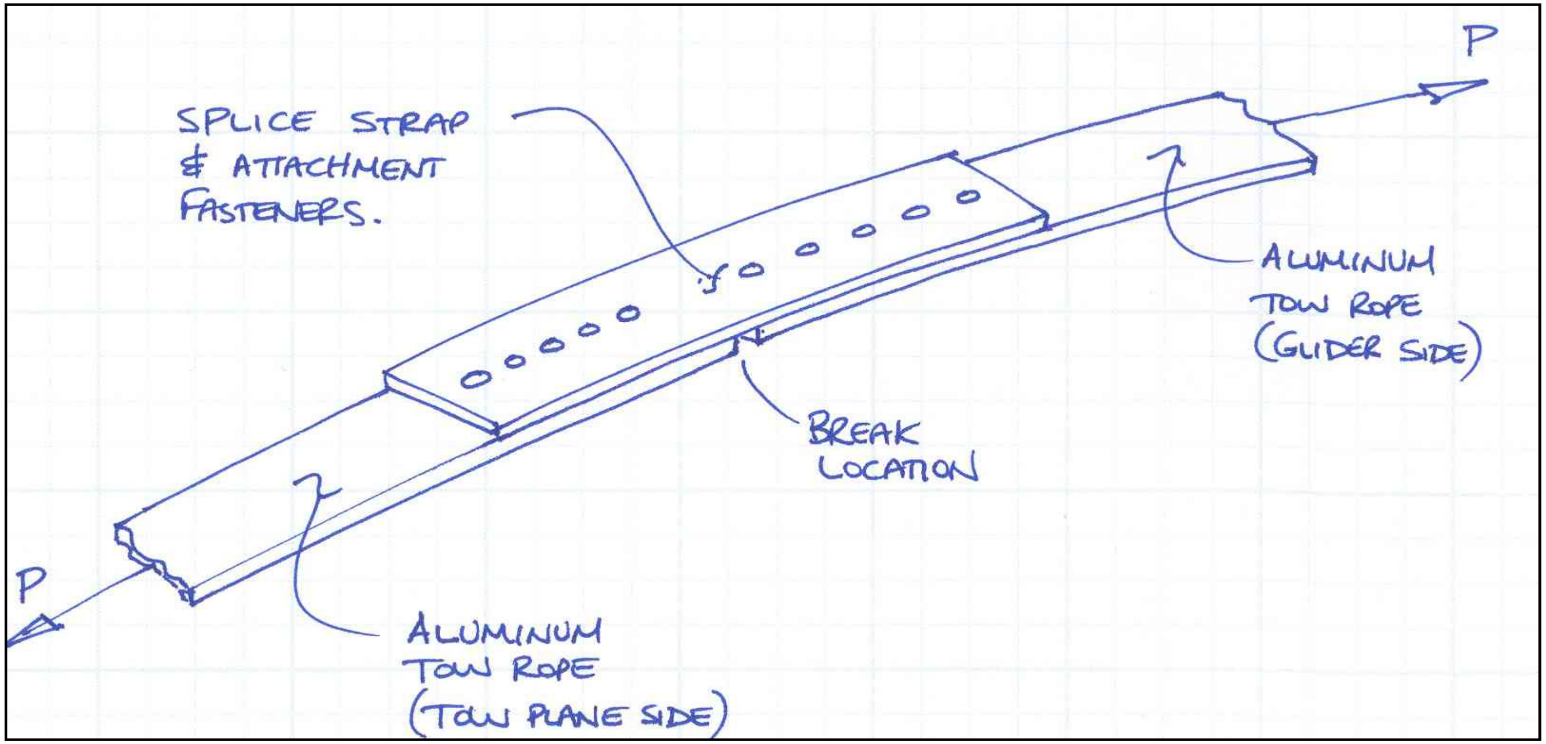
Bearing: 5,960 #

Our aluminum rope will fail in bearing of the clevis bolt on the attaching hole at a predicted load of 5,960 #. Any repair splice that we design must be at least strong enough to carry this load.

Repair Analysis

A Simple Splice Repair

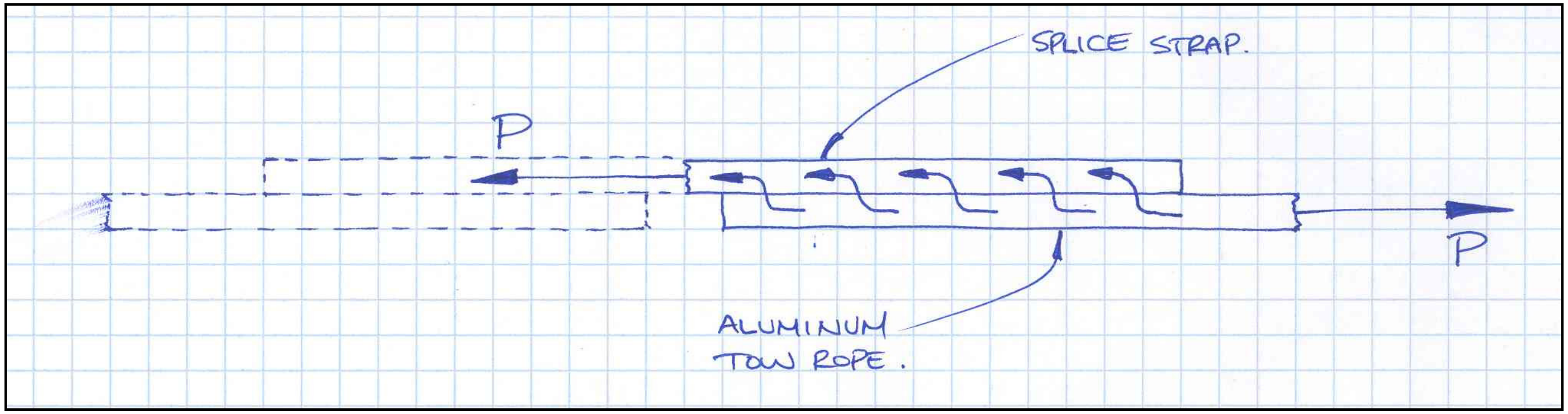
Our aluminum tow rope needs to be spliced together at the break location:



Repair Analysis

A Simple Splice Repair

Looking at the splice strap and repair fasteners in more detail:



By the time we reach the break location, all of the load in the aluminum tow rope needs to have been fully transferred to the strap splice. In this case, the load is transferred through five aluminum rivets.

Repair Analysis

A Simple Splice Repair

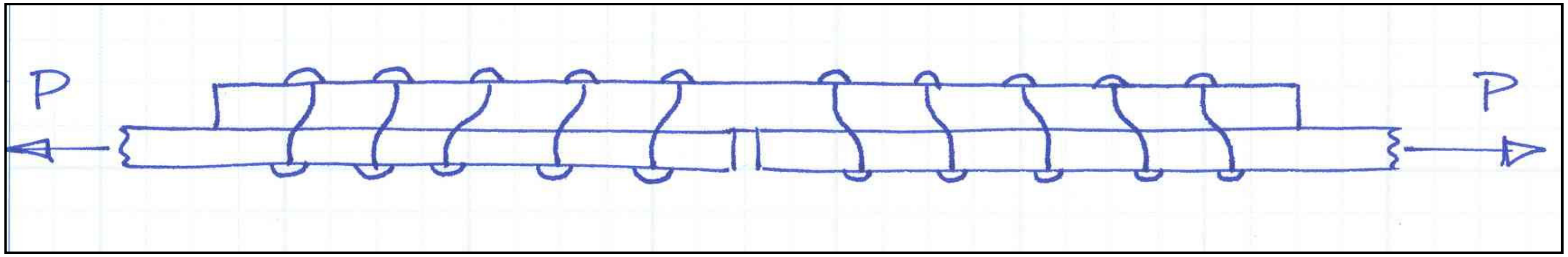
We have already determined that the design load is 5,960 # - our repair strap and the attaching fasteners need to be strong enough to transfer this load.

Let's first check the fasteners to confirm that they are capable of transferring the load from the aluminum rope to the strap - 5 x 1/4" 2017 'D' type rivets are utilized on each side of the strap that straddles the break.

Repair Analysis

A Simple Splice Repair

What should we check? Let's first have a look at what is happening with the fasteners when they are under load:

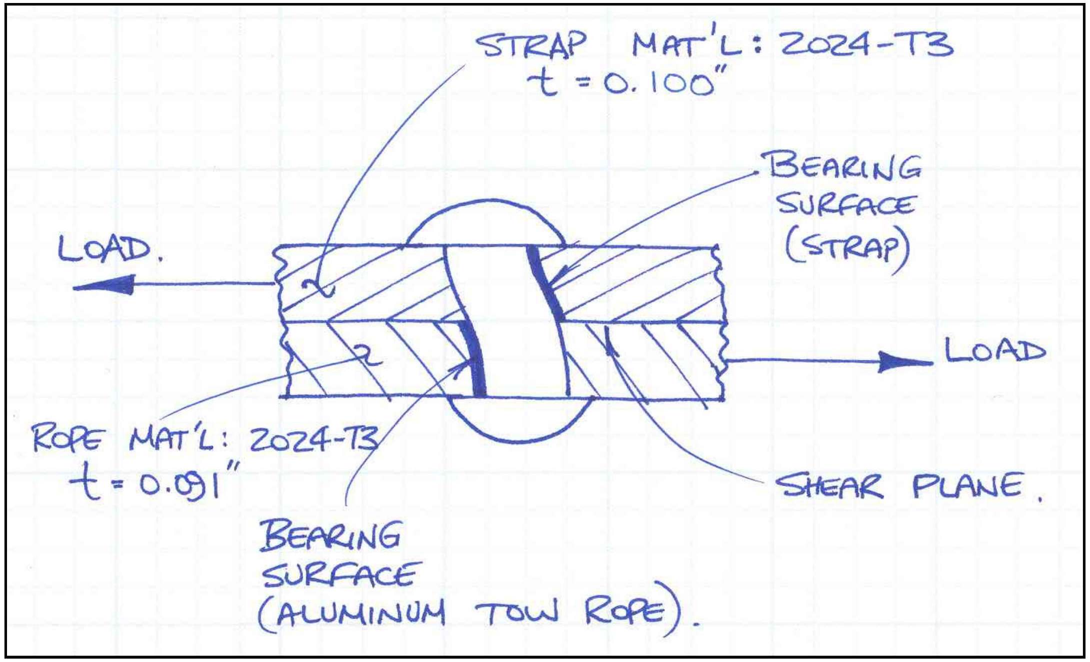


The strap and aluminum rope tend to act as a pair of scissors that attempt to shear the fasteners - a check to confirm that adequate fastener shear strength exists needs to be undertaken.

Repair Analysis

A Simple Splice Repair

Looking at a single fastener in more detail:

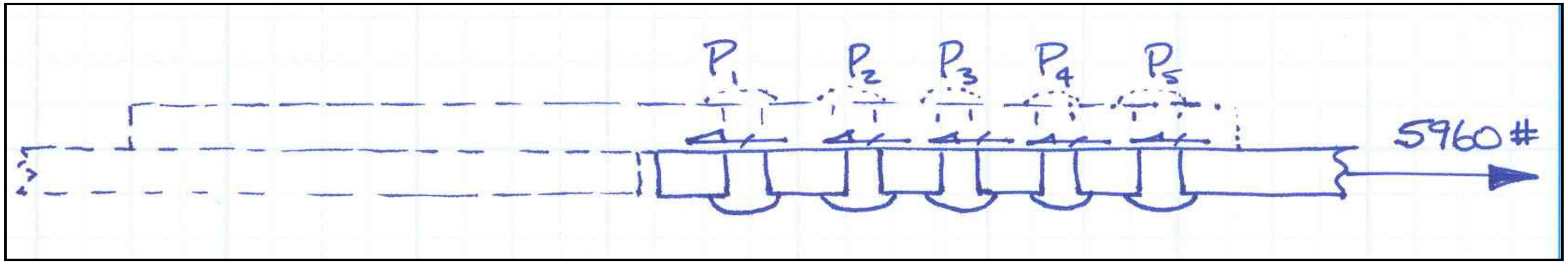


The fastener bears up against one side of the hole - sides opposite for the strap and the rope. This is the means by which loads are physically transferred from one to the other. It is now obvious that a check needs to be undertaken to confirm that neither the strap, nor the aluminum rope will fail in bearing.

Repair Analysis

A Simple Splice Repair

Fastener Shear Check:



For purposes of this example, it may be assumed that all 5 fasteners are equally loaded. Therefore, the 'applied' fastener shear loads are:

$$P_{shr} = \frac{5960\ \#}{5\ \text{fasteners}} = 1{,}192\ \#\ \text{per fastener}$$

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Repair Analysis

A Simple Splice Repair

Fastener Shear Check (cont'd):

From Mil-Hdbk-5, a 1/4" D rivet can carry 1970 # of shear - we call this the 'allowable' load.

Table 8.1.2(b). Single Shear Strength of Solid Rivets[a]

Undriven			Driven			Rivet Size							
Rivet Material	F_{su} (ksi) Min	F_{su} (ksi) Max	Rivet Material	F_{su}^{b} (ksi)	Rivet Designation	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8
						Driven Single Shear Strength, lbs[c]							
5056-H32	24	n/a	5056-H321[d]	28[e]	B[f]	99	203	363	556	802	1450	2290	3275
2117-T4	26	n/a	2117-T3	30[e]	AD	106	217	389	596	860	1555	2455	3510
2017-T4	35	42	2017-T3	38[e]	D	134	275	493	755	1085	1970	3115	4445
2024-T4	37	n/a	2024-T31	41[g]	DD	145	297	532	814	1175	2125	3360	4795
7050-T73	41	46	7050-T731[d]	43[e]	E[h]	152	311	558	854	1230	2230	3520	5030
Monel	49	59	Monel	52[e]	M	183	376	674	1030	1490	2695	4260	6085
Ti-45Cb	50	59	Ti-45Cb	53[e]	T	187	384	687	1050	1515	2745	4340	6200
A-286	85	95	A-286	90[e]	-	317	651	1165	1785	2575	4665	7375	10500

a All rivets must be sufficiently driven to fill the rivet hole at the shear plane. Driving changes the rivet strength from the undriven to the driven condition and thus provides the above driven shear strengths.
b Shear stresses are for the as driven condition on B-basis probability.
c Based on nominal hole diameter specified in Table 8.1.2(a).
d The temper designations last digit (1), indicates recognition of strengthening derived from driving.
e The bucktail's minimum diameter is 1.5 times the nominal hole diameter in Table 8.1.2(a).
f Should not be exposed to temperatures over 150°F.
g Driven in the W (fresh or ice box) condition to minimum 1.4D bucktail diameter.
h E (or KE, as per NAS documents).

Repair Analysis

A Simple Splice Repair

Fastener Shear Check (cont'd):

So, the allowable fastener shear load is 1,970 # and the applied load is 1,192 # - clearly we have enough fasteners to carry the repair design load without failing the fasteners in shear. We can now write a margin of safety:

$$MS = \frac{\text{Allowable}}{\text{Applied}} - 1$$

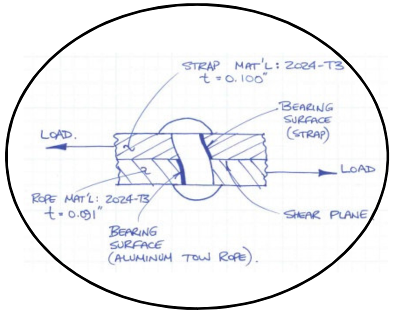
$$= \frac{1{,}970}{1{,}192} - 1$$

<u>MS = +0.65</u>

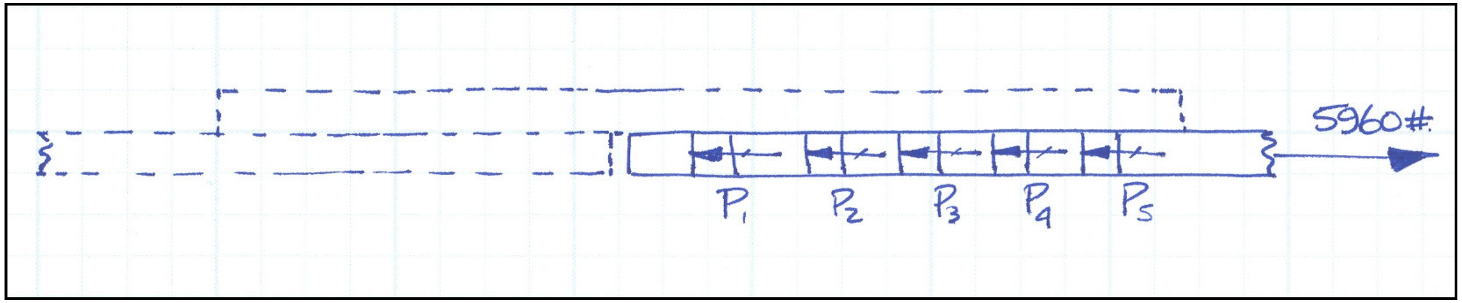
We have a positive margin in fastener shear - our fasteners can carry 65% more load than they need to.

Repair Analysis

A Simple Splice Repair



Fastener Bearing Check:



For purposes of this example, it may be assumed that all 5 fasteners bear equally on all holes. Therefore, the 'applied' fastener bearing loads are:

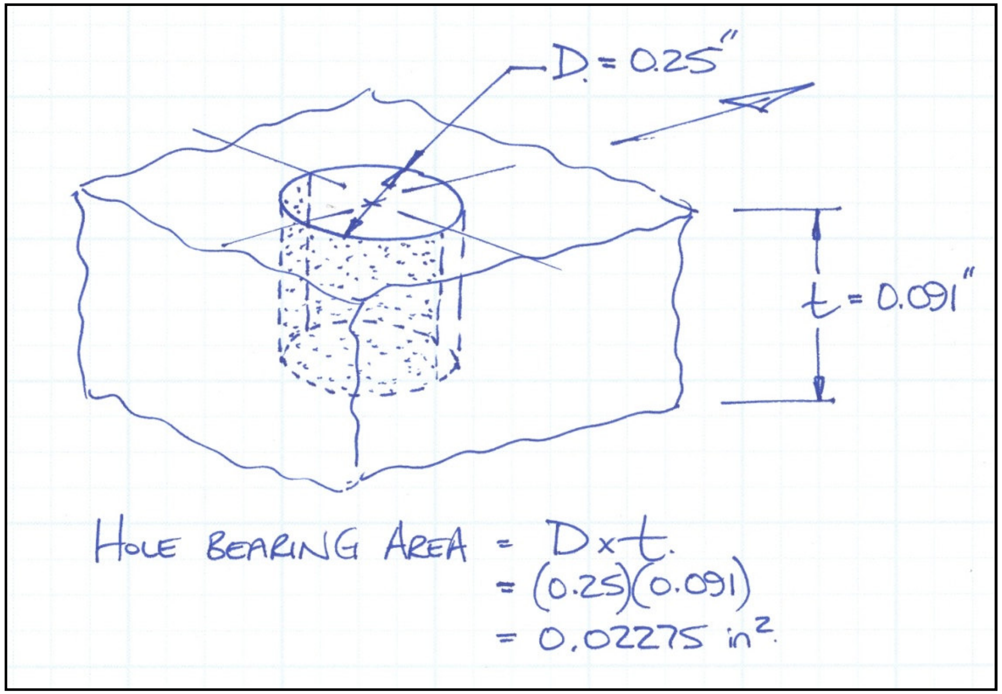
$$P_{brg} = \frac{5960\ \#}{5\ \text{fasteners}} = 1{,}192\ \#\ \text{per fastener}$$

Repair Analysis

A Simple Splice Repair

Fastener Bearing Check:

From slide 11, the bearing allowable for 2024-T3 sheet is 131,000 psi. The hole bearing area is:



Note that the fastener bears on both the strap and the aluminum rope. Both are fabricated from the same material, however, the rope is thinner than the strap and therefore has a smaller bearing area. This means that the aluminum strap is more critical in bearing.

Repair Analysis

A Simple Splice Repair

Fastener Bearing Check:

Therefore the allowable bearing load per fastener is the ‘allowable’ bearing stress multiplied by the bearing area:

$$P_{brg} = F_{bru} \times A_{brg}$$

$$= 131{,}000 \times 0.02275$$

$$= 2{,}980\ \#$$

Repair Analysis

A Simple Splice Repair

Fastener Bearing Check:

So, the allowable fastener bearing load is 2,980 # and the applied load is 1,192 # - clearly we have enough fasteners to carry the repair design load without any bearing failures. We can now write a margin of safety:

$$MS = \frac{\text{Allowable}}{\text{Applied}} - 1$$

$$= \frac{2{,}980}{1{,}192} - 1 \qquad \underline{MS = +1.50}$$

We have a positive margin in fastener bearing - our fasteners can carry 150% more load than they need to.

Repair Analysis

A Simple Splice Repair

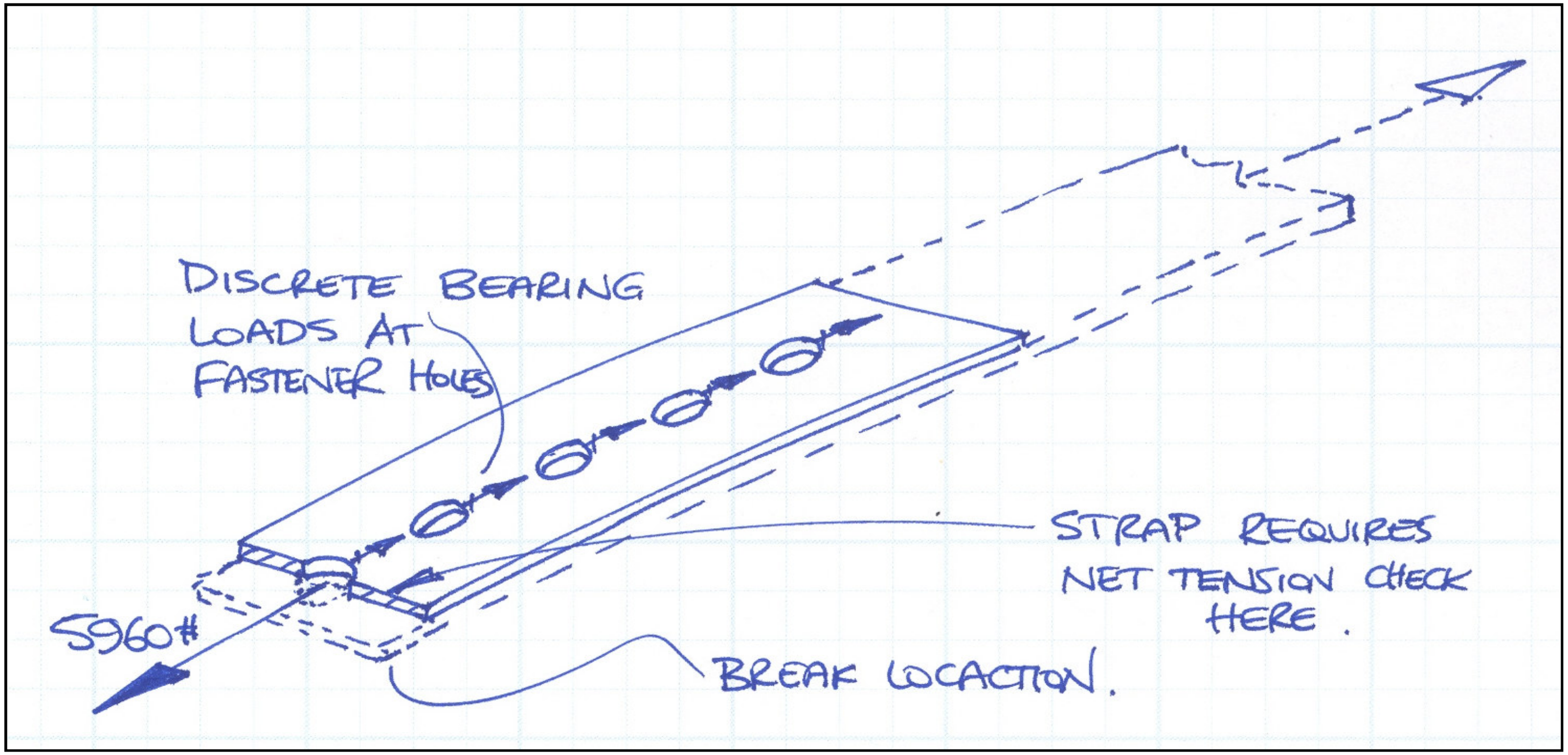
Strap Check:

We've looked at the fastener attachment details and we've found positive margins - the fasteners are sufficient to carry the design load from our aluminum tow rope into the strap, but is the strap itself strong enough to carry the design load? A net tension check of the strap at the most highly loaded location (applied load of 5,980 #) is required.

Repair Analysis

A Simple Splice Repair

Strap Check:



Repair Analysis

A Simple Splice Repair

Strap Check:

The gross tension area is equivalent to the strap width multiplied by the thickness. However, at the critical location a 1/4” hole exists so that the fastener may pass through - this must be accounted for in order to determine the net tension area:

$$A_{net} = W\,t - D\,t$$

$$= (W - D)\,t$$

$$= (2.0 - 0.25)(0.100)$$

$$= 0.175\ in^2$$

Repair Analysis

A Simple Splice Repair

Strap Check:

From slide 11, the tension stress allowable for the strap material (2024-T3) is 65,000 psi. Therefore, the allowable tension load at our critical section is:

$$P_{tens} = F_{tu} \times A_{net}$$
$$= 65{,}000 \times 0.175$$
$$= 11{,}375\ \#$$

Therefore, the margin of safety is:

$$MS = \frac{\text{Allowable}}{\text{Applied}} - 1 = \frac{11{,}375}{5{,}980} - 1$$

$\underline{MS = +0.90}$

Our strap has a positive margin in net tension - it is 90% larger than it needs to be.

Repair Analysis

A Simple Splice Repair Summary

- Our aluminum rope broke and a strap repair was designed to join the two broken halves
- A repair design load was developed by looking at a ‘Blue Print’ rope system, finding and analyzing the weak link
- The strap was analyzed to confirm it could carry the repair design load - it can
- The attachment fasteners were checked to confirm that they could carry the repair design load across the break - they can
- The repair is equivalent in strength to the ‘Blue Print’ rope system

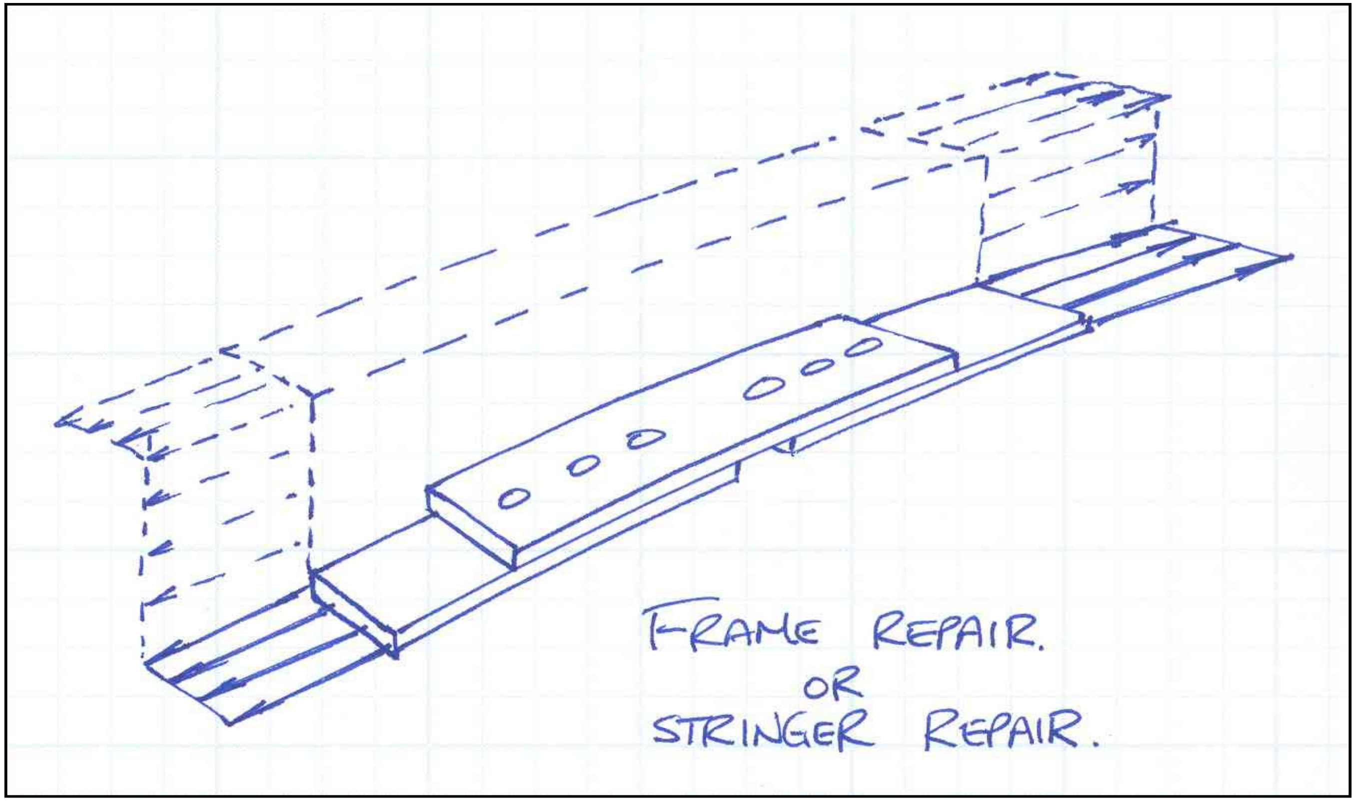
Repair Analysis

Summary of Concepts

- Fasteners are designed to transfer loads from one item of structure to another
- In shearing applications, which typically accounts for the majority of repair designs, loads are transferred from one element to another through bearing
  - Fasteners need to be strong enough in shear to transfer the required loads
  - Structural elements need to be strong enough to carry the bearing loads

Summary of Concepts

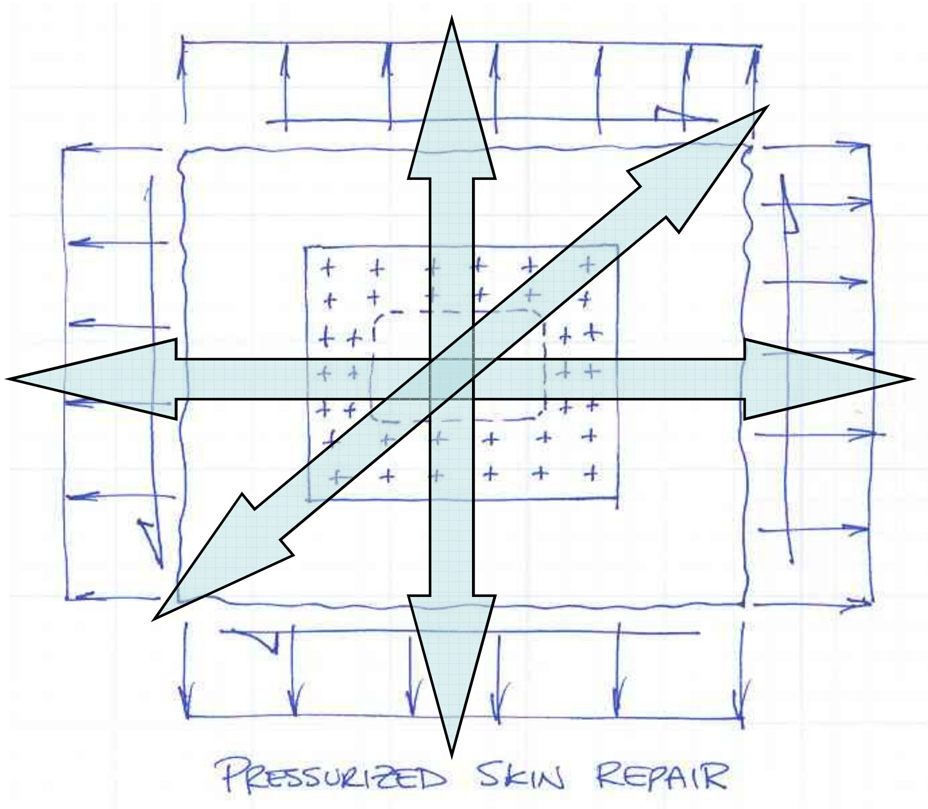
Repair Analysis



A strap is installed over the damage site which consists of a cutout in the flange. The aluminum rope analogy applies identically.

Repair Analysis

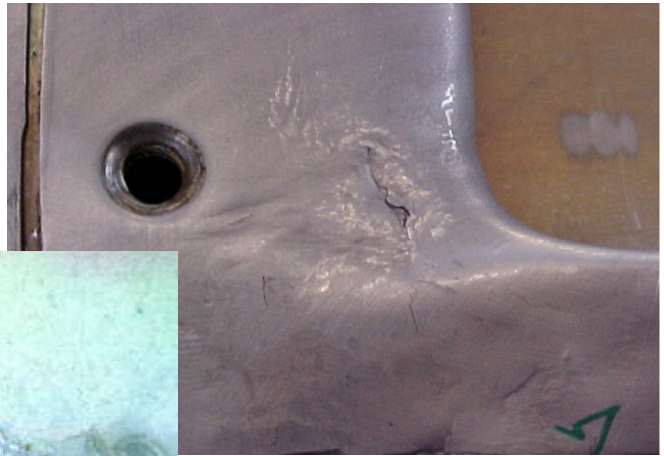
Summary of Concepts

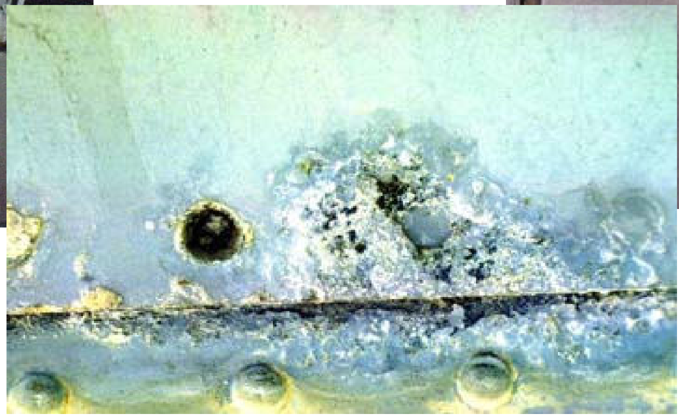


A doubler is installed over the damage site which consists of a cutout in the skin. The aluminum rope analogy applies in three different directions - the 45 deg direction is as a result of the panel shear loads which are reacted in diagonal tension.

Foi encontrado um dano, e agora? É necessário

REPARAR





Por onde começar?

NÃO ESTRAGUE AINDA MAIS

- Olhe para a estrutura, não só para a zona danificada mas também para a zona envolvente, verifique se existem reparações nas imediações
- Confira os registos da aeronave (logbook) (FC/FH, situações anómalas reportadas…)
- Não assuma, confirme sempre tudo.
- Obtenha o desenho do componente afectado
- O que é que está mal?
- Qual o material?

- Reparação coberta pelo manual?
- Contactar o fabricante de imediato?
- Disponibilidade de material e elementos de fixação
- Obtenha o desenho de montagem da estrutura
- Como é que a peça está carregada?
- Elabore um esquema com os elementos do dano e da aeronave o mais detalhado possível (croquis, fotos, etc…)

- Pense em três possíveis soluções
- Mais furos é mau
- É necessário desmontar para reparar?
- Materiais diferentes?
- Elementos de fixação diferentes?
- Ferramentas especiais?
- Compensa reparar? Sucata?
- Problema repetitivo?

Onde procurar os dados necessários

- Manuais da aeronave
- Desenhos das peças
- MIL-HDBK-5
- Especificações dos fabricantes
- Base de dados de histórico

Como começar?

- Baseie todas as reparações na estrutura da aeronave
- Mantenha a equivalência da resistência, rigidez e direcções de carregamento
- Mantenha a vida da estrutura e a tolerância ao dano
- Repare para a vida da aeronave no ambiente onde opera
- Inicie a reparação na furação existente

- Os elementos de fixação devem fazer a estrutura trabalhar como uma só (não duas peças unidas por molas).
- A carga nos elementos de fixação é de tensões diferentes dos elementos de reparação e estrutura
- As cargas na aeronave são LIMITE (“Limit loads”)
- Cargas ÚLTIMAS (“Ultimate loads”) são as LIMITE x 1,5

- A carga admissível é o valor máximo que uma estrutura pode aguentar antes da falha.
- A carga aplicada é o valor máximo aplicado à estrutura.

- A Margem de Segurança indica a porção de resistência extra duma estrutura ou união

$$MS_{estrutura} = \frac{Admissível}{Aplicado} - 1.0$$

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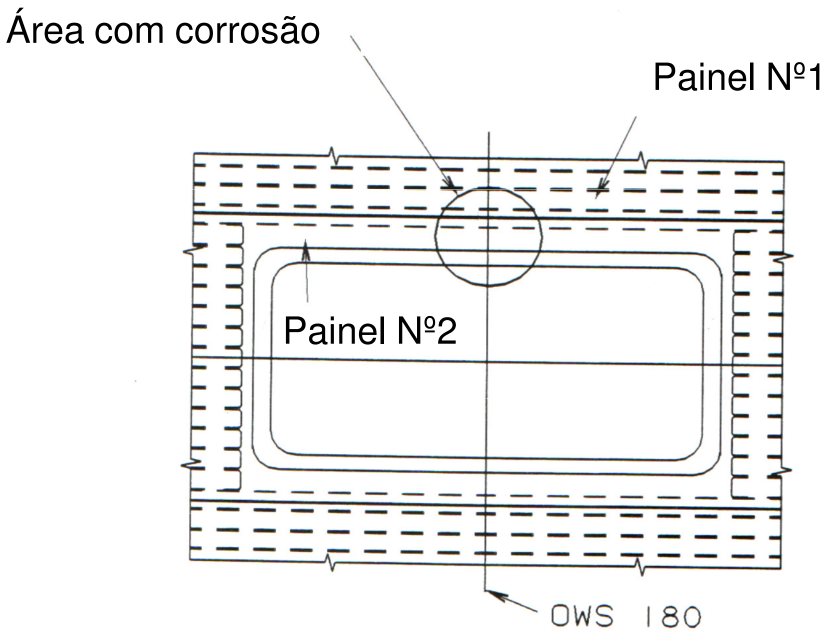
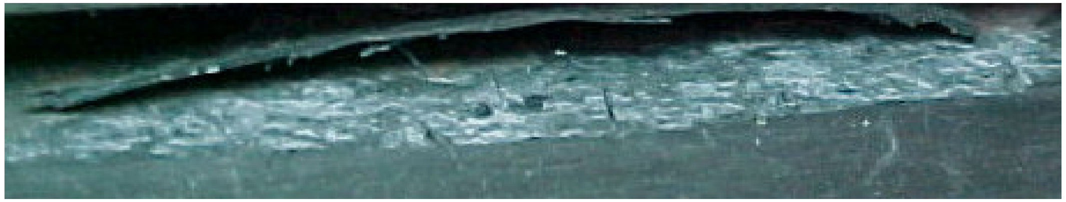
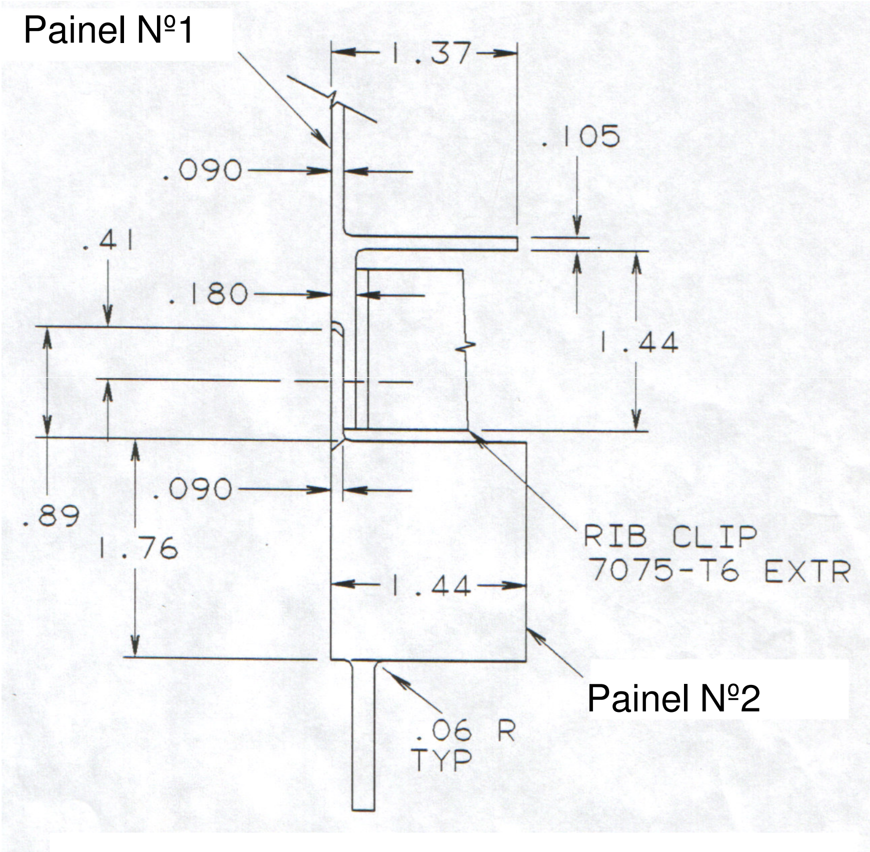
EXEMPLO

Foi detectado corrosão severa numa união de painéis duma asa. A profundidade e extensão da corrosão não está coberta pelos manuais da aeronave.





1. Obter o desenho das peças afectadas



Os painéis 1 e 2 são feitos de Alumínio extrudido 7075-T6.

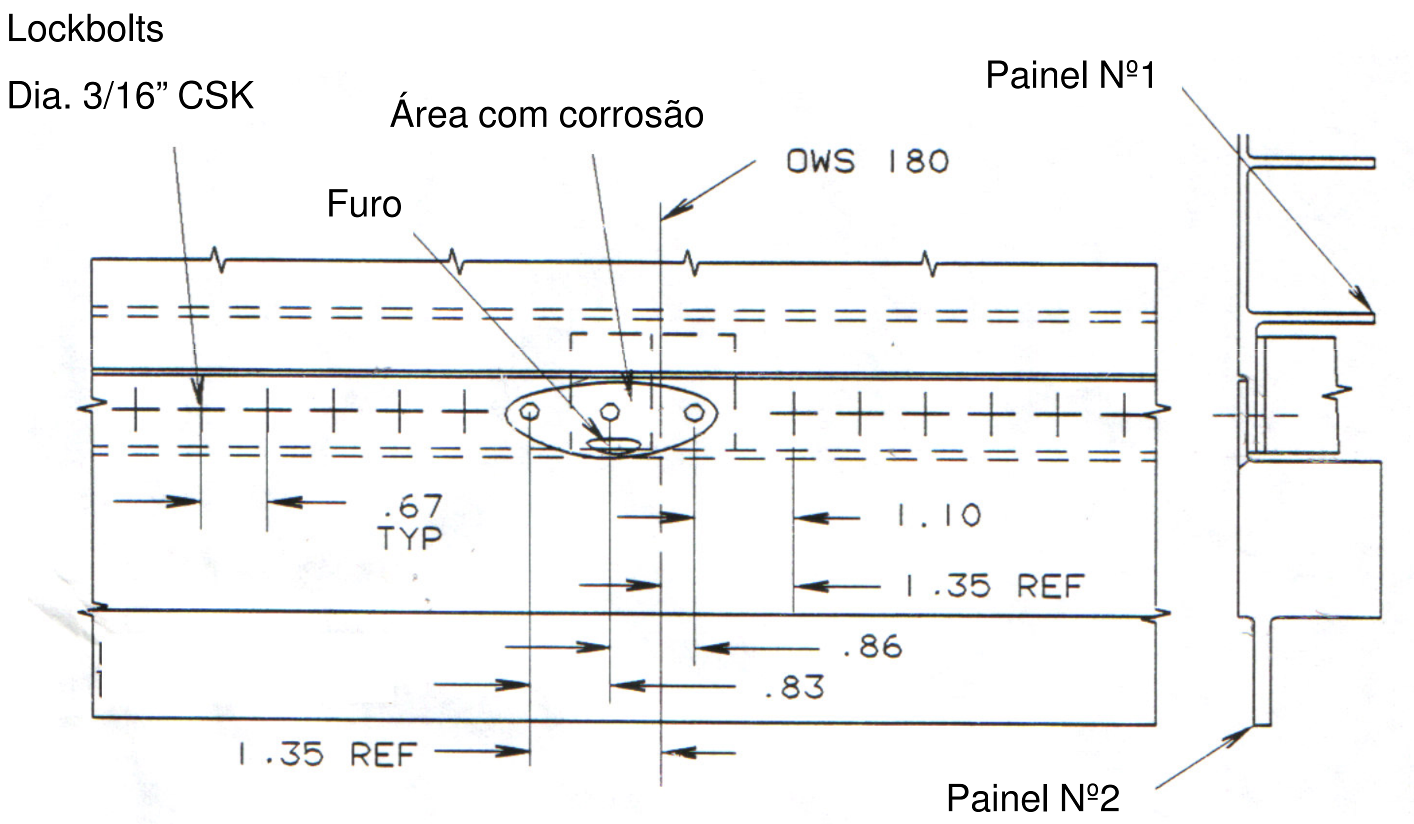
Propriedades 7075-T6 Extr.

FTU = 81000 PSI

FCY = 73000 PSI

FBRU = 146000 PSI (E/D = 2)

2. Eliminar a corrosão (a corrosão não é estrutural)

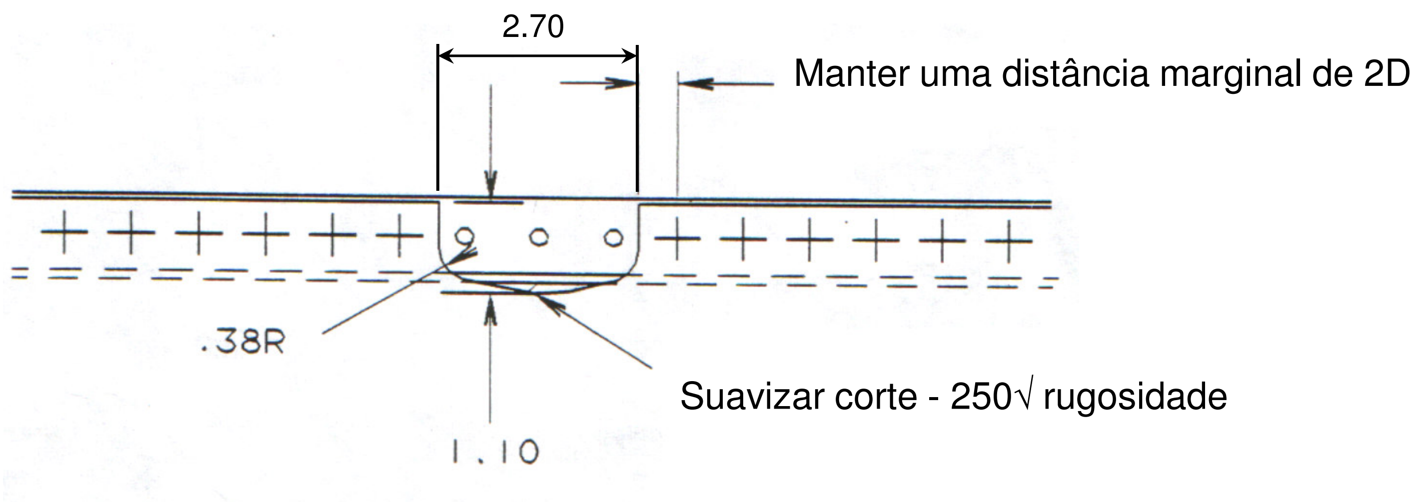


3. Eliminar a zona danificada

- Muitas vezes devido à extensão do dano torna-se necessário eliminar completamente a zona afectada
- Deve-se optar sempre por efectuar raios largos num corte. A zona danificada deve ser substituída por um enchimento ("filler"). Caso alguma furação não seja utilizada, deve ser obturada com um rebite. Se possível efectuar "cold work" antes de cravar o rebite
- Após o corte deve ser feito um desenho com todas as dimensões do mesmo

3. Eliminar a zona danificada (cont.)

- No nosso caso optou-se por eliminar a flange danificada



4. Desenhar a reparação

- Considerar a resistência à tensão, compressão e corte perdidos pela remoção da secção do painel. (A resistência perdida tem de ser reposta pela reparação).
- A reparação mais simples consiste em utilizar múltiplas chapas metálicas, que podem ser facilmente fabricadas.
- Neste exemplo vamos utilizar duas chapas de reparação (doublers). Consegue-se um sistema “fail-safe” e resistência à fadiga na primeira fila de elementos.

4. Desenhar a reparação (cont.)

- Utiliza-se o mesmo material que dos painéis (7075-T6)
- Para elementos de fixação vamos utilizar Hi-Loks 3/16” (estes elementos são equivalentes aos Lockbolts existentes)
- Os elementos escolhidos devem fornecer um sistema crítico à ovalização (“bearing critical).

Do MIL-HDBK-5 vem:

PROPERTIES FOR 7075-T6 CLAD

ULTIMATE TENSILE STRENGTH FOR .040 & .050 = 72000 PSI
(FTU) FOR .063 - .090 = 73000 PSI

COMPRESSIVE YIELD STRESS FOR .040 & .050 = 63000 PSI
(FCY) FOR .063 - .090 = 64000 PSI

ULTIMATE BEARING STRESS FOR .040 & .050 = 144000 PSI
(FBRU - 2.0 E.D.) FOR .063 - .090 = 146000 PSI

ULTIMATE SHEAR STRENGTH FOR .040 & .050 = 43000 PSI
(FTU) FOR .063 - .090 = 44000 PSI

BEARING STRENGTHS OF 3/16 HL18 AND HL56 IN 7075-T6 CLAD

(.040 THICK) = 1080 LBS

(.050 THICK) = 1354 LBS

(.063 THICK) = 1723 LBS

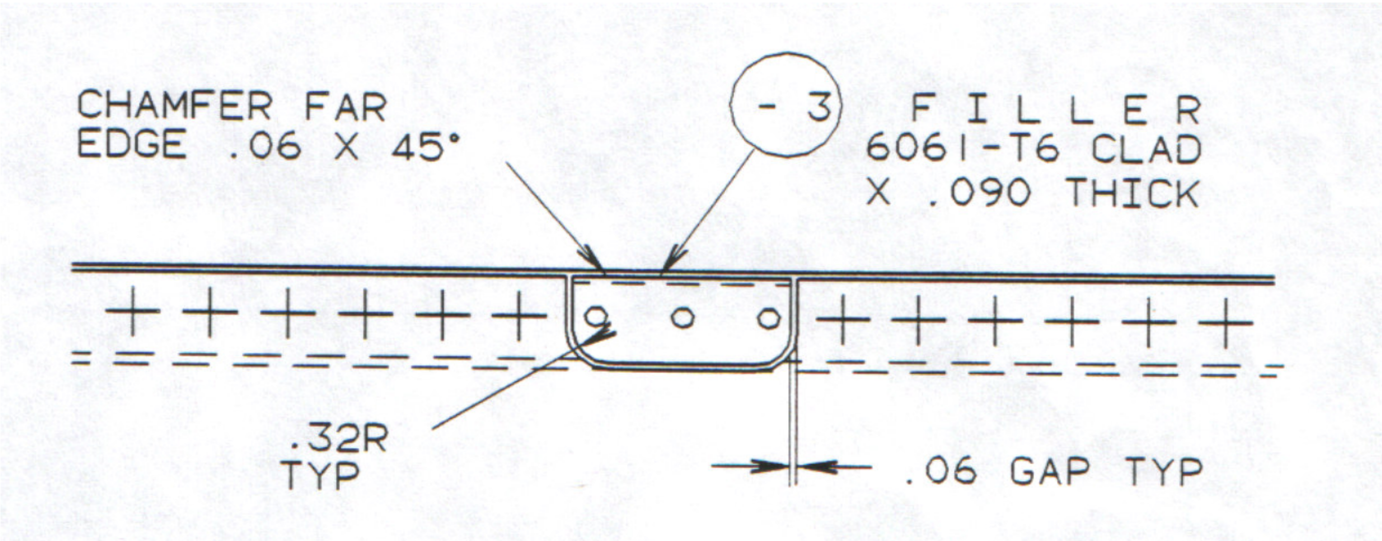
(.071 THICK) = 1941 LBS

(.080 THICK) = 2190 LBS

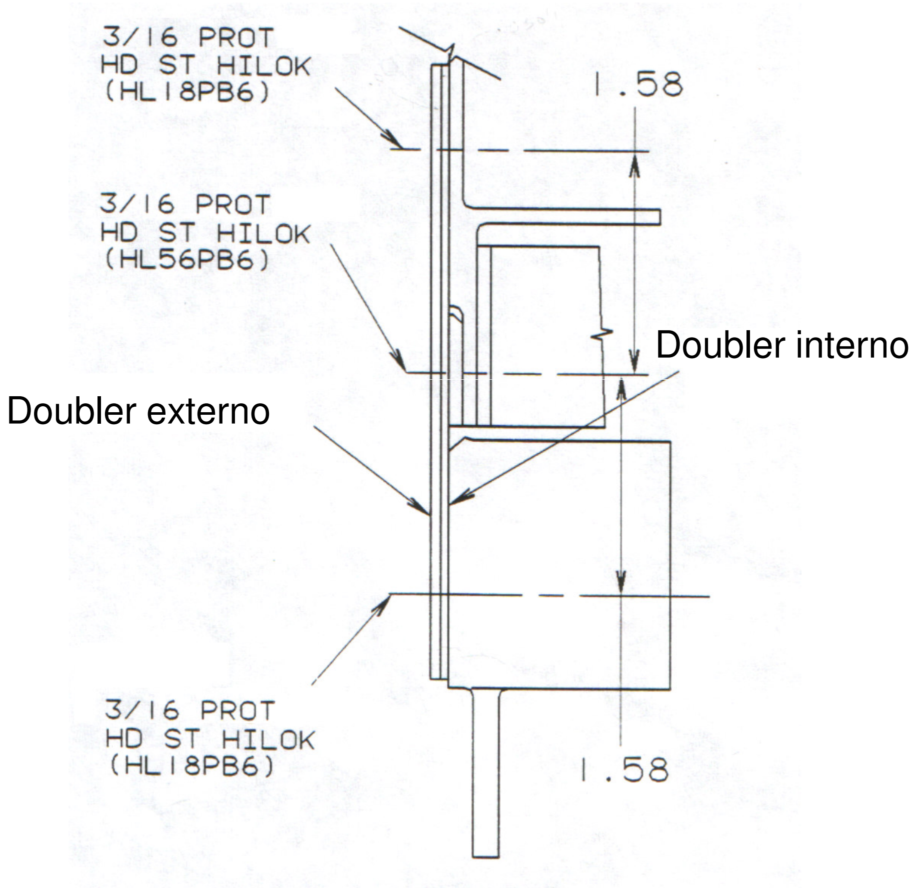
(.090 THICK) = 2467 LBS

5. Colocar um "filler" para preencher o espaço da falange removida

- O material do "filler" deve ter propriedades ligeiramente inferiores ao material original ou da reparação. Serve para garantir que o mesmo não "trabalha"



6. Para as chapas de reparação vamos considerar uma espessura cerca de 25% superior ao painel original



Consideramos então um "doubler" de 0,063" e um de 0,050". Vamos utilizar chapa "CLAD" que fornece protecção adicional contra a corrosão

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7. Cálculos preliminares

Vamos então calcular a perda de resistência da flange danificada ao longo da envergadura:

•Resistência perdida #2 = (largura da flange menos diâmetro do furo ao longo da envergadura) X Espessura da flange X FTU do painel #2 = (1,10 – 0,190) X .090 X 81000 = 6634 Lbs

•A perda de resistência do painel devido à nova furação no painel #2 = 1,44 X 0,190 X 81000 = 22161 Lbs

•A perda de resistência do painel devido à nova furação no painel #1 = 0,090 X 0,190 X 81000 = 1385 Lbs

•A perda total de resistência = 6634 + 22161 + 1385 = 30184 Lbs

7. Cálculos preliminares (cont.)

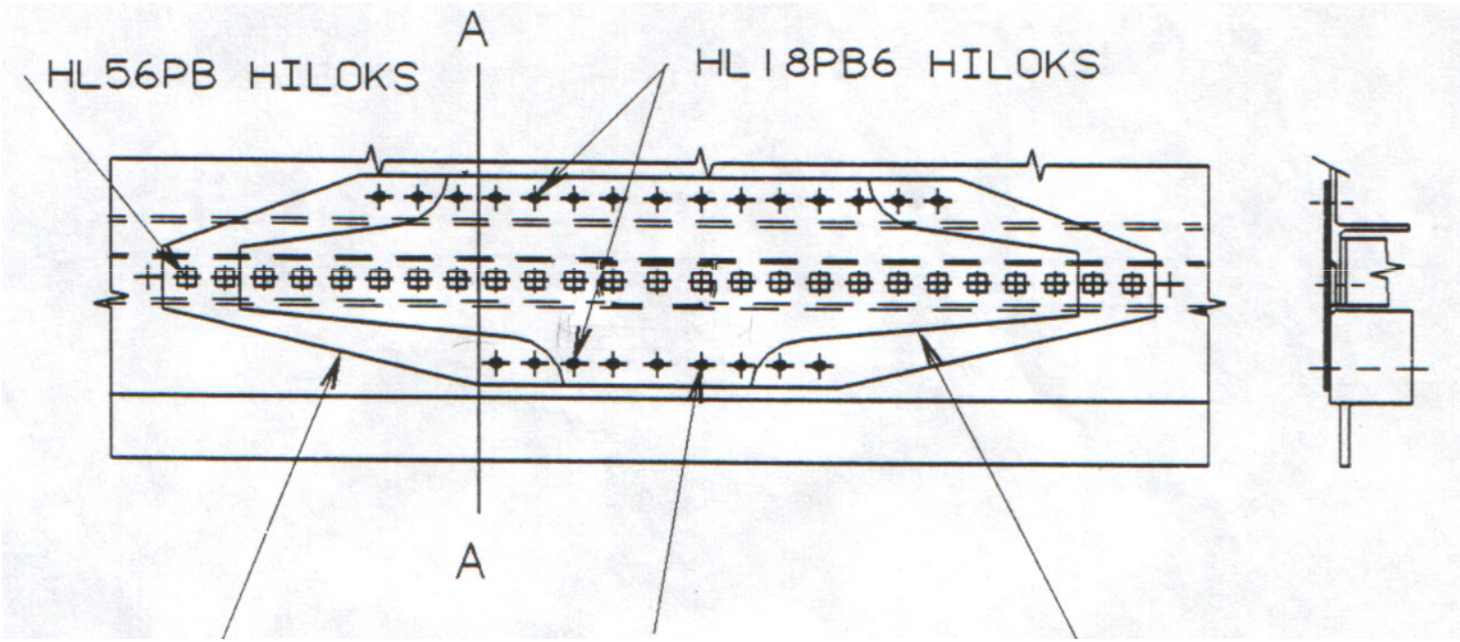
• A área total do doubler de reparação é então
= (30184 / 72500) = 0,416 SQIN

•A largura dos doublers da reparação é então
= (0,416 / (0,050+0,063)) + (3 X 0,190) = 3,95”.
(Vamos utilizar uma chapa de 4,35” e obtemos assim uma margem de segurança de 10%)

•Vamos então calcular o número mínimo de elementos de fixação necessários para cada lado da zona danificada.
= 30184 / (1354 + 1723) = 9,8 = (10)

8. Esquema da reparação

• Vamos então fazer um esquema da reparação com os dados obtidos até ao momento



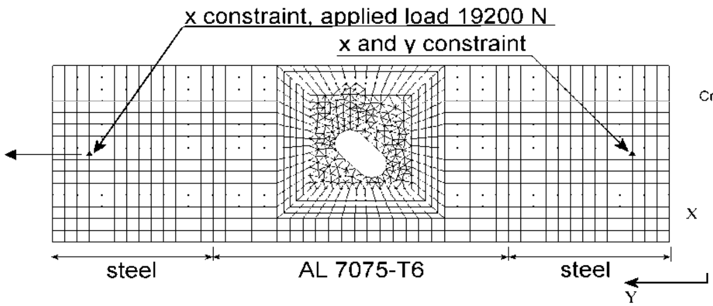
Doubler interno
7075-T6 Clad 0,050”

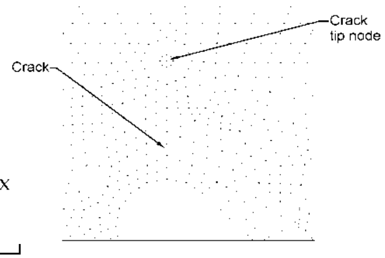
Manter esta fila a um mínimo (dificuldade de furação devido à espessura)

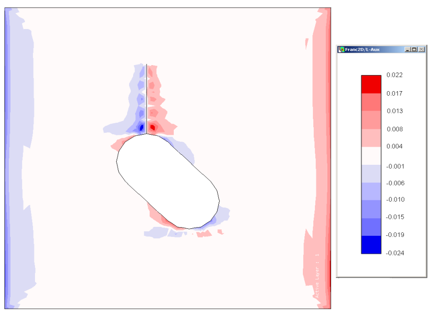
Doubler externo
7075-T6 Clad 0,063”

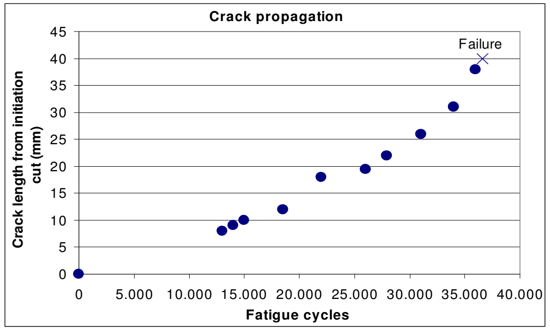
- Temos então 11 elementos em “bearing” no doubler de 0,050” e 7 no doubler de 0,063”.
- Estes elementos suportam (11 x 1354) + (7 x 1734) = 26955 Lbs. Que é muito superior à perda de resistência na fila “A”
- Perda de resistência à compressão = 0,090 X 73000 = 6570 Lbs/IN
- A resistência à compressão de ambos os doublers é = 0,113 X 63500 = 7175 Lbs/IN, que é mais do que adequado
- Perda de resistência ao corte = 42000 X 0,090 X 2,70 = 10206 Lbs
- A resistência ao corte dos doublers nas primeiras 4” (fila A) é = 4X 0,113 X 37000 = 16724 Lbs

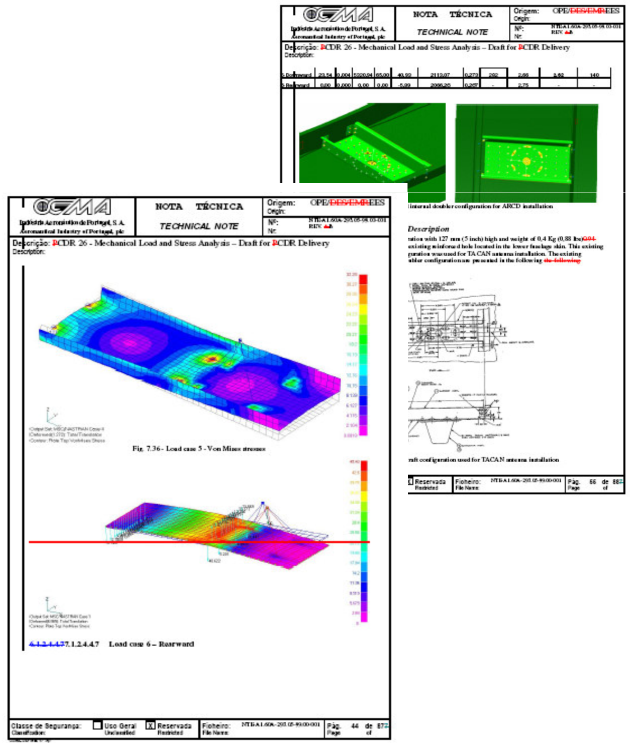
9. A reparação está então pronta para ser submetida para o departamento de “stress analysis” e de análise de fadiga. Os quais muitas vezes usam modelos de elementos finitos para realizar os cálculos necessários.











Guardar um registo de todas as reparações efectuadas:

- Aumenta a rapidez na resposta a um pedido de reparação para um dano semelhante.
- Facilita a correcção de problemas recorrentes na origem.
- Facilita o desenvolvimento de procedimentos de reparação padrão.

FIM DO MÓDULO III