Fundamentals
M7
MAINTENANCE PRACTICES

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M7.18
Disassemly, Inspect., Repair & Assembly Technics
Structural Topics

EASA Part-66
CAT B1

Training Manual

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M7 MAINTENANCE PRACTICES

M7.18 DISASSEMBLY, INSPECTION, REPAIR AND ASSEMBLY TECHNIQUES

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TYPES OF DEFECTS AND VISUAL INSPECTION TECHNIQUES, CORROSION REMOVAL, ASSESSMENT AND REPROTECTION

Inspection of Metal Aircraft Structures

Introduction

This section gives general guidance on the inspection of those parts of a metal aircraft structure which, because of their remoteness, complexity or boxed−in design, are not readily accessible for routine maintenance or require special attention in the light of operational experience.

Deterioration may arise from various causes and can affect the strength, life time and therefore also the airworthiness negatively. Generally all types of damages are checked for, but essentially the main types of defect being inspected for are **corrosion** and **metal fatigue**.

Cleanliness

To prevent negative influences, but also to prevent corrosion it is important that the aircraft is periodically cleaned carefully.

Also for inspection reasons it is advisable to clean the structure to detect possible damages.

Care should be taken not to damage protective treatments when using scrubbing brushes or scrapers.

- Any cleaning fluids used should have been approved by the aircraft constructor.
- For final cleaning of a boxed−in type of structure an efficient vacuum cleaner, provided with rubber−protected adaptors to prevent damage, should be used.
- The use of air jets should be avoided as this may lead to dirt, the products of corrosion, or loose articles, being blown from one part of the structure to another.

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BOEING

747-400 MAINTENANCE PLANNING DOCUMENT

SECTION 2 - STRUCTURAL MAINTENANCE PROGRAM

B. NOTES

1. Tasks for detecting corrosion, stress corrosion, and minor accidental damage using visual and/or Non-Destructive Test (NDT) procedures are specified. After discrepancies are found, repair or modification action may be required to assure continuing airworthiness of the airplane.

2. INSPECTION

   An examination of an item against a specific standard to detect irregularities and discrepancies such as wear, deterioration, damage, corrosion, cracking, etc.

   INSPECTION TASK DEFINITIONS:

   - INSPECTION - GENERAL VISUAL (GVI)

     A visual examination of an interior or exterior area, installation or assembly to detect obvious damage, failure, or irregularity. This level of inspection is made from within touching distance unless otherwise specified. A mirror may be necessary to ensure visual access to all surfaces in the inspection area. This level of inspection is made under normally available lighting conditions such as daylight, hangar lighting, flashlight, or drop-light and may require removal or opening of access panels or doors. Stands, ladders, or platforms may be required to gain proximity to the area being checked.

   - INSPECTION - DETAILED (DET)

     An intensive visual examination of a specific structural area, system, installation or assembly to detect damage, failure or irregularity. Available lighting is normally supplemented with a direct source of good lighting at an intensity deemed appropriate by the inspector. Inspection aids such as mirrors, magnifying lenses, etc. may be used. Surface cleaning and elaborate access procedures may be required.

   - INSPECTION - SPECIAL DETAILED (SDI)

     An intensive examination of a specific item(s), installation or assembly to detect damage, failure or irregularity. The examination is likely to make extensive use of specialized inspection techniques and/or equipment. Intricate cleaning and substantial access or disassembly procedures may be required.

Figure 1 Structural Inspection

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Inspection Techniques / Visual inspection

General

The structure should be inspected periodically inspected for:

- Any signs of distortion
- Movement between its different parts at their attachment points
- Loose or sheared fasteners
- Signs of rubbing or wear in the vicinity of moving parts, like flaps, doors, control surfaces, flexible pipes, etc.

Visual Examination

Many of the inspection operations on aircraft structures can be carried out visually. So during visual examination a inspection of the surface is suitable. Because of the complexity of many structures, special visual aids are necessary to enable such inspections to be made in a correct and accurate way.

Aids for Visual Examination

As optical aids during structural inspection can be used:

- Torches
- Mirrors
- Loupes
- Borescope/Endoscope

Application of a visual Examination

The visual examination is only suitable for detecting surface damages or defects which move to or along the parts surface.

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Mk 1 Eyeball

Figure 2 Visual Examination

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Structural Damage and Investigation of Structural Damage

Definition of a Structural Damage

The term structural damage contains:

- every type of permanent deformation,
- every type of gradual change in section,
- every type of strength loss caused by e.g. fatigue or heat exposure.

Causes/Main Groups of structural Damage

Deformations, gradual change in section and strength loss caused by heat exposure at structural parts have different causes which are classified according to Structural Repair Manual (ATA-Chapter 51) in four main groups:

- Mechanical action (accident or forced damage)
- Chemical/electrochemical reaction (corrosion damage)
- Thermal action (heat damage)
- Inner metallurgical characteristics (fatigue damage)

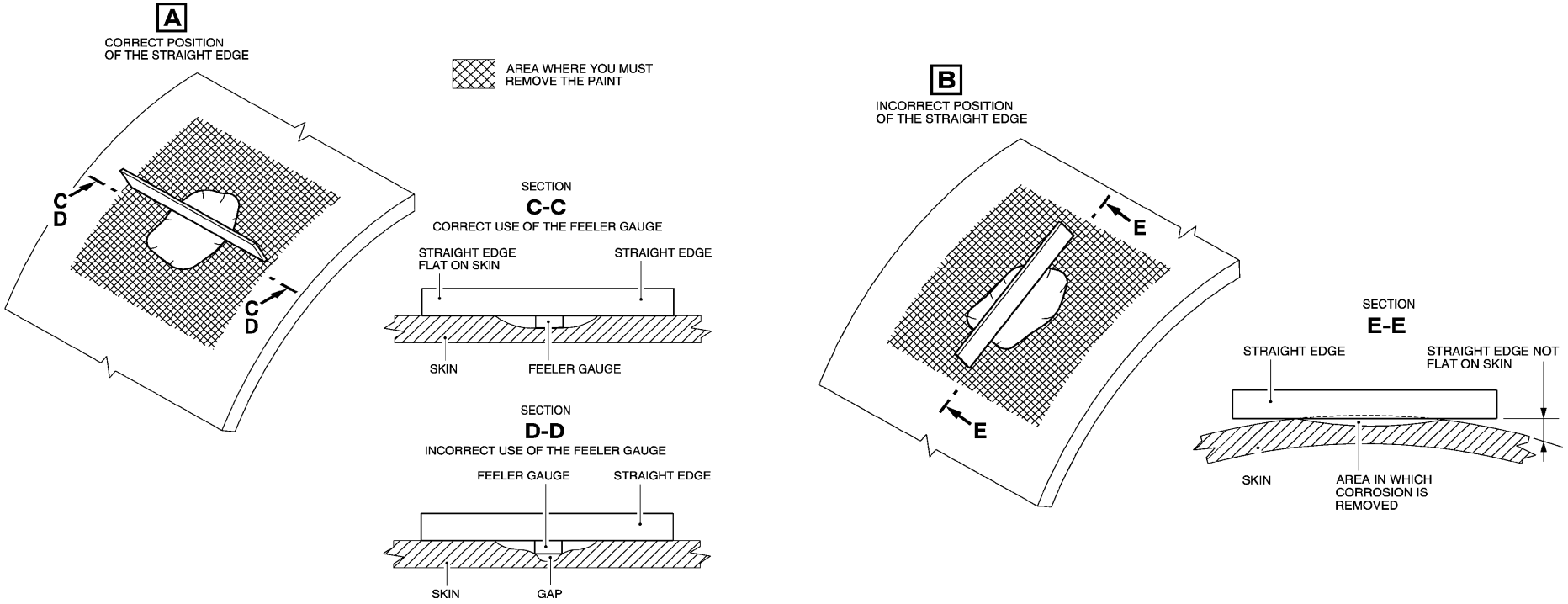
Investigation of structural Damage

In order to take the right repair action of a structural damage the following points have to be considered:

- Location of damage, type of damage (if not done in the first place) and extent of damage have to be determined. For this probably further actions are necessary, like e.g.:
  - removing unwanted materials from the surface
  - cutting extremely damaged areas out
  - removing all loose mounting devices
  - doing a component/aircraft measurement
  - inspect adjacent components for probable damages

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Measurement using a Feeler Gauge
Figure 5

Figure 3 Investigation of Structural Damage

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Types of Structural Damage

Types of damage at metal structures

Due to the relatively high ductility of aluminium materials damages of structural parts made out of aluminium can be relatively easy detected.

Schadensart	Beschreibung
Scratch	A scratch is a line of damage of any depth and length in the material and results in a cross-sectional area change. It is usually caused by contact with a object.
Gouge	A gouge is a damage area of any size which results in a cross–sectional area change. It is usually caused by contact with a relatively sharp object which produces a continuous, sharp or smooth channel-like groove in the material.
Mark/Abrasion	A mark is to be understood as a damaged, scratched area of any size. The damage must be treated as an area and not as a series of individual scratches, gouges etc.
Crack	Fracturewith the most significant cross-sectional area change; Often caused by fatigue.
Nick	A small loss of material, due to a knock etc. at the edge of a member or skin.!
Dent	Permanent deformation without cross-sectional area change.
Hole	A hole constitutes a complete penetration of the surface. The adjacent area is without damage.
Corrosion	The destruction of metal by chemical or electrochemical action with possible significant cross-sectional area change.
Crease	A probably sharp-edges deformation caused by a compression (e.g. hard landing). A correct judging of the damage ist essential, since cracks can develop very fast out of it!
Distortion	Any twisting, bending or permanent strain which results in misalignment or change of shape. Often caused by FOD, vibrations or loose mountings of components.
Heat Damage	Punctual (e.g. lightning strike) or extensive (e.g. burn) heat exposure at metallic structural parts, which can result in a loss of strength. For damage investigation a hardness testing or a test of electrical conductivity can be done. Exact procedures are noted in the particular NDT - manual of the manufacturer.

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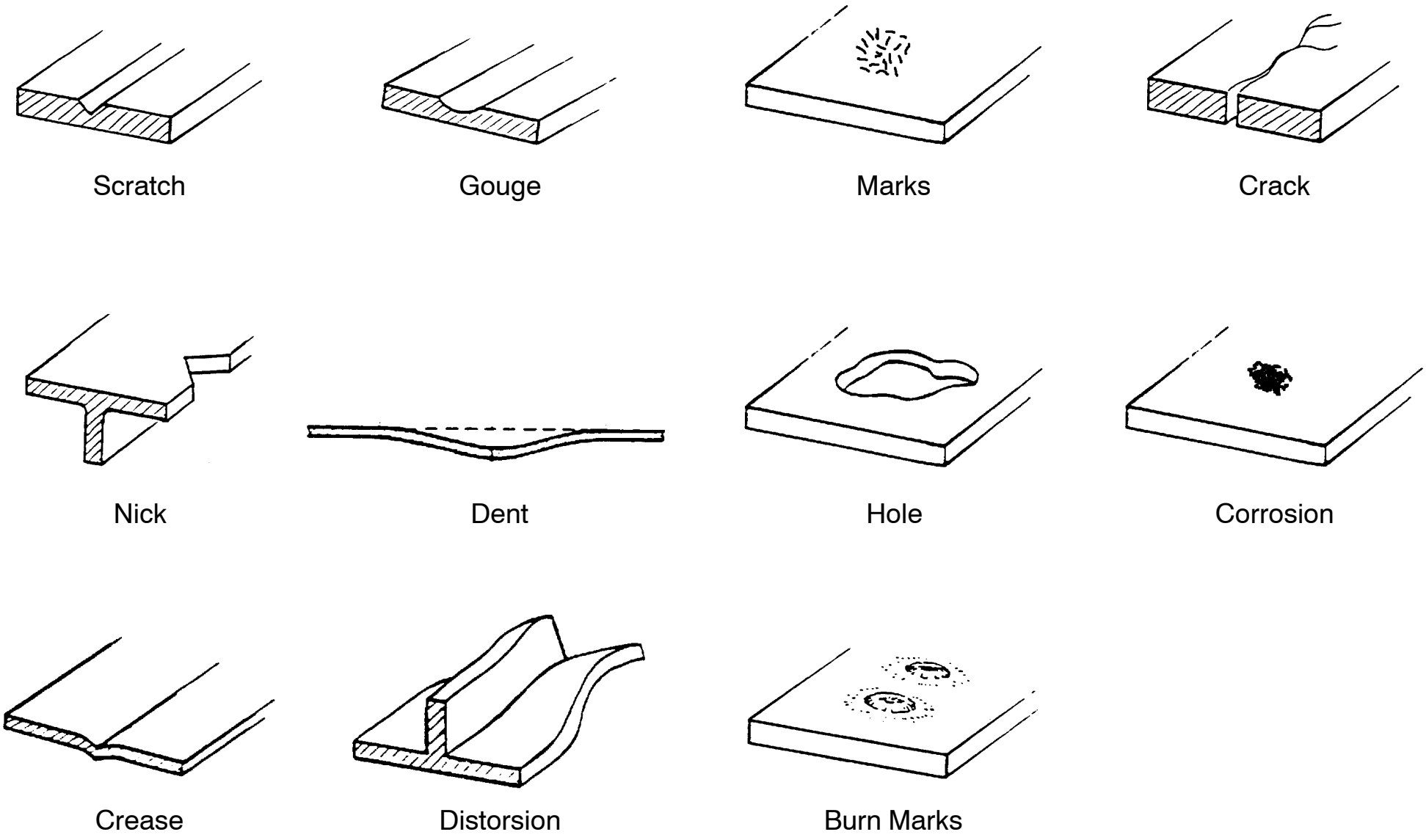


Figure 4 Types of Damage at Metallic Structures

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Types of Damages at Composite Structures

The damage investigation at composite structures is because of their special material characteristics quite difficult in some parts.

Generally for composite structures it is valid that plastic deformations in the meaning of a dent (like e.g. at Aluminium-Alloys) are not possible. That means such parts are either broken or not broken.

But it is also possible that during overload (e.g. birdstrike at one leading edge) a part deforms in such a way that some of the fibres are bursting and the other fibres are flipping the part back into its original form since to their high rigidity.

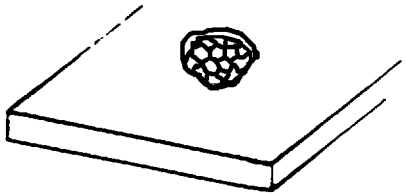
Hereby, an apparent integrity of the part is pretended. An indicator can e.g. be a damaged topcoat.

In difference to metal materials there are the following damage types at composite materials:

Schadensart	Beschreibung
Crack	Fracturewith the most significant cross-sectional area change
Hole	Hole in/through the material
Delamination	Division between the two different layers of a laminate
Debonding	Local debonding of glued parts
Moisture	Absorption of water, e.g. caused by surface damages
Chemical Attack	Decomposition of the binder or adhesive resin by chemical attack
Abraison	A damage with a significant cross-sectional change, rough surface without sharp boundarys
Gouge	Damage with cross-sectional change, sharp boundarys, burred. Chipping of fibres possible.
Nick	Nick at the edge of the material, sharp-edged, Also: short mark, ”knocked in”

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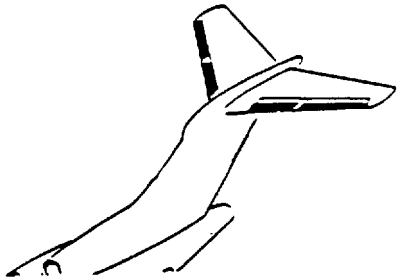
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Hole



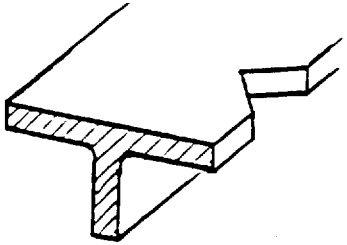
Delamination



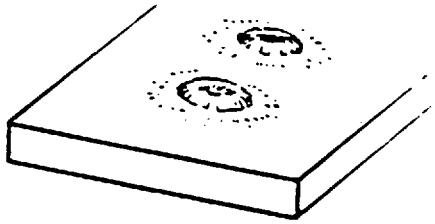
Abrasion



Debonding



Nick



Burn Marks

Figure 5 Types of Damage at Composite Structures

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CORROSION DAMAGES

Introduction

The presence of corrosion in aircraft structures is liable to result in conditions which may lead to catastrophic failures.

It is therefore essential that any corrosive attack is detected and rectified in the earliest stages of its development.

Influencing Factors

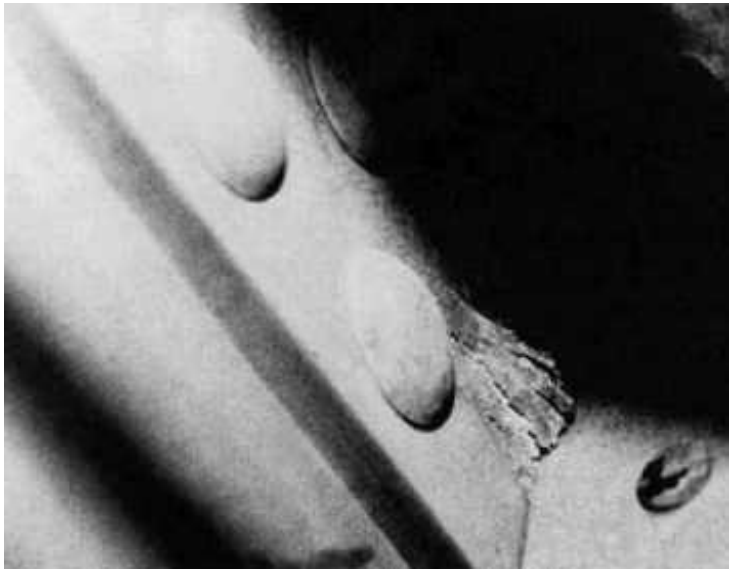
By the nature of their operation, aircraft are exposed to frequent changes of atmospheric temperature and pressure and to varying conditions of relative humidity; therefore, all parts of the structure are subject to some form of condensation. The resultant water takes into solution a number of corrosive agents from the atmosphere or from spillages. By this the water is converted into a weak acid and will corrode most metal surfaces.

Especially areas where the protective treatment has been damaged or is inadequate react very sensitively.

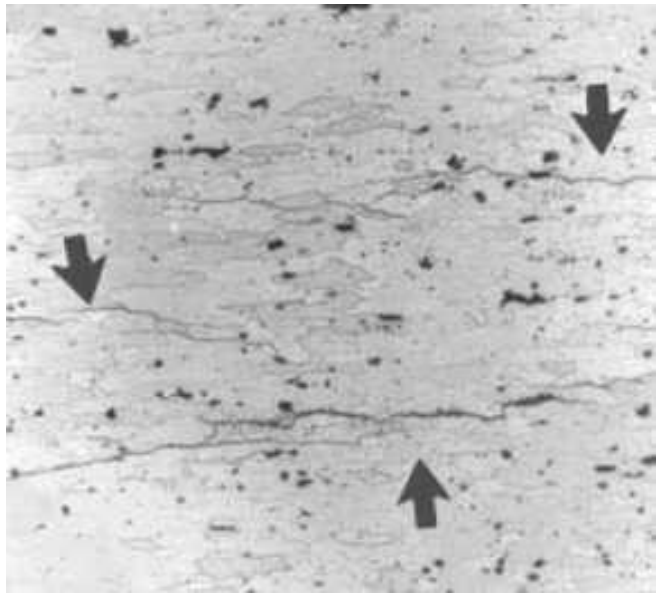
Cases of serious corrosion have been found in both closed and exposed parts of structures of aircraft.

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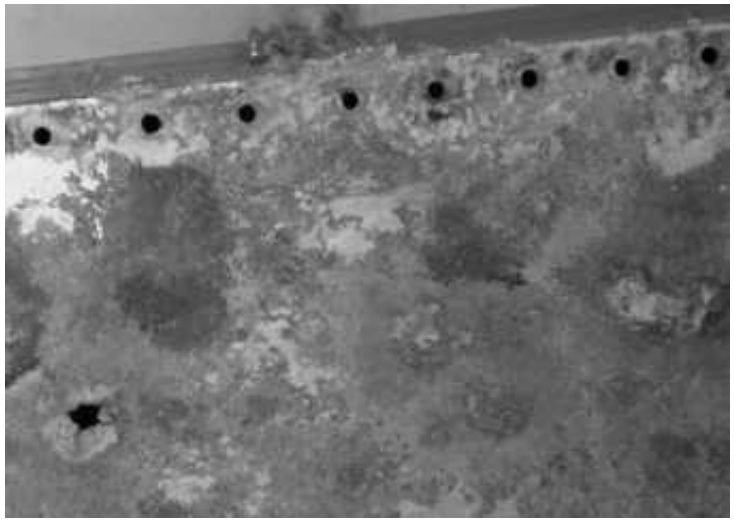
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Exfoliation caused by corrosion



Intergranular corrosion



Crevice corrosion

Figure 6 Corrosion Damages

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Detection of Corrosion

Introduction

The early identification and removal of corrosion will help to maintain the serviceability, safety and function of the aircraft. This is only possible if the inspection for corrosion is done regularly and precisely.

ATTENTION: All corrosion found must be immediately and completely removed.

This is essential because corrosion which remains will cause new corrosion and further decrease the strength of the structure.

After the corrosion is completely removed the extent of the damage must be examined and compared with the allowable damage limits.

Ensure that the repair area is given the correct surface protection to prevent further corrosion.

Detection of Corrosion

Corrosion can be found by the following methods:

- visual inspection,
- dye penetrant inspection,
- ultrasonic inspection,
- eddy current inspection,
- X–ray inspection.

The applicable procedures are given in the Nondestructive Testing Manual (NTM).

Visual Inspection

The following list details some of the equipment to help do a visual inspection for corrosion:

- magnifying glass,
- mirrors,
- borescope, fiber optics,
- other equivalent equipment.

Appearance

When inspecting a painted surface, corrosion is usually seen as:

Condition of Paint and Surface

When there is corrosion on a metallic surface you will usually see a dulled or darkened area. White, grey or red dust or particles may also be observed.

Paint Bulging

If small bulges and irregularities are inspected on an undamaged outer paint coat near the surface it can be a sign of filiform corrosion.

Paint Peeling

In areas that are unsecured against mechanical damages (e.g. cargo door) a peeled paint can be a sign of corrosion damages since the surface protection is damaged.

Bulging

If corrosion occurs in a gap between adjacent components the corrosion products can cause a bulging at the components because of their higher volume. Between fastening elements and at thin sheets this can be watched very well.

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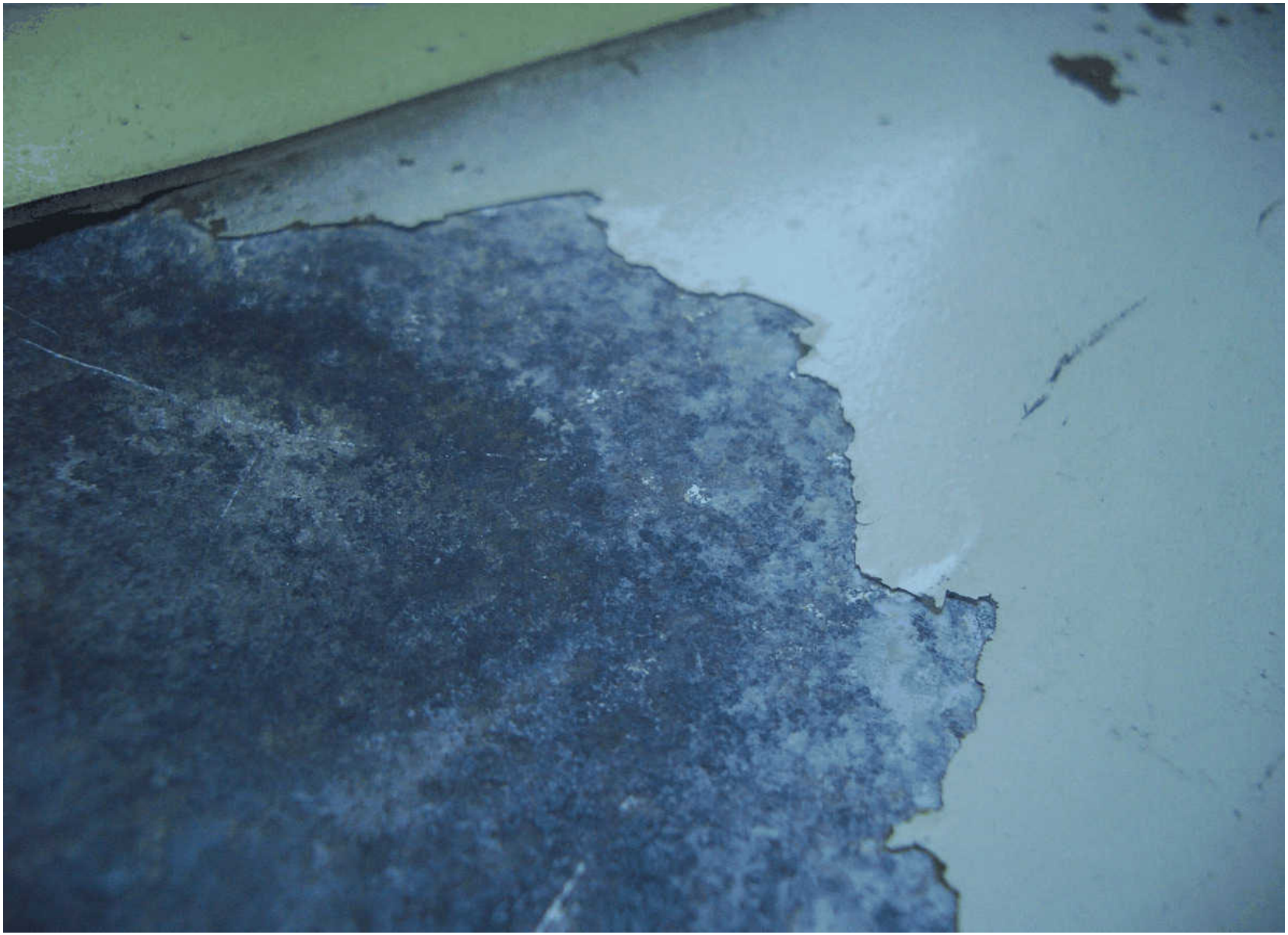


Figure 7 Detection of Corrosion at the Surface

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Corrosion Removal

Preparation

Before starting to remove corrosion, protect all adjacent areas/equipment against the effect of chemical strippers, cleaning agents and surface treatment materials. Use suitable masking paper and tape.

Cleaning

Remove all dirt, grease and other foreign matter from the affected area with cleaning agent.

Paint Removal

Two methods of paint removal are possible; mechanical and chemical.

Where the corrosion is light and contained within a small area, use the mechanical method (e.g. grinding).

Where the corrosion is heavy and covers a large area, the use of paint strippers is recommended.

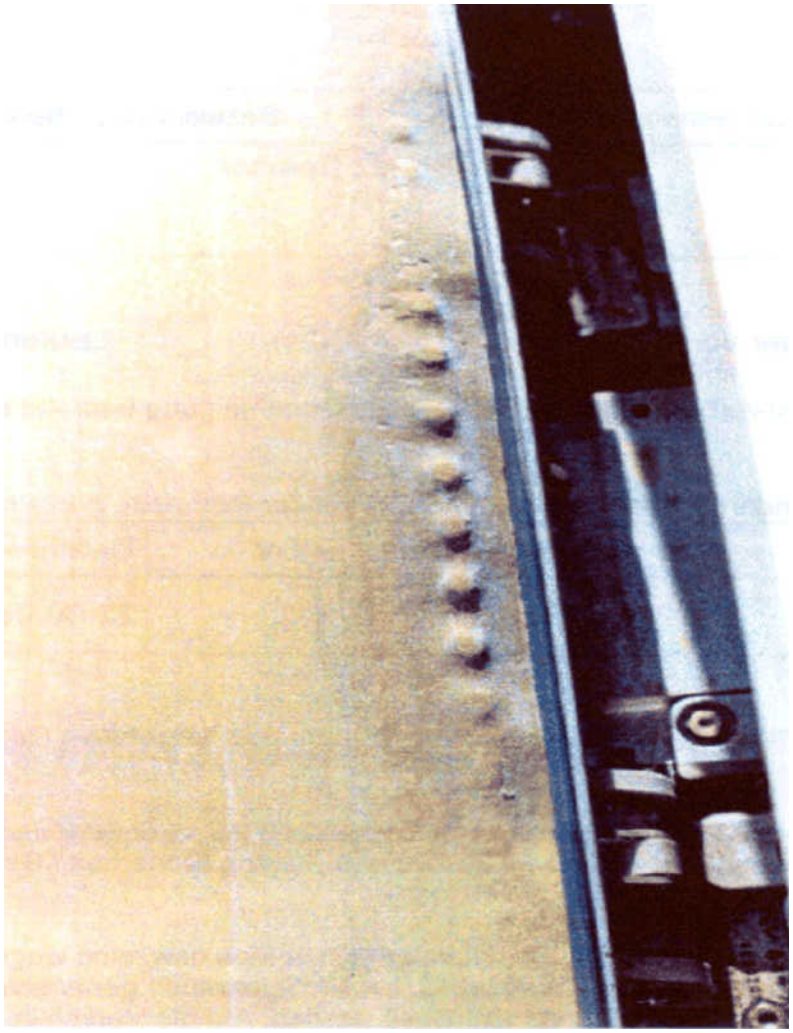
Removal of Fastening Elements

Any fasteners located within the area of corrosion and affected by the corrosion must be removed because of the reasons that follow:

- corroded rivets/bolts must always be changed against undamaged fasteners,
- possible corrosion under the fastener head or in the countersink has to be detected and removed,
- the fastener head must not be grinded, since the strength of the fastener would be reduced,
- foreign metal particles from the fasteners could unintentionally be spread around the surface and so could cause to new corrosion.

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Bad Example of Corrosion Removal:

- The corrosion has been removed with a steel brush, without removing the fasteners. After that the surface protection has been brought back on the surface.

Figure 8 Bad Example of Corrosion Removal

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Corrosion Removal on Aluminium Alloys

Techniques for Corrosion Removal

In the structural repair manual (SRM) some procedures for the mechanical removal of corrosion are depicted. The following treatment advices for the corrosion removal on aluminium components have to be followed in particular:

Manual Removal (by Hand)

- Abrasion by hand is only suitable for areas of light corrosion. Emery cloth and abrasive pads with aluminium oxide are the most common methods used.

Grinding

- For corrosion removal on aluminium components only use **Aluminium-Oxide (corundum)** grinding tools! These have rounded down abrasive grains and do not create sharp-edged grooves on the soft aluminium surface. They can be identified by their red-brown color.
- To roughly remove corrosion products a 240 abrasive grain should be used. For the last grinding step a **400** abrasive grain should be used to create a **smooth surface.**
- During all grinding works it has to be observed that no high temperatures on the component surface are created. This can create a change of grain structure of the material and can cause a loss of material strength.

CAUTION: THE USE OF SAFETY GOGGLES OR A FACE SHIELD IS MANDATORY WHEN USING MOTOR-DRIVEN GRINDING WHEELS.

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Figure 9 Typical Grinding Tool Shapes

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CORROSION REMOVAL ON ALUMINIUM ALLOYS (CONT'D)

Corrosion Removal by Wire Brushing

- Heavy corrosion can roughly be removed with a wire brush.
- the wires have to be made out of corrosion resistant steel (CRES), in order that abrasion particles do not cause further corrosion.
- After brushing a grinding rework is essential to smooth the surface.

Abrasive Blast Cleaning

- Abrasive blast cleaning is used for the removal of large area corrosion on flat sheets.
- Glass balls, aluminium oxide powder or nutshells can be used as shots.
- The blasted area has a rough-textured dim surface, so that remaining corrosion is hard to see!

Rotating Files

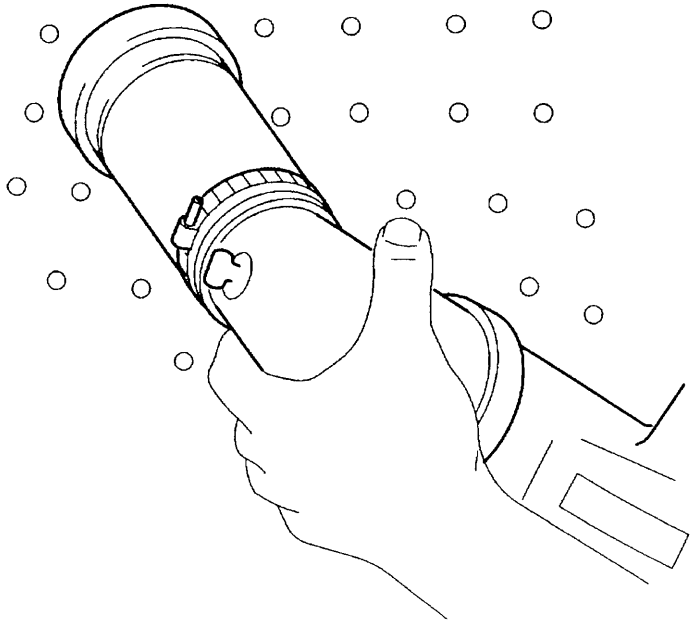
- Cutter made out of carbide are suitable for punctual removal of heavy corrosion and for determination of the corrosion depth which is needed for comparison with the specified limits in the SRM.
- Primarily for work at integrally milled components and at radii these mill cutters are used.

General Advices

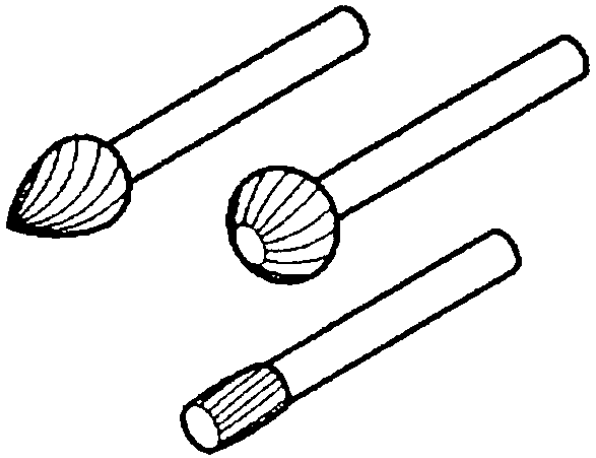
- Corrosion must be removed entirely. Minimal remaining corrosion is the origin for new corrosion!
- The working depth must be compared with the specified limits in the SRM! If the working depth limits are exceeded according to the SRM the component has to be repaired or replaced!

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Portable Blasting Machine



Rotating Milling Cutter

Figure 10 Abrasive Blasting Cleaning and Rotating Milling Cutter

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Corrosion Removal from Steel and Titanium Alloys

Corrosion Removal from Carbon Steel

Carbon steel in its heat-treated form is used in those areas where high structural or aerodynamic loads occur on the aircraft.

Red iron rust is one of the more familiar types of corrosion found on carbon steel. This type of corrosion is generally caused by the formation of ferrous oxides due to atmospheric exposure.

Red iron rust attracts moisture from the atmosphere which promotes additional corrosion. Red rust first shows on unprotected aircraft hardware such as bolts, nuts and exposed fittings.

Slight corrosion on highly stressed steel parts is potentially dangerous and the rust must be removed and controlled. Corroded steel parts should be removed from the aircraft where possible, for treatment.

Corrosion Removal from Stainless Steel and Nickel Chromium Alloys

Stainless steel and nickel chromium alloys are used where corrosion resistance is one of the major considerations in the design of structural parts and components. In most applications these steels will have no other surface protection except for matching color schemes of the surrounding structure, dissimilar metal protection or organic coatings. Stainless steels however, are not to be considered free from the possibility of corrosion occurring.

Corrosion on these steels usually appears as pitting, usually black in color.

The existence of corrosion prevents a passivated environment on the surface of the steels, and creates an active–passive corrosion cell. It is necessary therefore, that the corrosion is removed completely.

Corrosion Removal from Titanium and Titanium Alloys

Titanium alloys are used in various areas in the aircraft structure, especially in high temperature areas and areas where high strength members are exposed to a corrosive environment.

Exposure of the surface of titanium to fire resistant hydraulic fluids (Skydrol) causes hydrogen embrittlement with subsequent pitting of the surface.

Titanium alloy is generally resistant to corrosion. Corrosion however, when it does occur is recognized as a black or white colored oxide.

WARNING: SMALL CHIPS OR SILVERS OF TITANIUM THAT RESULTS FROM MACHINING CAN EASILY IGNITE AND ARE TO BE CONSIDERED AS AN EXTREME FIRE HAZARD. IN THE CASE OF A FIRE DEVELOPING, EXTINGUISH WITH DRY TALCUM POWDER, CALCIUM CARBONATE, SAND OR GRAPHITE. DO NOT USE WATER, CARBON DIOXIDE, CARBON TETRACHLORIDE OR ORDINARY DRY CHEMICAL FIRE EXTINGUISHERS.

Suitable Abrasives for Corrosion Removal from Steel/Titanium

For corrosion removal from steel/titanium parts abrasives with **silica carbide** should be used.

They can be identified by their green-blue color.

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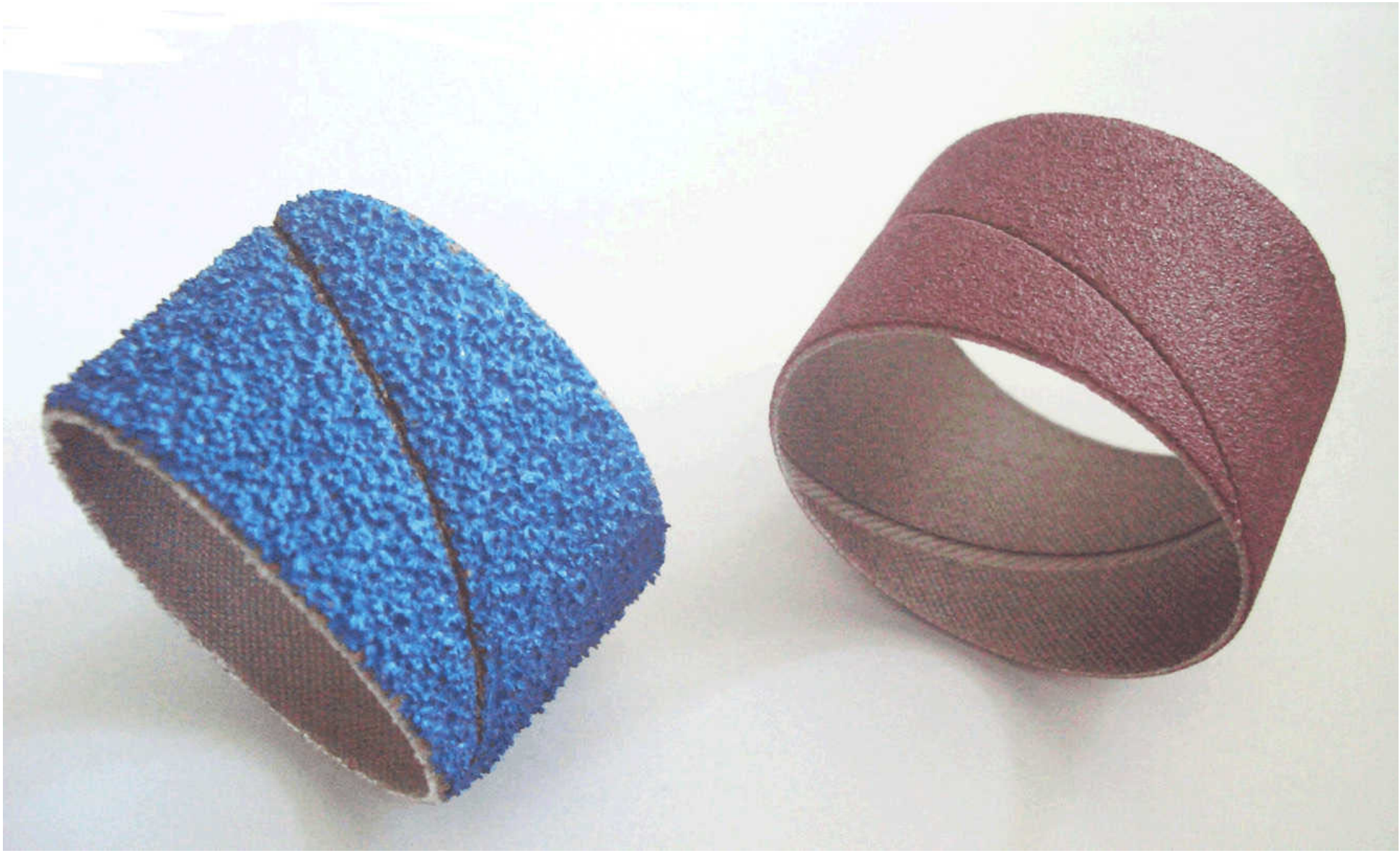


Figure 11 Carbon Silicide (Left) and Aluminium Oxide (Right) Abrasives

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Checks after Corrosion Removal

Complete Corrosion Removal

Always ensure that the corrosion has been removed completely, that means 100%. Minimal areas with remaining corrosion are the origin for new corrosion damages! For an inspection of the complete removal of the corrosion a x10 magnifying glass is recommended.

Hidden Corrosion/Remaining Corrosion

To detect possible remaining corrosion in underlying metal layers (exfoliate corrosion, intergranular corrosion, stress corrosion) the concerned area has to be checked with a suitable NDT procedure (eddy current inspection).

Danger of Cracking caused by Corrosion Damages

The area which has been freed from corrosion has possibly also to be checked for potential paths of cracks. Also an exact remaining wall thickness can be measured by an ultrasonic inspection, which is needed for comparison with the specified limits in the SRM.

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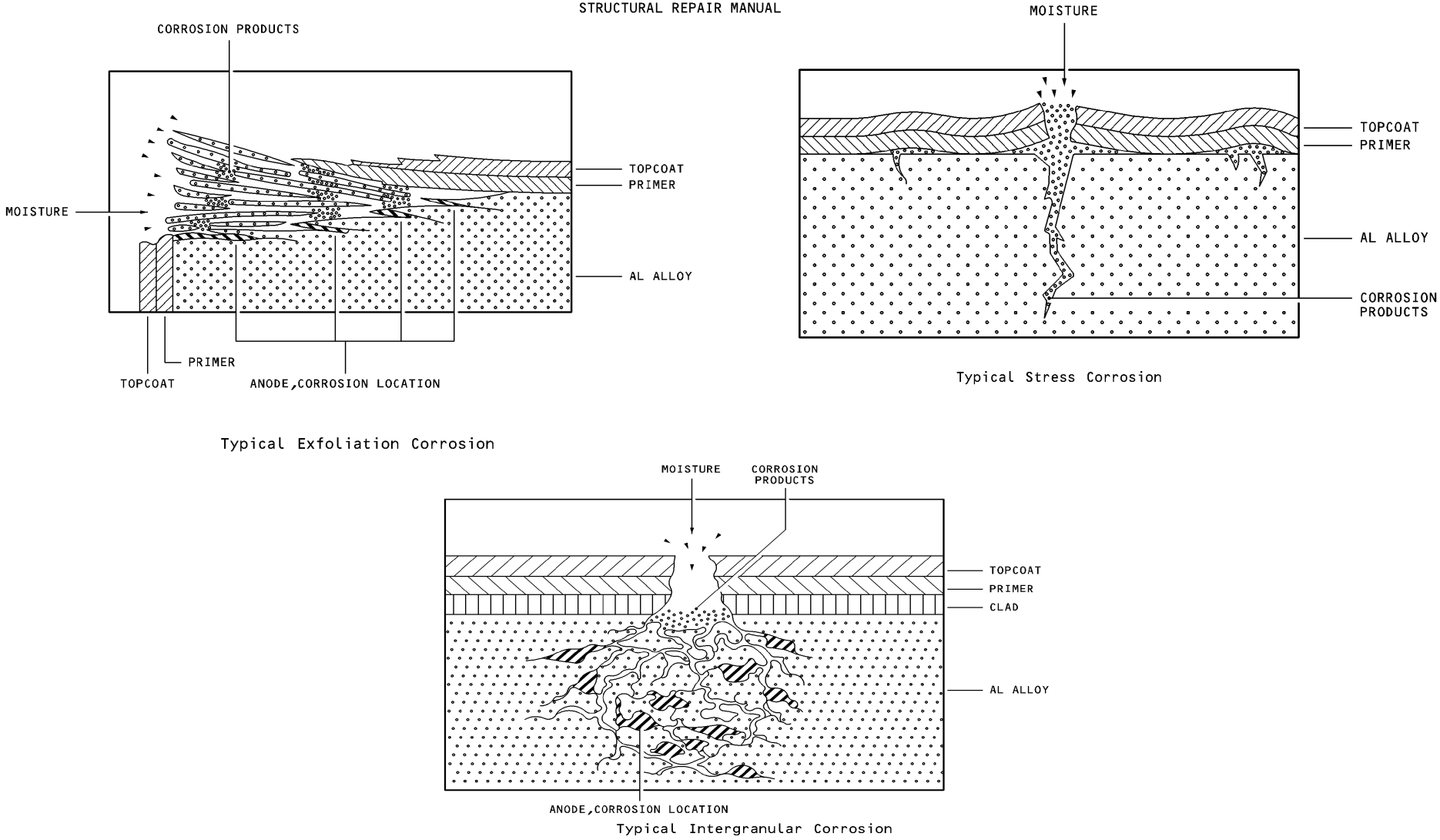


Figure 12 Corrosion Types with Possible Remaining Corrosion (after Removal Work)

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Surface Protection

General

The surface protection of aircraft materials has a very high importance in these days.

Due to the fact that the materials have to accept increasing loads in the course of time, the performance of the materials had to be improved. But normally with a higher strength the corrosion sensitivity of a material starts to increase.

This problem can be solved by using a suitable protective system, which prohibits the direct contact with aggressive media or electrolytes, like e.g. aqueous solutions of salts, acids or bases.

The choice of a protective system depends on several factors:

- Material (aluminium, titanium, magnesium, steel, fibre-reinforced composite,.....)
- Operational conditions (fitting position, mechanical loads e.g. abrasion, temperatures, stress,.....)
- Pollution (toilets, galleys, cargo compartment,....)

Pretreatments

Pretreatment is the initial treatment of the metal (e.g. with Alodine/Iridite, CAA, SAA etc.) and has the following functions:

- To increase the corrosion resistant properties of the metal by chemical or electrolytical procedures,
- To give a good surface for the adhesion of the subsequent paint coats.

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Pretreatments

Material	Pretreatment	Remarks
Aluminium Alloys	Chromic or sulphuric anodizing	Electrolytical treatment (surface gets an oxide coating)
	Chemical conversion coating	Chemical treatment (same function as anodizing)
	Wash-Primer	Usually used in field repairs
Steel Alloys	Cadmium Plating	Electrolytic application of cadmium sacrificial protection
	Phosphatisation	Chemical treatment, application of zinc or manganese phosphates (sacrificial protection)
	Hard Chromium or-Nickel Plating	Electrolytical treatment to prevent contact of moisture and oxygen with the steel alloy. Highly resistant to wear, low coefficient of friction.
	Silver Plating	Electrolytical treatment, good resistance against fretting corrosion under hot conditions.
Corrosion-Resistant Steels	Cadmium Plating	Used when in contact with aluminium alloys. Decreases galvanic effects. Sacrificial protection.
	Zinc Spraying	Thin layer of pure zinc. Used when in contact with aluminium alloy. Decreases galvanic effects. Sacrificial protection.
Titanium	Anodizing	Electrolytical treatment. Decreases galvanic effects.

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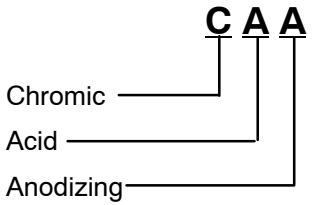
Anodizing

General

The term **„ANODIZING“** means an anodic treatment, a direct current chromic acid treatment of the aluminium surface.

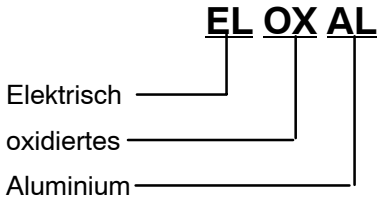
CHROMIC ACID ANODIZING

This treatment is called “CAA“ by the manufacturers.



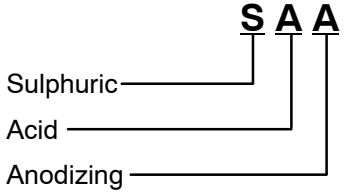
ELOXADIZING

This process is comparable to anodizing, which uses sulfuric acid:



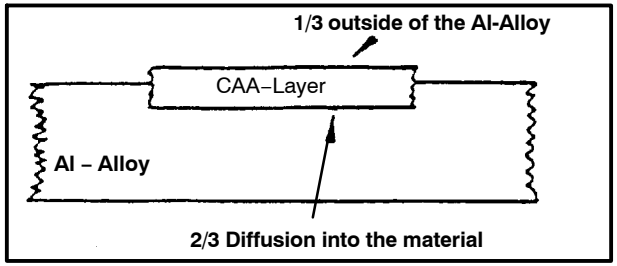
SULPHURIC ACID ANODIZING

Since about 1987 Airbus Industries have used sulfuric acid anodization.



Characteristics of anodized Layers

In this case a hard and brittle layer is created, which is very resistant to wear but cracks easily.



During eloxadizing the natural oxide skin is thickened by chemical means.

Disadvantage:

- Eloxation layers have ceramic properties - that means they are not elastic. Parts that are subject to bending or other distortions can crack more easily because of their eloxation layer.

Application of Anodizing

Anodizing is used with all integrally milled structural components of Airbus airplanes. In addition it is used on all bonded surfaces and on the outer skin of the fuselage.

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On the A300–600 and A310 airplanes almost all surface sheet metals (as shown in the illustration) are anodized in addition to the plated coat.

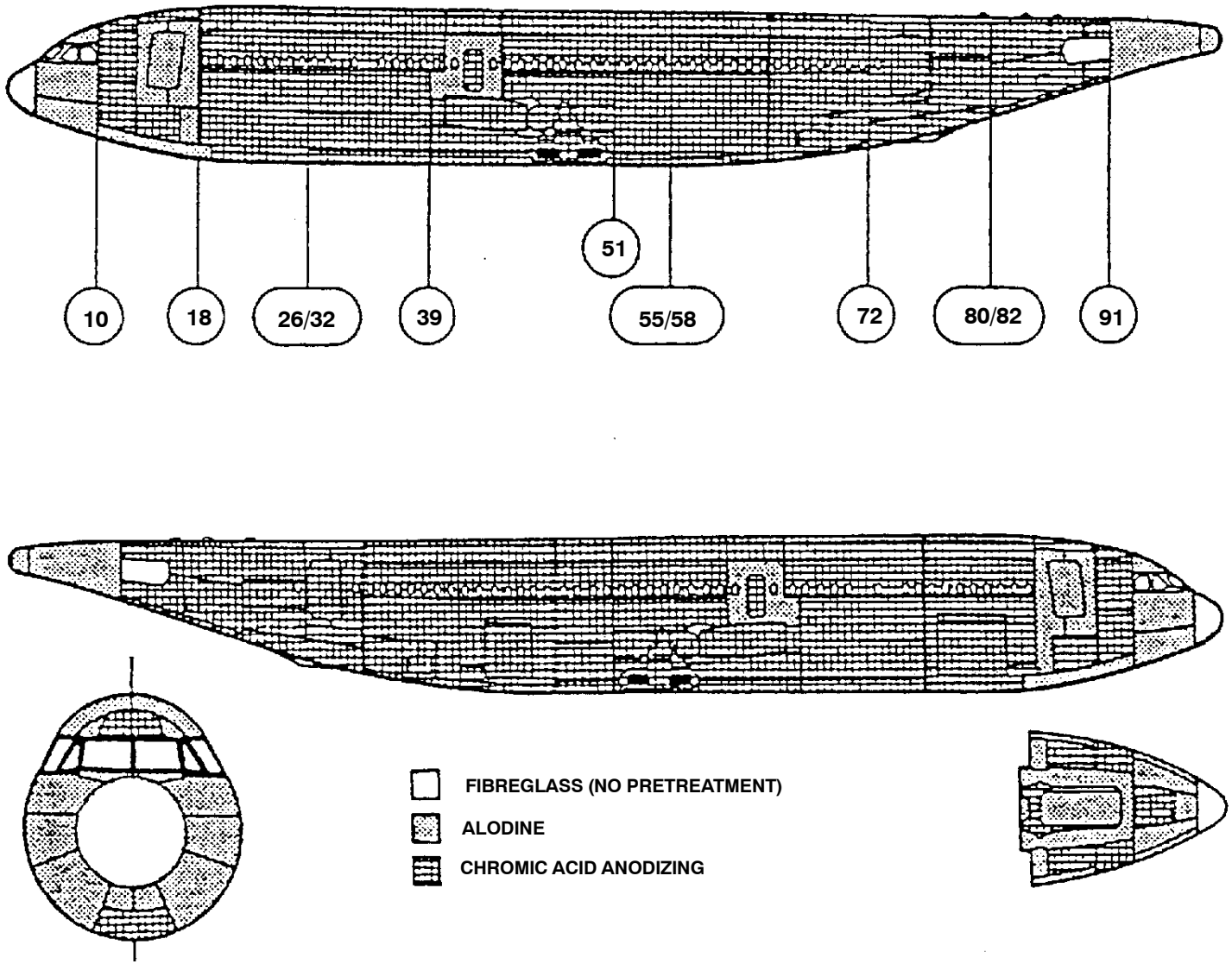


Figure 13 Airbus - Anodizing

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Chromate–Conversion Procedure

CHEMICAL CONVERSION COATING (CCC)

General

Alodine 1000 is used by the airplane manufacturer for coating plated aluminium. Lufthansa has replaced Alodine 1000 by Iridite 14E or Alodine 1200, because the protection provided by Alodine 1000 is insufficient.

Characteristics

By chemical conversion coating the surface is roughened which provides a good contact for paint coatings. Also, an **aluminium-chromium-oxide** cover is formed which is up to 0.001mm thick and provides for a certain corrosion protection even without paint coating. This coating is insoluble by water and organic solutions and can endure minor deformation without cracking. Cutting edges, bores and worked out scratches are chemical conversion coated with Iridite 14E or Alodine 1200.

ATTENTION: Components that are subjected to operating temperatures of more than 70°C should not be treated with CCC because the adhering property of the coating will decrease.

In case of larger areas the paint is applied at Lufthansa without CCC, but the first layer of paint (washprimer) also effects a chemical surface treatment and provides, together with the following layers, a good corrosion protection.

Safety Instruction

When handling with solvents, cleaners, stains, adhesives, CCC materials and paints the following safety advices have to be followed:

1. Do not inhale the fumes for a long time. Do not use the above-mentioned materials in small rooms without sufficient ventilation.
2. Avoid contact of these materials with your skin. Rubber or plastic gloves must be worn when working with solutions, cleaning agents, corrosives, etching mediums, and CCC material (Alodine and Iridite).

Application Areas

Chemical treatment of the surface is used when anodic oxidation (eloxation) is not possible or not advisable. The protective covers that are created present a **good contact area for paint** and improve chemical continuity. A number of methods exist for chemical treatment.

In recent years, acidic surface treatments without electrical current have been introduced for aluminium and aluminium alloys. These are procedures for chromium or phosphate plating. the corrosion protection is not quite as high as with the eloxation process, but much more economical. Chromium and phosphate plating procedures differ in the kind and strength of the created layers.

During chromium plating the thickness of the layers is not more than 0.001mm. Phosphate plating layers can reach a thickness of up to 0.003mm.

In the maintenance manuals, standard processes manuals and structural repair manuals you will find notes for the application of these surface protection procedures.

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A340-200/-300

STRUCTURAL REPAIR MANUAL

APPLICATION OF PROTECTIVE TREATMENT TO METAL PARTS

1. General

A. The following sections detail the necessary treatments for metal repair parts. The required paint coatings are given in Chapter 51-23-11.

B. The table below shows the original protection and choice of alternative solutions for field repairs only.

NOTE: This table does not cover major part replacement.

NOTE: CAA protection is recommended, especially in areas subject to corrosion nevertheless chemical conversion coating or wash primer is acceptable although the level of protection is degraded versus CAA.

MATERIAL	ORIGINAL PROTECTION FOR DETACHABLE REPAIR PARTS <1>	REPAIR ALTERNATIVES <4>	PARAGRAPH
Alumium	CAA unsealed + paint <3>	Chemical conversion coating + paint or wash primer + paint <2>	2.
	Chemical conversion coating + paint		
	SAA unsealed + paint <3>		

Protective Treatments on Alumium

Table 1

<1> If the required treatments are not practicable, refer to the column 'Repair Alternative'. Use the abbreviation 'CAA' for Chromic Acid Anodizing 'SAA' and for sulfuric acid anodizing.

<2> The application of wash primer is preferred in those areas that would be difficult to clean after the application of chemical conversion coating. This would prevent a chemical product being trapped between parts and subsequently causing corrosion.

<3> Anodic coating is considered to be the superior protection.

<4> The repair alternatives in Table 1 are not allowed for bonded structure.

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Figure 14 CCC-Application

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Paint Finishes

Paint Finishes

All coatings that are manually painted or sprayed on components are called paint finishes.

We talk about a paint finish when the applied substance builds a layer whose thickness can be measured after drying.

Another property of a paint finish is that the paint can be removed with corrosives or by any other means in case of repair.

Paint System

A “paint system“ is the complete build up of all layers of a paint finish.

The build-up of consecutive individual layers is carried out by following precise working instructions which are established in close cooperation with the paint manufacturers and the paint shops. In the course of the production of a certain aircraft type over many years, modifications to the surface preparatory treatment, the composition of primer and coating lacquer are common.

A paint system that has been specified by the respective authorities is principally applicable to all aircraft types. The layers consist of type-approved specified products.

In Germany these Products are specified according to the specification LN 9368. These specifications are noted in the material performance sheets.

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Figure 15 Paint Finish

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Aircraft Paint Finish

Aircraft Paint Airbus

The following three layers comprise the paint system for the Airbus outer fuselage skin:

Wash Primer for cohesion, Paint Primer (Intermediate Primer) as corrosion protection and a Topcoat.

These layers are applied to the completely pretreated sheet metal surfaces. The first layer is applied to the chromium-treated or anodized sheet metal surface.

The chemical basis of the three layers is as follows:

1. **Wash Primer:**
   - a passivating cohesion primer on a Polyvinylacetate base (PVA).
2. **Paint Primer:**
   - a Polyurethane lacquer with corrosion inhibitors like zinc-chromate or strontium-chromate, fully cured
3. **Topcoat:**
   - a polyadded, fully cured Polyurethane

CAUTION: WASH PRIMER (FCR-PRIMER) MUST NOT BE PUT ON HIGH-TENSILE STEEL (HHT) WITH A TENSILE STRENGTH OF MORE THAN 180 KSI (1240 N/MM^2). IN THIS CASE THE PRIMING IS DONE WITH EPOXIDE-PRIMER.

Aircraft Paint Boeing

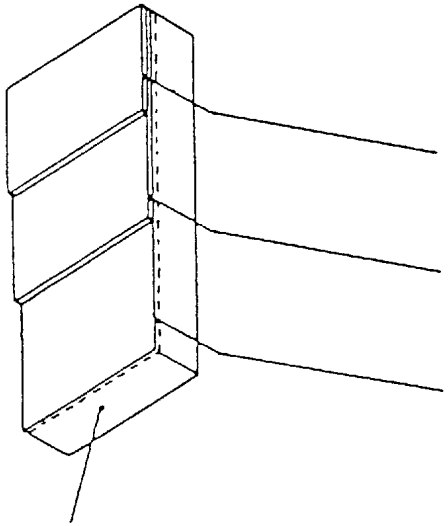
Boeing uses a two-layer system. This system contains out of:

1. **Epoxy Primer:**
   - fully cured epoxy paint system, after curing resistant against chemicals and hydraulic fluid
2. **Topcoat:**
   - a polyaddes, fully cured Polyurethane

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Boeing Two-Layer System



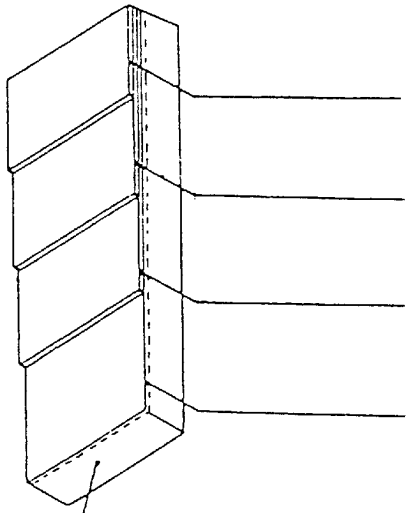
Topcoat: Polyurethane lacquer or Desmophen-Desmodur (DD) (BMS 10–72)

Primer: Polyurethane-based or Epoxy Primer (BMS 10–11 or BMS 10–79)

Pretreatment: CCC (Chemical Conversion Coating)

2024 or 2024 CLAD
7075 or 7075 CLAD

Airbus Three-Layer System



Topcoat: Polyurethane lacquer or Desmophen-Desmodur (DD)

Primer: Polyurethane-based or Epoxy Primer

Wash Primer: FCR (Filiform Corrosion Resistant)

Pretreatment: CAA (Chromic Acid Anodized) or CCC (Chemical Conversion Coating)

2024 or 2024 CLAD
7075 or 7075 CLAD

Figure 16 Paint Systems

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AIRCRAFT PAINT FINISH (CONT'D)

There are two main reasons for paint finishes on airplanes and airplane parts:

- a pleasant finish to the outside airplane surface**,** and
- The protection of the cabin, the structure and parts against corrosion, erosion, mechanical damage etc.

Only approved paint finishes can satisfy these requirements.

Wear

The wear of paint finishes in operation varies strongly from aircraft to aircraft. It depends on the area of operation, long or short haul distances etc. Apart from the normal ageing process, mechanical and chemical stresses and maintenance occurrences affect paint deterioration.

Date of Paint Overhaul

Because of the described facts, it is not laid down how and when the overhaul and renewal of the paint finish should take place. Usually the person responsible for the analysis test will determine the extent of the repair.

Inspection of the Paint Finish

If there are no special requests according to the task (such as paint removal for crack testing or color change etc.), the person responsible for the analysis test will determine the extent of the repair.

The paint finish has to be inspected for its general condition which means for

- surface polish
- brittleness
- calcification
- cracks
- color change
- satisfactory adhesion
- separation due to chemicals
- signs of corrosion below the finish

If in doubt, small test areas have to be removed.

Paint Repairs

Generally it has to be made a difference between three types of surface protection repair.

1. Fixing:

A proper paint finish, which is conform with the described points, is fixable.

Fixing means the cleaning and maintenance of the existing paint finish. It includes the repair of small imperfections as long as they can be carried out with a paintbrush and appear to be optically justifiable.

2. Partial or Total Renewal:

This requires that the existing paint finish is solid in structure and has a satisfactory adhesion.

Partial or Total Renewal means:

a paint finish that is aged or damaged is partially or totally sanded and repainted (depending on analysis test).

3. Basic Renewal:

Heavily-aged paint finishes with cracks, poor cohesion, dissolved by Skydrol or visible corrosion of the metal have to be completely removed.

A basic renewal includes paint removal, corrosion inhibition if required and the build up of the complete paint system.

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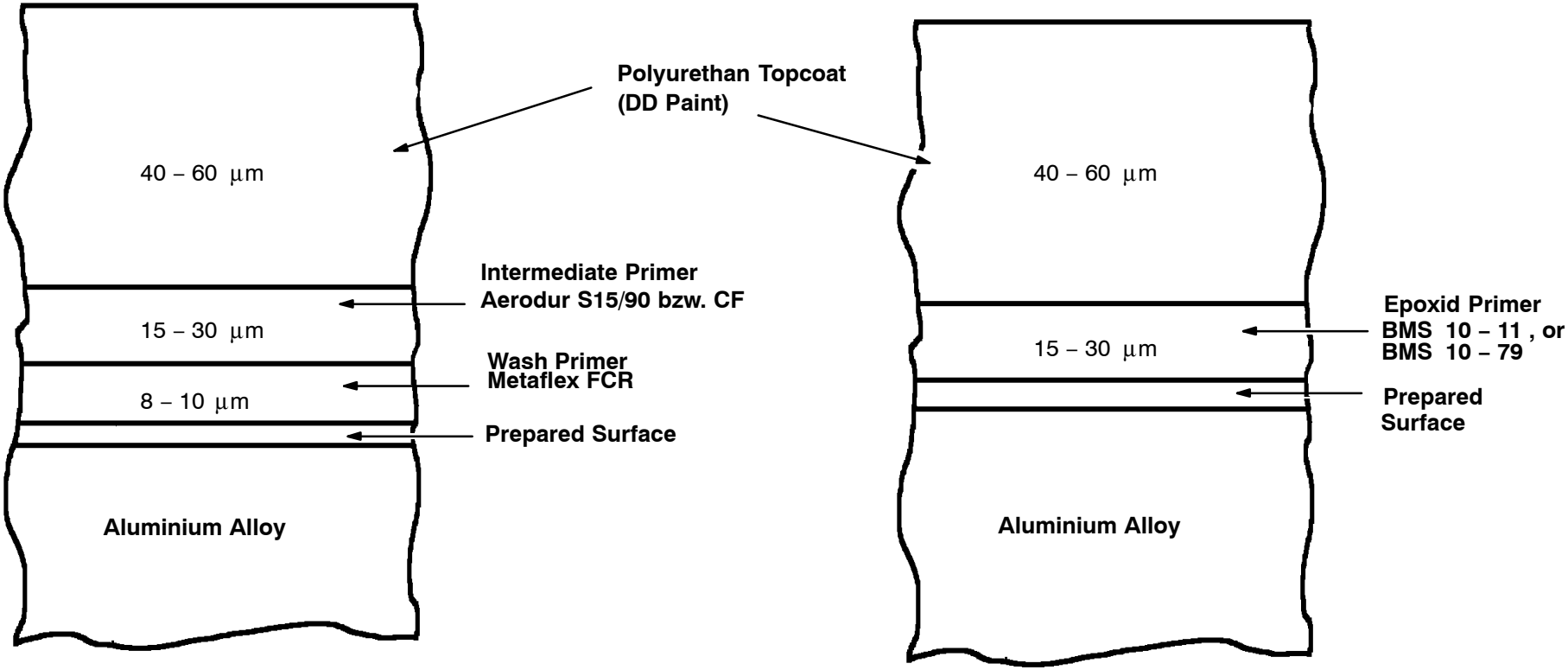


Figure 17 Paint Build-Up

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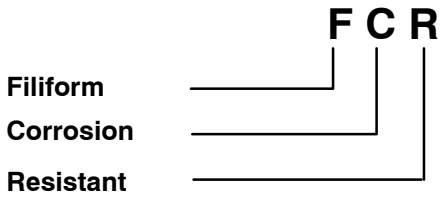
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Wash Primer/FCR-Primer

Wash-Primer/FCR-Primer

The wash primer, also known as FCR primer, is the first layer to be painted on metallic structures, especially aluminium, and it acts mainly as an adhesion contact.

The abbreviation FCR means:



General

The FCR primer consists of phosphoric acid parts (which chemically react with aluminium) and zinc-chromate pigments (which act as *moisture inhibitors*).

Zinc-chromate (ZnCrO4) is nor solvable in water.

The FCR primer is not to be used as a *one-layer primer* but must be covered with a paint or intermediate primer layer.

Function of Wash Primers

In the interior structure, e.g. stringer, ribs, etc. the FCR primer acts as corrosion protection for the sheet metal parts.

On the outer surface, e.g. fuselage outer planking, the FCR primer acts primarily as adhesion contact.

The FCR primer improves the adhesion of the three-layer paint system on the prepared, corrosion-protected sheet metals, which have been plated, chrome-plated, or anodized with chromatic acid.

Pot Life Time

The pot time is 8 hours at 20°C.

Curing Time

Depending on the humidity and temperature the curing time is between 2 and 8 hours!

ATTENTION: If the curing time is not observed before the next coat, corrosion protection and adhesion will be impaired.

Layer Thickness

The thickness of the layers should be between 0.08 and 0.012mm (equivalent to one cross-coat).

Additional Advices

- In cases of humidity higher than 75% or temperatures below 15°C, the use of FCR primer is not recommended.
- If its use cannot be avoided, a decrease in adhesion and corrosion protection will result and the curing time will be increased.
- Coating lacquer must not be applied directly to the FCR primer. It must also not be used as the only corrosion protection.
- It is always necessary to subsequently apply Aerodur S15/90 or CF Primer 37047.

  CAUTION: WASH PRIMER (FCR-PRIMER) MUST NOT BE APPLIED TO STEELS WITH ABREAKING STRENGTH OF MORE THAN 180 KSI (1240 N/MM^2). IN THIS CASE EPOXIDE PRIMER IS USED.
- When using alternative products it is important to ensure that the primer is compatible with the component to be coated (if in doubt consult the manufacturer or refer to the current specification sheets). Not observing this can lead to loss of airworthiness!

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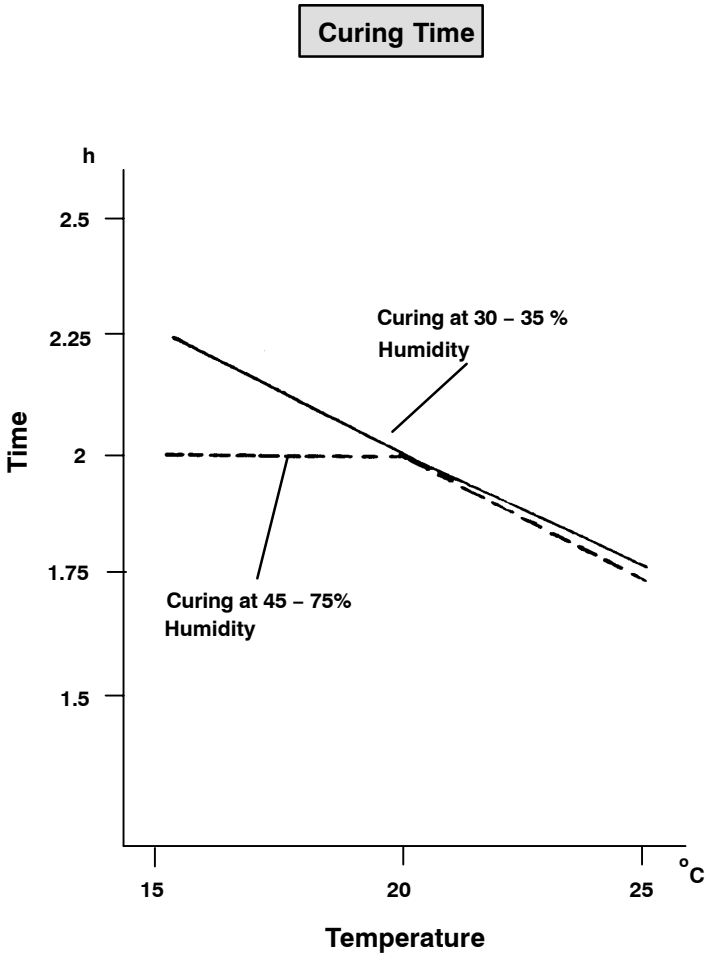


Figure 18 Curing Time FCR Primer

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Intermediate Primer

General

The following products

- Aerodur S 15/90 (contains strontium chromate ; SrCrO4)
  intensive green/yellow dull
- Aerodur CF 37047 (chromate free)
  light grey-white and dull

are widely used.

Characteristics and Application Areas

The intermediate primer is applied to the Wash Primer or to Alodine-treated aluminium surfaces and is the main corrosion protection paint.

The functionally comparable 'paint primer' (WL 5.7050) of the Airbus manufacturer contains zinc-chromate.

Pot Life Time

- Pot life time after preparation is 6 hours at temperatures of 18-22°C
- Additionally a so called "maturing time" of 15-30 min is recommended.

Cure Times

- Dry so that dust will not cling after 30 minutes.
- Can be sprayed over after a minimum of 4 and a maximum of 72 hours. After that it has to be sanded.
- Depth hardening after about 4 hours (can be shortened by heating up to 125°C)
- Thickness of layer of one cross-coat 0.012 up to 0.015mm (dry film).

ATTENTION: If the curing time is not observed before the next coat, corrosion protection and adhesion will be impaired.

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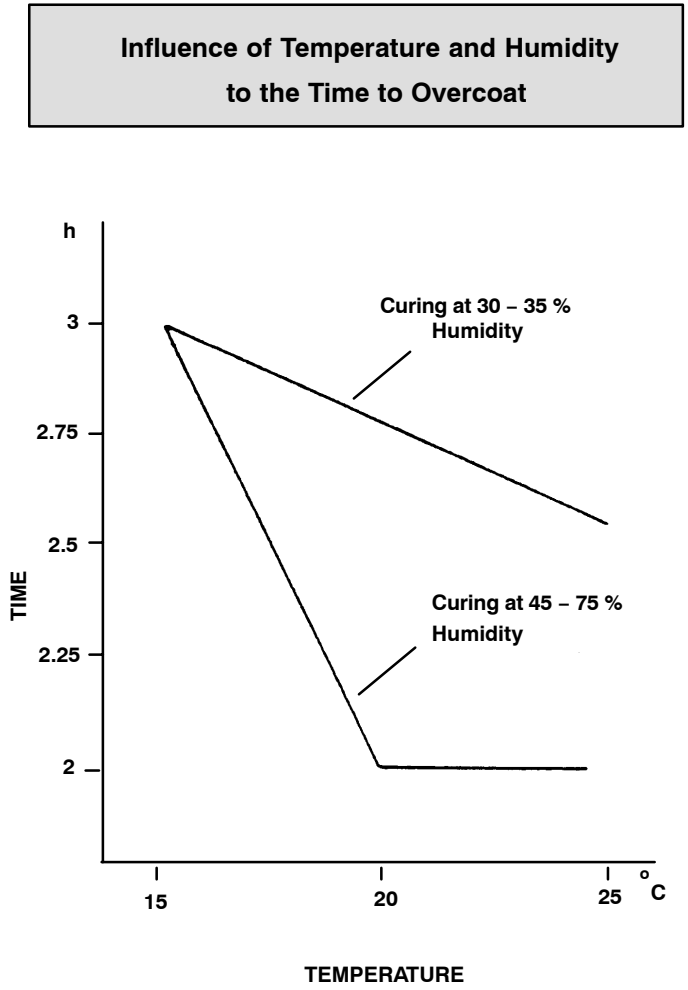


Figure 19 Cure Time Intermediate Primer

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Epoxide Primer

Characteristics and Application Areas

After chemical reaction has taken place (thermo–setting), the epoxide primer is relatively resistant to chemical attack.

Resistance to hydraulic oils is not guaranteed at curing times less than 72 hours!

Epoxy Primers can contain zinc-chromates but **no phosphoric acid**. This makes them very suitable for **coating high strength steel parts** with a breaking strength of more than 180 KSI/1240 N/mm^2.

Phosphoric acid would cause hydrogen embrittlement.

Pot Life Time:

- 4 hours

Cure Time:

- 24 hours at 18°C
- 36 hours resistant to hydraulic oil (short contact)
- 5 hours resistant to hydraulic oil at 80°C (before oven-drying a vaporizing time of one hour is needed)

ATTENTION: If the curing time is not observed before the next coat, corrosion protection and adhesion will be impaired.

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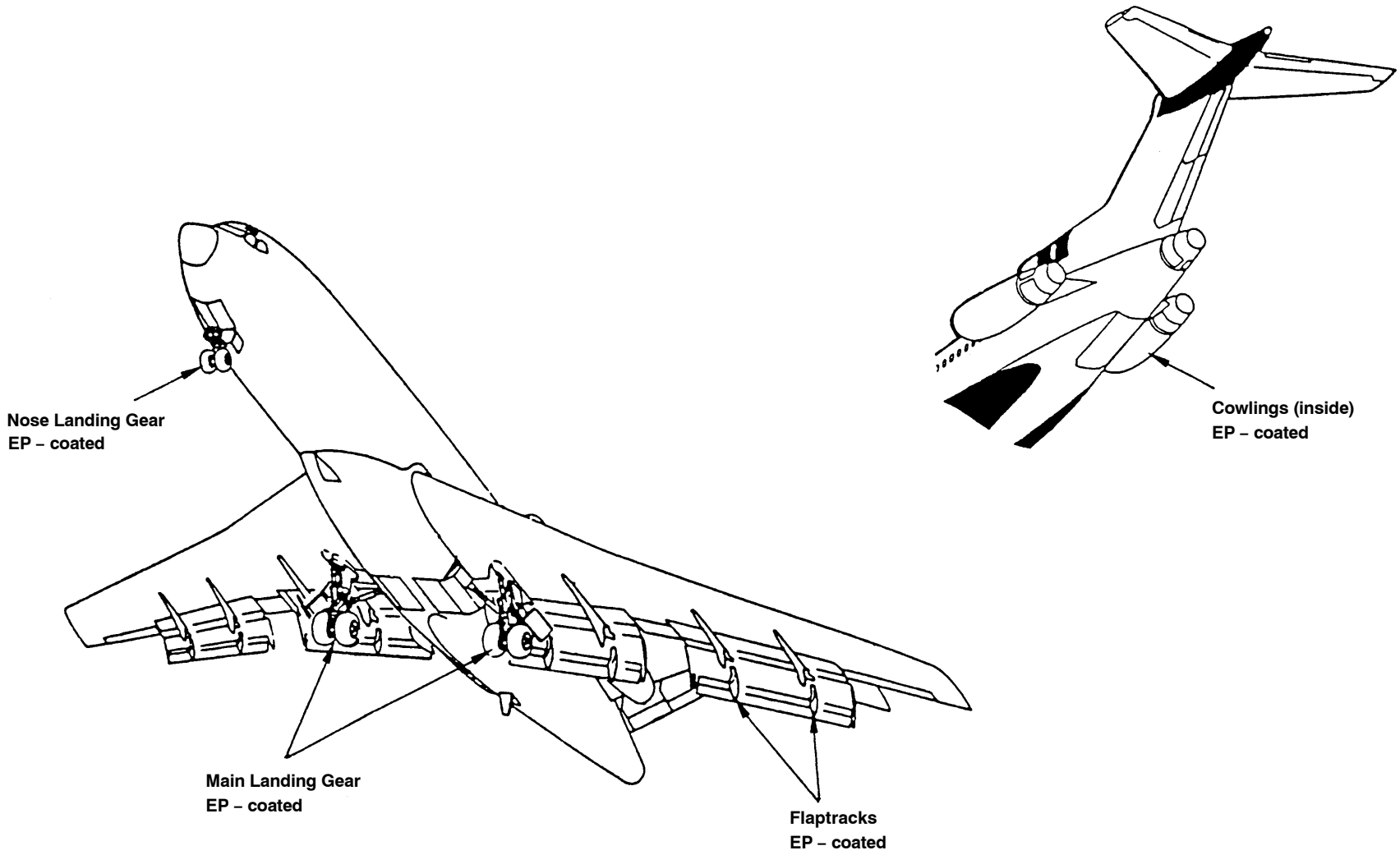


Figure 20 Epoxide Primer Application

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Top Coats

General

The top coat is applied as the last layer on previously-applied wash primers and intermediate primers.

Application Areas

The application of coating lacquer is performed on all outer cabin parts which are subject to weather conditions and to such components of the interior structure as have contact with hydraulic oils or other aggressive fluids.

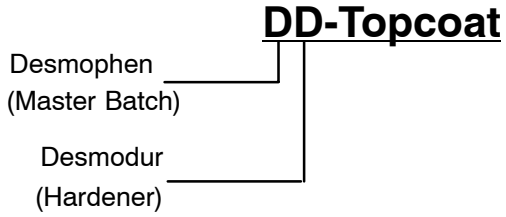
The coating lacquer is not part of the decorative paint finish. This is applied onto the coating lacquer, but is not a technical part of the three-layer finish system.

Characteristics

At present, airplane manufacturers and operators use identical coating lacquers. These are Polyurethane products (PU or PUR coating lacquers).

Currently e.g. products from the manufacturers Sikkens (C21/100 or HF-High Flexible), Cellomer, Finsh, De Soto, ICI,.....are being used.

The Sikkens Aerodur Finish HF is identical to the widely-used DD Finish:



Additional Advices

Coating lacquers can be protected against general aging and decay by an additional clear varnish. The life–span of a multi-layer paint finish system can thus be increased by 25 - 50%.

For aviation use, a special “Clear Coat UVR“ (Ultra violet Resistant) is available. Several manufacturers have already integrated this protection into their respective coating lacquers.

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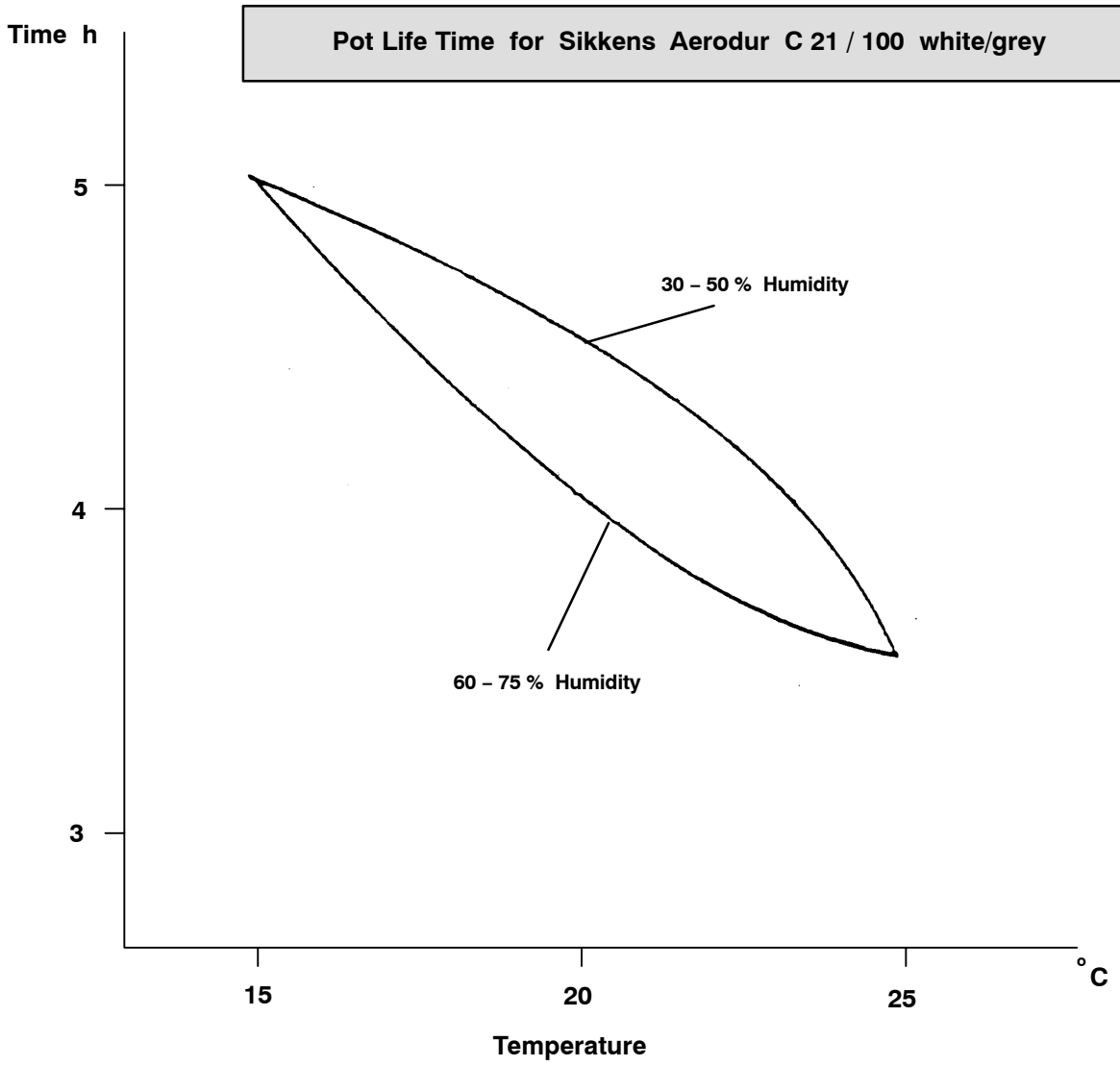


Figure 21 Pot Life Top Coat

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Electrically-conductive Paints

General

These products are identical to

”antistatic paints” and ”antistatic primers”.

Characteristics

Antistatic primer is a electrically conductive primer for plastic components, which do not conduct electricity by themselves, like e.g. fibre glass composites (Radomes).

Application Area

All plastic components of the outer skin (basically in the secondary structure) must have this priming.

Exception:

- Antennae covers

  Since the antistatic primer is not exposed any more after application of the coating lacquer, it is not possible to localize it optically. This means that before application of the coating lacquer and after complete hardening has been achieved, a resistance test or conductivity test must be performed by trained personnel:

Direct Current Measuring-Ohmmeter

- *Measuring range 1-20 MOhm*
- *Resistance smaller 10 MOhm*
- *Distance between feelers 305 mm*
- *Minimum curing time 1-2 hours*

Additional Advices

- To achieve sufficient conductivity a minimum of 75% of all countersinks in composite components must be covered with electrically-conductive paint.
- If pore fillers are used, the antistatic primer **must** be applied first.
- In the areas of antennae covers where the antistatic primer must not be applied, the paint finish is to be applied as if it were a normal outer skin.

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The black depicted areas are the antenna covers of a B737

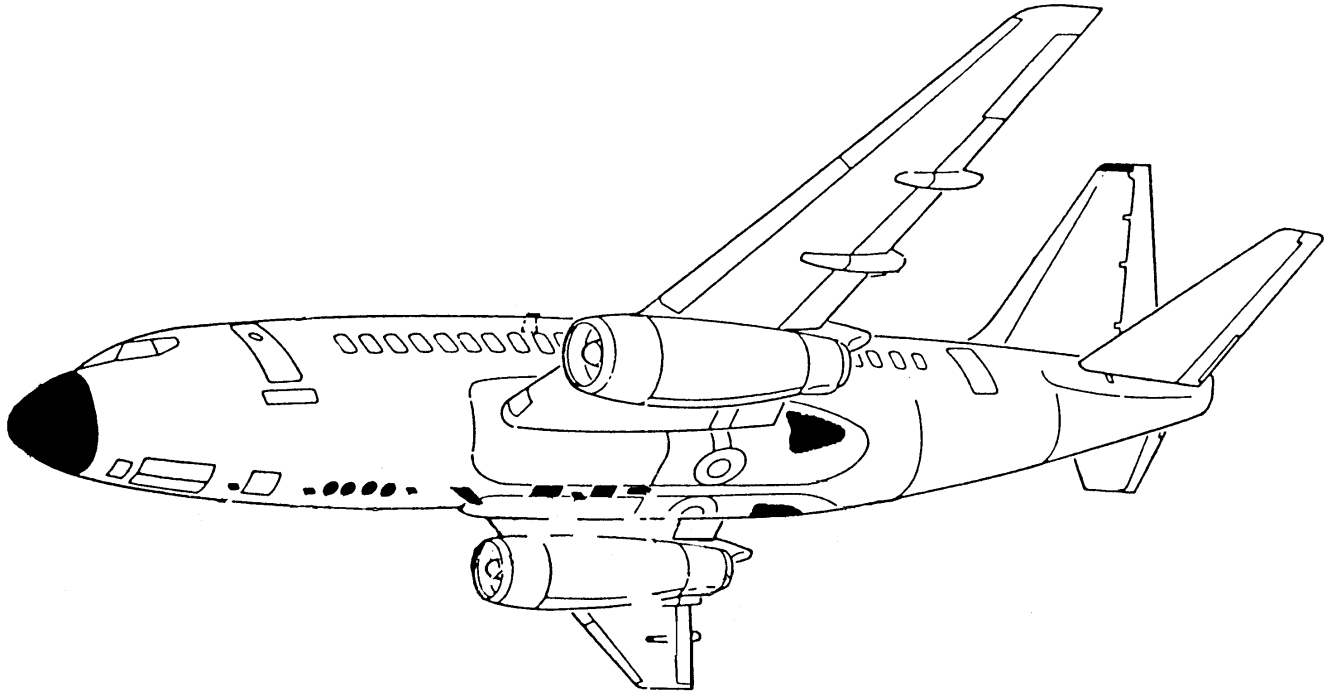


Figure 22 Electrostatic Coating

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Corrosion Inhibitors

General Application Areas

Water-displacing inhibitors are applied due to the reasons that follow:

- to stop corrosion that has already started for a certain time (until the repair can be carried out)
- in areas that do not permit corrosion removal or permit corrosion removal only to a certain extent and where the build-up of correct paint finish systems is also impossible.
- to make the surface in susceptible areas water-repellent in addition to the paint finish systems and other surface protection treatments, to enhance corrosion protection.

Characteristics

Water repellents have wax-like characteristics after they have dried. Their effectiveness is based on a **good wetting ability** and **penetrating properties**.

They penetrate existing corrosion products to the metal surface and build a constant film. This prevents moisture and oxygen from contact with the metal and prevents the spread of corrosion.

Product Overview

The following products are currently available in the aviation world:

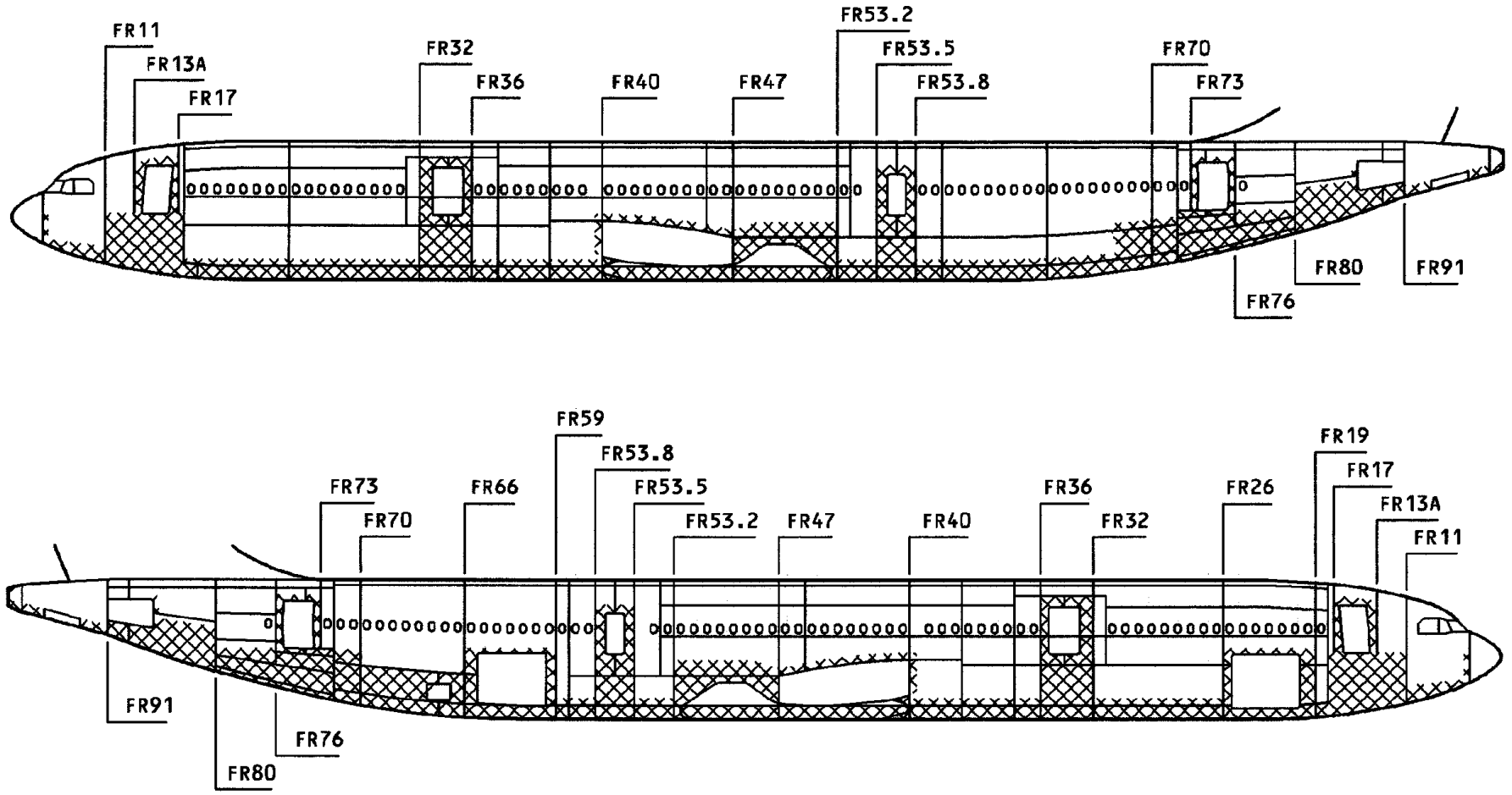
- LPS 3
- Boeshield T9 H5 (carcinogen!)
- Tectyl (carcinogen!)
- Adrox
- DINOL

When using these materials it is imperative to cover the following components before starting work:

- Electrical plug connections
- Oxygen system components
- Silicon parts (door seals, bearing seals, pipe fixtures)
- Piston rods of hydraulic cylinders
- Control cables, pulleys, cable covers

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LUBRICANT-RUST INHIBITOR (WATER REPELLENT FLUID)

NOTE: WATER REPELLENT FLUID IS ALSO APPLIED BELOW THE FLEXIBLE LAVATORY/GALLEY POSITIONS AS SELECTED BY THE AIRLINE

NOTE: FOR THE FRAME STATIONS REFER TO CHAPTER 51-00-00

Figure 23 Corrosion Inihibitor & Water Repellent

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Dinitrol Products

Characteristics of different Dinitrol Products

Currently mainly three different Dinitrol types with the following characteristics are in application:

DINITROL AV 8

- Used as a ”T9”-replacement, a highly viscous water-displacing compound with strong surface-wetting and gap-penetrating (capillary action) characteristics.
- After drying, this compound builds up a dry film of about 8µ thickness.
- DINITROL AV 8 is used as a precautionary corrosion protection in the landing gear areas, pylon areas and on fittings. Existing corrosion can be stopped or inhibited by AV 8 if it cannot be removed by maintenance immediately.
- AV 8 can be removed with naphtha (Varsol) or with tri- or per- chlorethylene. Alkaline degreasing agents are also applicable to a certain extent.

  DINITROL AV 8 replaces AV 5, AV 5-2, AV 5 B, AV 5 B-2.

DINITROL AV 30

- is a thixotropic, special, yellowish-brown, transparent wax that doesn’t melt or bond at temperatures below 70°C.

  ’Thixotropic’ means ’thickened’. The compound can only be processed with some difficulty.
- The product builds up an elastic film which does not crack when being deformed, e.g. together with a sheet parts.
- The product is used in airplane overhaul for long term protection of the entire cell structure.

  DINITROL AV 30 replaces AV 25, AV 25B, AV 50

DINITROL AV 100 (Type D)

- is a strong, wax-like film.
- Applied as a thixotropic fluid, AV 100 builds up a resistant, even mechanically abrasion-proof film.
- Under special conditions the penetration of AV 100 into narrow capillary tubes can be improved by pretreating with AV 8.
- Under these circumstances an intermediate cure time of the AV 8 is required. This cure time must last at least 1 hour (refer to specification sheet).
- ***Cure Time***, or airing time of AV 100 D ***ca. 6 hours***
- AV 100 can be rinsed off with TRI, PER or Varsol.

  DINITROL AV 100 D replaces AV 100 and AV 100 B.

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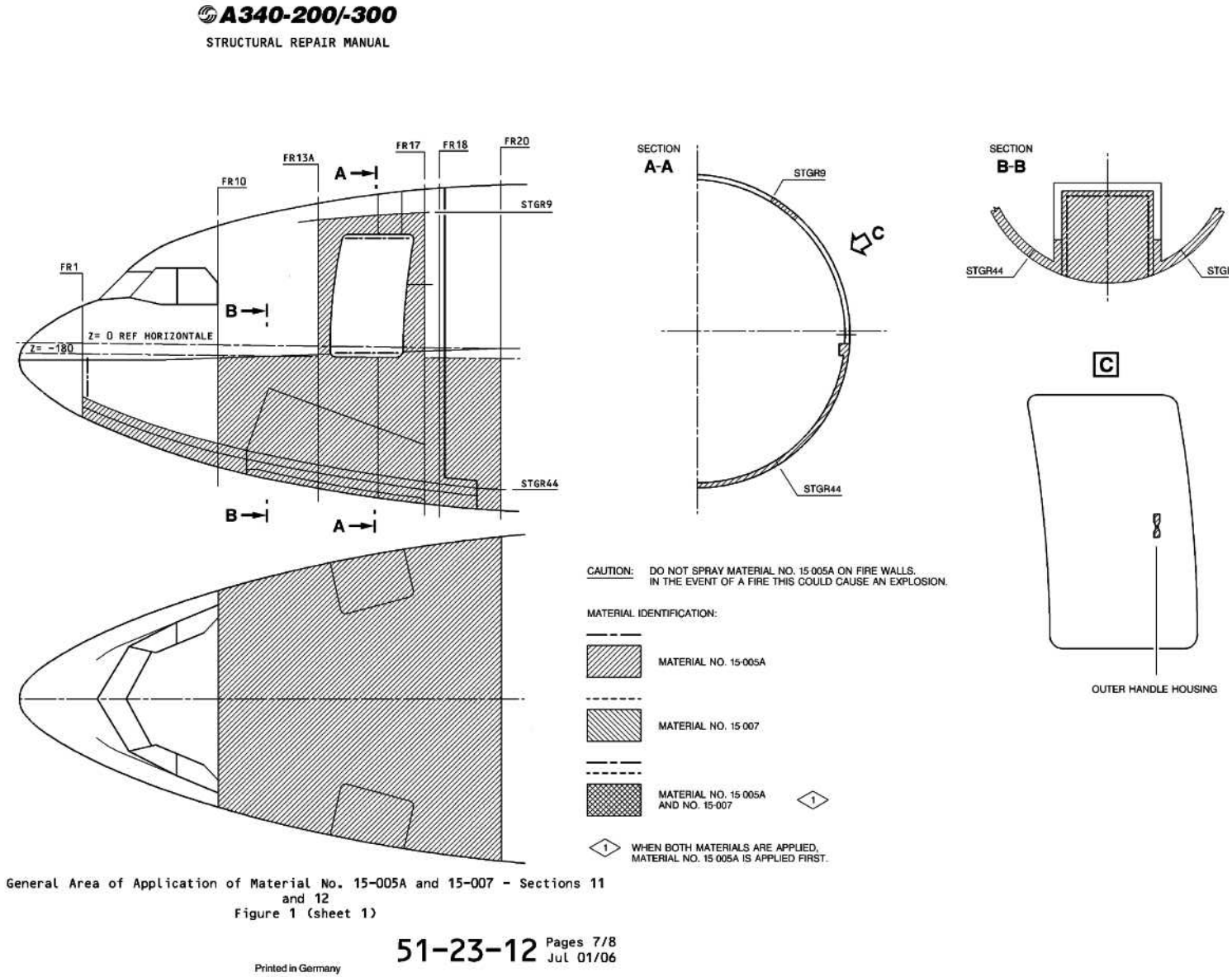


Figure 24 Application of Corrosion Inhibitors Detailed

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Sealing Compounds

General

Sealants are applied in such areas where absolute tightness of an area have to be achieved without welding or soldering. Sealants are permanently elastic sealing compounds with a resisting power against different external attacks.

Functions of a Sealing Compound

Sealing Compounds are mainly used in aircraft to seal fuel tanks and maintain cabin pressure. A large application area for sealing compounds is also the filling of gaps between riveted or bonded parts, to prevent the penetration of moisture and therefore corrosion.

A further application area is the smoothing of discontinuities on the aircraft exterior, in order to increase the aerodynamic performance of wings or fuselage or to ensure the safe drain of condensation water in the lower fuselage.

The sealing compounds are delivered in different textures, brushable or porous for filling or for application with a triangular bag. They are mostly two-component products with different pot life times.

Characteristics of Sealing Compounds

The most sealing compounds are cold-vulcanized rubber products with a hardness of ca. 30 to 70 shore-A-grades. The materials have an excellent adhesion on metallic bare and painted surfaces, under the fundamental premise that these are absolutely **greaseless and dry** and that the sealing compound is mixed in the denoted mix ratio and homogeneous without any bubbles.

Denomination of Sealing Compounds

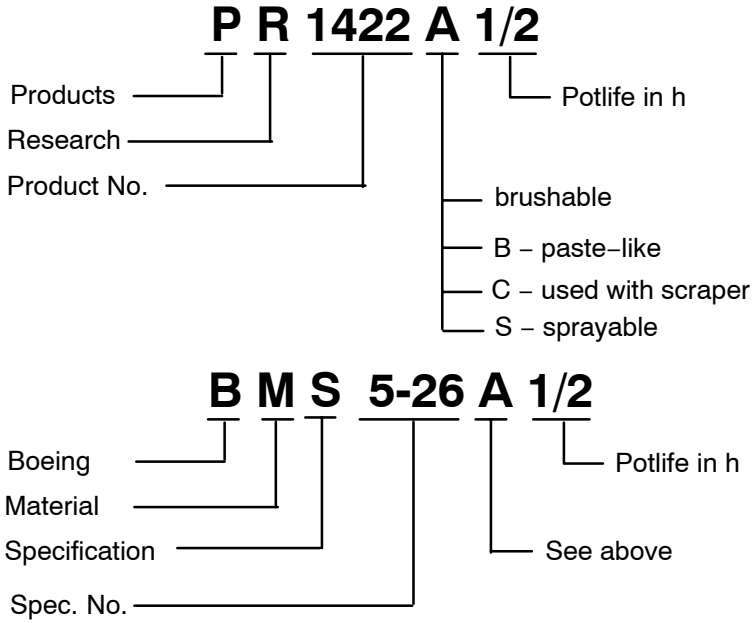
An often used sealing compound is sold under the denomination **PR1422** by the company ,,Products Research". It is in comply with the requirement in the MIl–S 88O2–Spec.

This universal sealing compound is used by Boeing under the denomination **BMS 5–26**. It is used for sealing fuel tanks, pressurized cabins and in many other areas.

PR 1422 is durable against:

- – Petrol, kerosene, lubricants, water
- It is applicable in a temperature range from –53°C to + 135°C.
- It adheres excellently on aluminium, titanium, steel and many other materials as well as painted surfaces.
- It has a hardness of ca. 50 SHORE–A–grades.
- It is a 2 component-sealing compound (basis-material + hardener).
- It has a storage time of 6 months in the original packing under temperatures of 26°C.
- It is delivered in different textures.
- It is available as a sealant with different pot life times.

This Sealing Compound is denoted entirely as follows:



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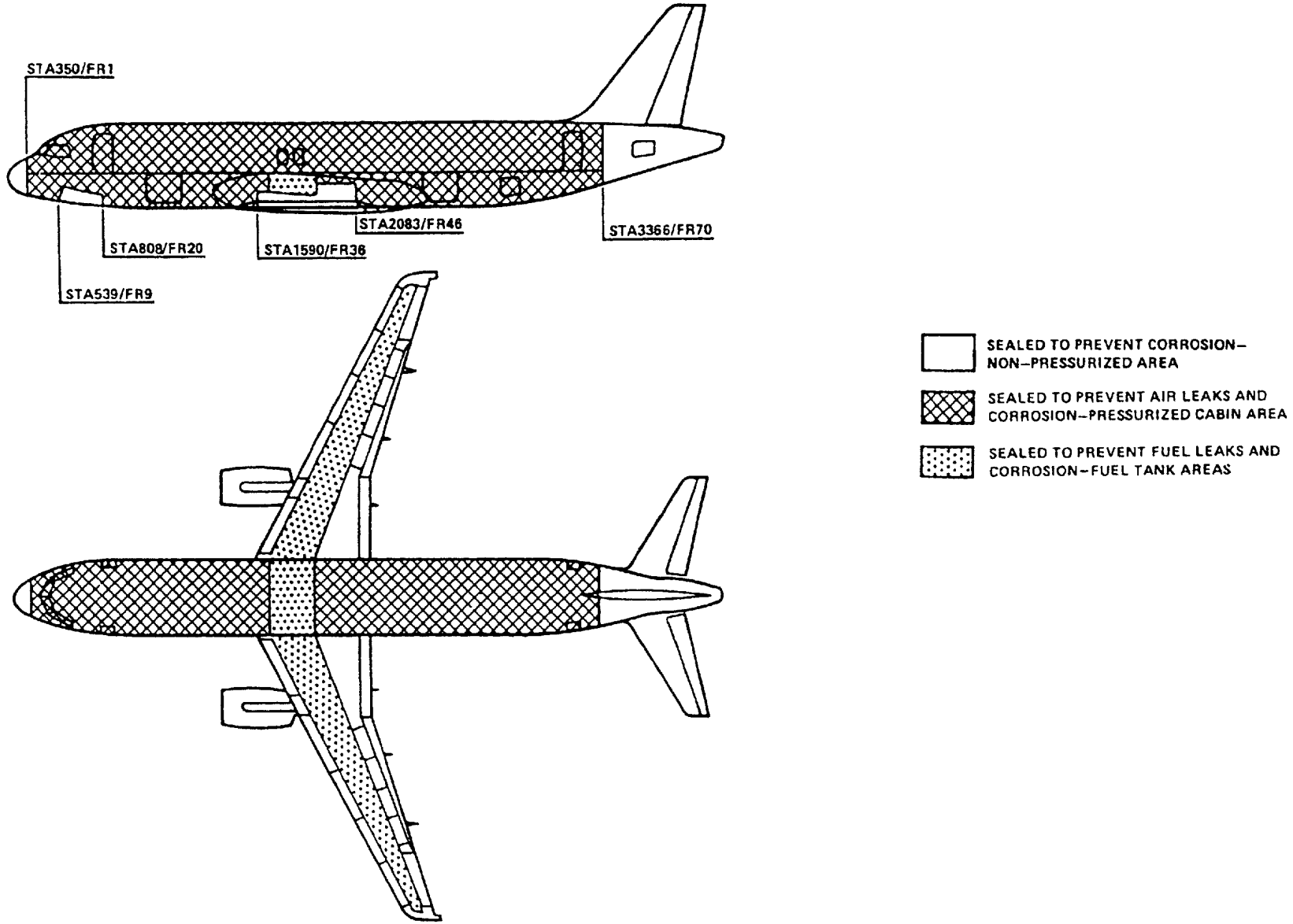


Figure 25 Types of Sealed Areas (A320/ATA 51-24-00)

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Materials and Definitions

Pot Life Time

Pot Life time of the mixed sealing compound.

Tack Free Time

This time follows directly the pot life time and is10 to 20 times as long as this. In this time the polymers start to cross-link. The wetting ability and therefore the adhesion do both start to decrease. Hence it has to be waited until the sealing compound loses all the viscosity and therefore can not be deformed anymore. It is prohibited to touch, move or fuel 'sealed' areas before the end of the tack free time!

Cure Time

Is the time the sealing material needs for total curing. The time is specified for room temperature and is approximately 2 to 3 times the tack free time.

Squeeze–Out Life

Is the time in which a sealing compound has the ability to flow under the pressure of a connection during a fastening or riveting action of two parts.

Pre Coat

Is a thin layer of brushable sealing compound which is brought onto the surface that has to be sealed in order to increase adhesion to the next layer that is brought on.

Wet Side Sealing

Is s sealing that is brought on the inner surface of a tank (e. g. fuel tank) and is in direct contact which the fluids in the tank.

Top Coat

Is a continuous film on metal structures which offers corrosion protection and protection against mycelium and bacteria which might be in the fuel.

The specific times and other conditions of the sealing compounds can be found in specifications or in the notices brought with the sealing compound itself.

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SEALANT TYPE	REMARKS	APPLICATION LIFE (Hours/Minimum)	TACK FREE TIME (Hours/Maximum)	CURE TIME (Hours)
PR 1422 - 1/2		0.5	12	48
PR 1422 - 2		2.0	36	72
PR 1422B - 1/2		0.5	12	48
PR 1422B - 2		2.0	40	72
PROSEAL 860B 1/6		0.33	1.5	4
PR 1431 Type 1		12	N/A	14 Days
PR 5401K		0.5	4.5	10
PR 1005 CH		---	0.33	4
PR 1005 L	Alternativ for PR 1005CH	---	0.33	4
PR 147		---	0.5	---
PS 890A - 1/2	Alternativ for PR 1422A - 1/2	0.5	10	40
PS 890A - 2	Alternativ for PR 1422A - 2	2	36	72
PS 890B - 1/2	Alternativ for PR 1422B - 1/2	0.5	10	30
PS 890B - 2	Alternativ for PR 1422B - 2	2	24	72
PR 146	Alternativ for PR 147	---	0.5	---
PR 1440 - 1/2	Alternativ for PR 1422A - 1/2	0.5	10	30
PR 1440 - 2	Alternativ for PR 1422A - 2	2	36	72
PR 1440B - 1/2	Alternativ for PR 1422B - 1/2	0.5	10	45
PR 1440B - 2	Alternativ for PR 1422B - 2	2	21	40
PR 1436**G**A 1/2		0.5	16	30
PR 1436**G**B 2		2	24	48
PR 1436**G**B 1/2		0.5	16	30
PR 1221A	Alternativ for PR 5401K			

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Interchangeability of Sealing Compounds

General

When applying sealing compounds generally the manufacturer instructions or the specifications on job cards have to be adhered. Here the sealing compounds, which are allowed to be used, are specified. These sealers must be used.

If it occurs that a sealing compound that is noticed in the work task is not available, the interchangeability of this sealer can be checked in SRM chapter 51.

SEALING COMPOUND FOR SPECIAL APPLICATIONS

For special applications special sealants are used, which fulfil exactly the desired requirements of the application.

BMS 5-18 (High Temperature Sealant)

- Group I = PR 1600 to 175°C
- Group II = PR 810 to 230°C
- Can be used as a Fillet and as a Faying Surface Sealant.

BMS 5-19A/B (Sealing Compound for Integral Tanks)

- (PR 9021) Only use with topcoat EC 776 or PR 1005, otherwise it is not fuel resistant!

SILICONE-SEALANTS

DC-RTV 731 (Acetic Acid Sealant)

- Temperature area: - 65° to + 230°C
- Color: white
- This compound emits hydrogen and can so not be applied on surfaces which suffer under hydrogen embrittlement.

DC-RTV 738

- This sealant is not emitting hydrogen, harmless concerning food and so can be used on HHT steels, titanium and even in the galley.
- Color: white

DC-RTV 3145

- Silicone sealant with an enlarged temperature area from -65° to + 300°C, for HHT steel. Food contact is allowed.
- Color: grey.

DC-RTV 3140

- This sealing compound is very thin and does not emit acetic acid; it is mostly used as coating.

DC-RTV 159

- Silicone sealant with an enlarged temperature area from -65° to + 300°C.
- Color: red
- Mostly used in the engine area for sealing of titanium parts or cowl structures.

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ORIGINAL SPECIFIED SEALANT	PERMISSIBLE SUBSTITUTES FOR ORIGINAL SPECIFIED SEALANT					
	BMS 5-26	BMS 5-32	BMS 5-63	BMS 5-79	BMS 5-95	PR-1826 PR-1828
BMS 5-26	---	NO	NO	NO	NO	YES
BMS 5-32	YES	---	NO	YES	YES	NO
BMS 5-63	NO	NO	---	NO	NO	NO
BMS 5-79	YES	YES	NO	---	YES	NO
BMS 5-95	YES	YES	NO	YES	---	YES

TABLE I

ORIGINAL MATERIAL	SUBSTITUTE MATERIAL
BMS 5-79	BMS 5-95
CLASS B-1/2	CLASS B-1/2
CLASS B-2	CLASS B-2
CLASS B-4	CLASS B-4
CLASS B-8	NONE
CLASS C-24	CLASS C-20
CLASS C-48	CLASS C-80
CLASS D-2	BMS 5-16

BMS 5-79 SEALANT SUBSTITUTION
TABLE II

Figure 26 Interchangeability of Sealing Compounds

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Application Areas of Sealing Compounds

Fuel Areas

In integral fuel tanks, seals must contain fuel for the life of the airplane under various conditions of temperature, pressure and structural loading and must be resistant against attacks of fuel.

Pressurized Areas

Seals maintain pressure at a predetermined minimum level under all flight conditions.

Environmental Areas

Seals on exterior surfaces prevent water and other fluids from entering and also function as aerodynamic smoothers.

Corrosion Areas

Seals protect the structure by preventing entry of corrosive fluids.

Electrical Areas

Seals provide protection for electrical components against moisture/fluids and so they ensure the serviceability.

Firewall Areas

Seals prevent spread of flames beyond the firewall until fire can be extinguished.

Acid Areas

Seals protect structure from attack by aggressive fluids like e.g. battery acids and toilet flushing fluid.

Environments

Sealants must maintain adhesion to the structure and have sufficient flexibility to function effectively under a variety of environmental and stress conditions.

- Differential pressure may vary from small negative values to positive values in a range of approximately 0.9 bar.
- The operating temperature range is approximately –70°C to + 50°C
- In some localized high-temperature areas the temperature can rise up to 200°C.
- Structural loads during flight and ground operations cause deflections, which the sealant must be able to withstand at all operating temperatures.

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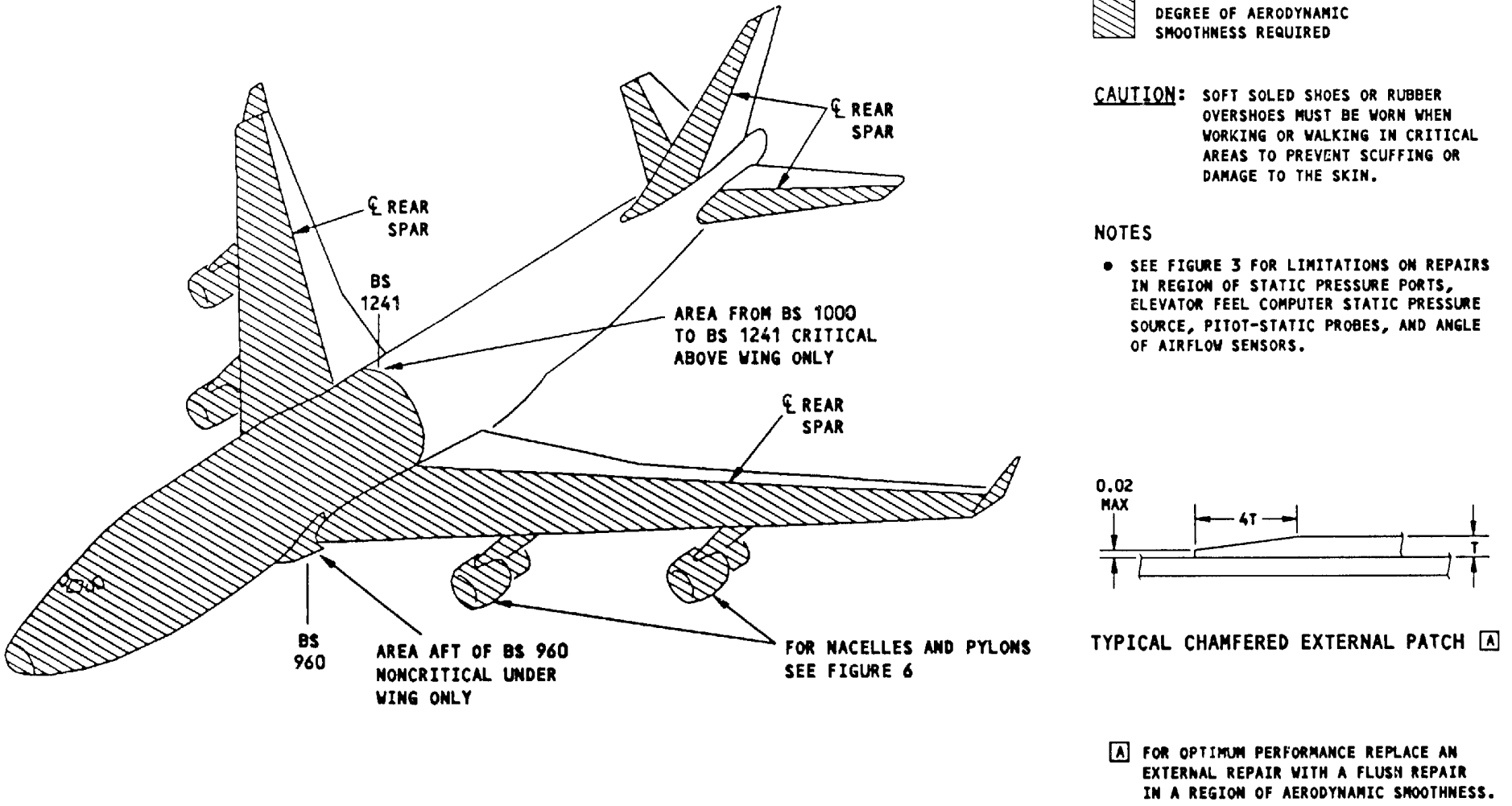


Figure 27 Typical Sealant Application Areas in Aerodyn. Smoothness-Critical Areas (51-10-01)

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Application of Sealants in Aircraft Production

FILLET SEAL

Functions and Application Areas

Fillet seals are applied at the edges of structural joints to prevent the intrusion of moisture/fluids and to achieve a smooth change of components.

They consist of beads of sealant that must adhere firmly to the structure on both sides of the seam being sealed.

Further they must be conforming to the dimensional requirements of the process specification.

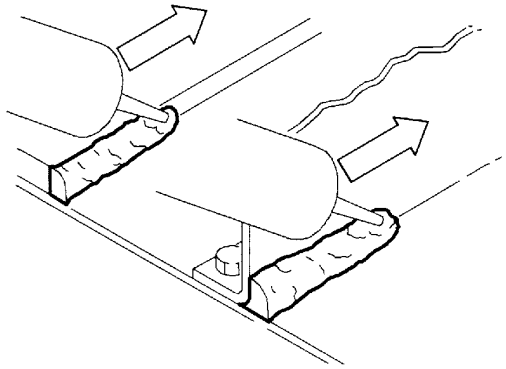
Fillet seals are used where maximum protection from fluid leakage is required, such as in fuel and pressure areas.

Work Sequence: Fillet Seal

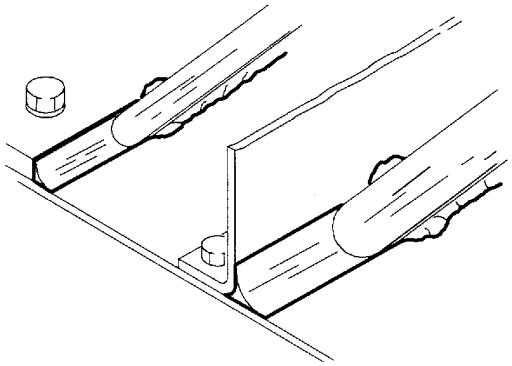
3. Apply sealant with a Semco-type flow gun, or equivalent.
4. Point nozzle tip into the seam and maintain the line of travel.
5. Force a bead of sealant ahead of the nozzle tip (Step 1).
6. Press sealant firmly into place with a fairing tool to obtain a shaped and smooth fillet (Step 2).
7. Apply second application of sealant to produce a full-bodied fillet (Step 3). Second application of sealant is required only for integral fuel tank sealing.
8. Obtain final configuration by forming the fillet with a fairing tool.
9. Press tool against the sealant and move parallel to the bead.

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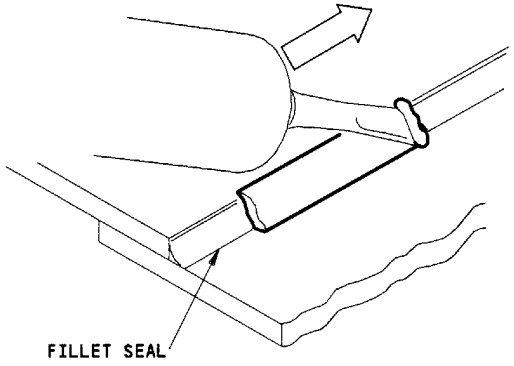
STEP 1
(APPLICATION)



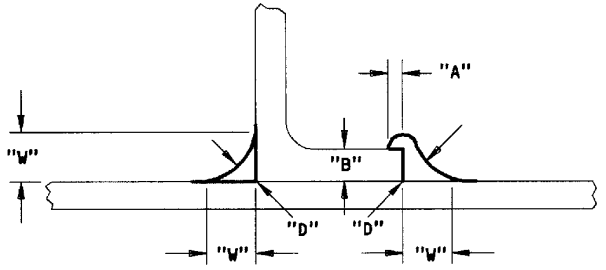
STEP 2
(FINISH)

FILLET SEAL

"A" = 0.04 TO 0.15 INCH EXCEPT "A" = 0 WHEN
"B" = 0.15 INCH OR MORE
"D" = 0.08 INCH MINIMUM
"W" = 0.12 TO 0.25 INCH



APPLICATION OF FILLET
FULL BODY SEAL



FILLET SEAL
FINISHED DIMENSIONS

Figure 28 Fillet Seal

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INJECTION SEAL

Functions and Application Areas

Injection seals are applied to fill box sections, open holes and tool holes that occur as the result of structural design.

Quite often, injections are required to continue or to back-up a fillet seal.

Work Sequence: Injection Seal

1. Wet all parts before assembly at the meeting surfaces.
2. Inject sealant into one end of the cavity or, if an injection hole is provided, with a Semco-type flow gun, or equivalent, until sealant emerges from all other openings.
3. When a seal is made at the bottom of a slot, apply the sealant so as to fill and have continuous contact with the bottom and sides of the slot.

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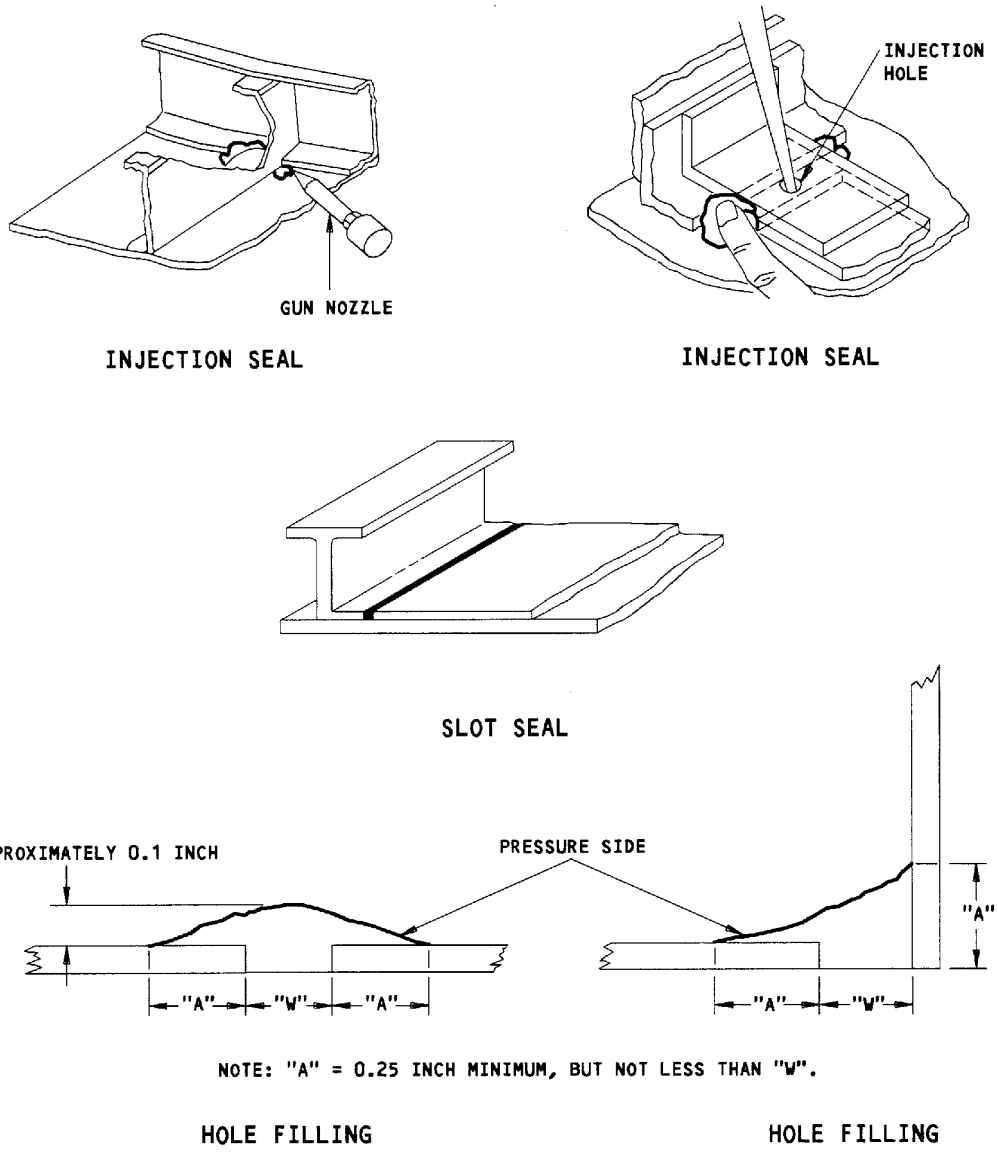


Figure 29 Injection Seal

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FAYING SURFACE SEAL

Function and Characteristics

Faying surface seals consist of a layer of sealant sandwiched between two fastened mating surfaces.

These seals are used primarily to prevent corrosion of aircraft structure, to keep the cabin pressurized and to facilitate leak tracing in the fuel tank.

Work Sequence: Faying Surface Seal

1. Sealant is applied to one faying surface with a roller to obtain a thin, uniform, continuous coating of sealant over entire faying surface area.

   Sealant shall be applied sufficiently thickly to completely mask surface underneath, yet thin enough to minimize size of the continuous bead required.

   Recommended thickness range is 0,005 to 0,015 inch.
2. Sufficient sealant shall be applied so the space between the assembled faying surface is completely filled and a small excess is extruded continuously along the joint.

   Extruded sealant shall then be faired with a fairing tool so that a continuous, smooth fillet is formed along the joint. This small fillet is necessary to assure adequate sealant contact with later applied fillet seals.
3. If possible, installation of all permanent fasteners shall be completed within the pot life time of the sealant.

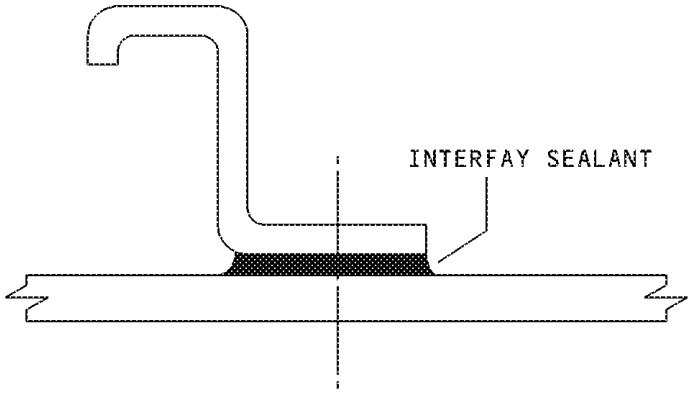
   If permanent fasteners cannot be installed within the required time, temporary fasteners (e.g. wing–nuts, Clecos or bolts) shall be used in each fastener hole to hold parts firmly together until permanent fasteners can be installed.

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A340-200/300

STRUCTURAL REPAIR MANUAL



NOTE: A LAYER OF SEALANT APPLIED BETWEEN THE MATING FACES OF ASSEMBLIES REQUIRED TO BE SEALED. WITH THIS KIND OF ASSEMBLY, THE SEALANT IS SQUEEZED OUT IN ORDER TO ENSURE THAT COMPLETE ASSEMBLY SEALING HAS BEEN ACHIEVED.

Figure 30 Faying Surface Seal

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AERODYNAMIC SMOOTHER

Function and Application Area

On the exterior of the aircraft, skin gaps are filled and surface discontinuities faired in with sealant to provide an aerodynamically smooth and so a turbulence free surface. At the same time the drain of water is improved and the attack of moisture/fluids is prevented.

Work Sequence: Aerodynamic Smoother

1. Remove all defective compound from the repair area and taper the remaining compound in order to produce a scarf joint.
2. Clean and degrease thoroughly surface to which compound is to be applied.
3. Cover the skin adjacent to the recess with masking tape.
4. Apply the compound with a flow gun, or a spatula.
5. Using a spatula, smooth the compound level with the masking tape.
6. Remove the tape immediately after smoothing or leave in place for the curing period. Smooth down the edges of the compound (which tend to lift with the tape) and remove excess compound with a wooden or plastic tool.

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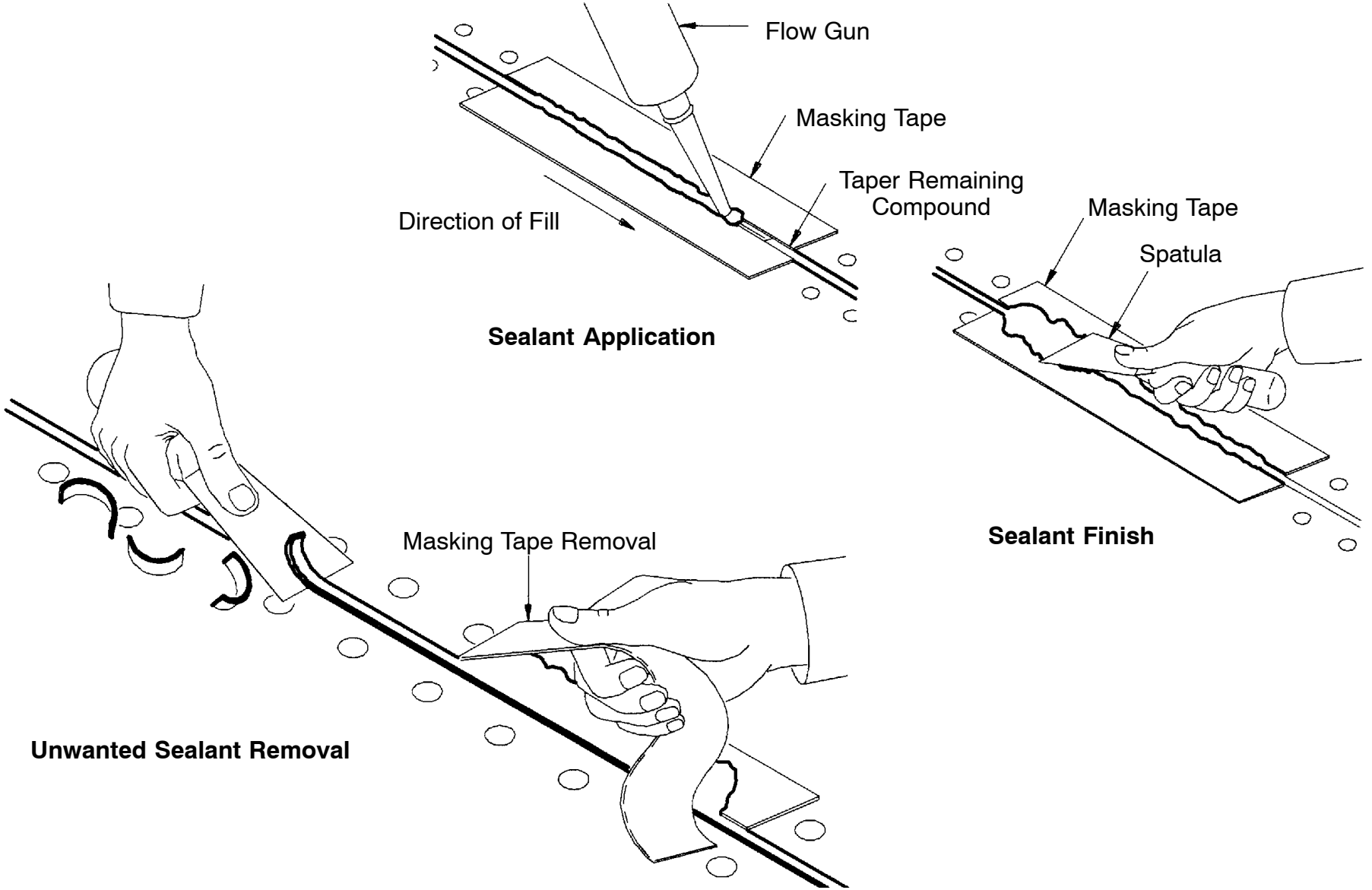


Figure 31 Aerodynamic Smoother

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FASTENER SEAL

General

All fastener sealing is a variation of one of the basic sealing processes.

Wet Installation

- **Flush head:** Apply sealant either to the underside of to the head or the countersink immediately prior to installation.
- **Protruding head:** Apply sealant to the underside of the head immediately prior to installation.

Fillet Sealing

- Treat the overlaying part of a fastener (head/locking head) in such a way with sealant that a cap of sealant is resulting.

Work Sequence: Fastener Seal

- Applying sealant to the fastener or hole at installation. Extruded sealant shall be continuously evident to indicate adequate sealing.
- Applying the sealant to the fastener after installation.
- Filleting around fastener after installation.

Sealing of Fasteners with Metal Seal Covers

1. Fill over 1/2 to 2/3 full of sealant and press cover down over fastener until flange contacts structure.
2. Remove excess sealant from top of seal cover.
3. Fair out sealant around base of cover.

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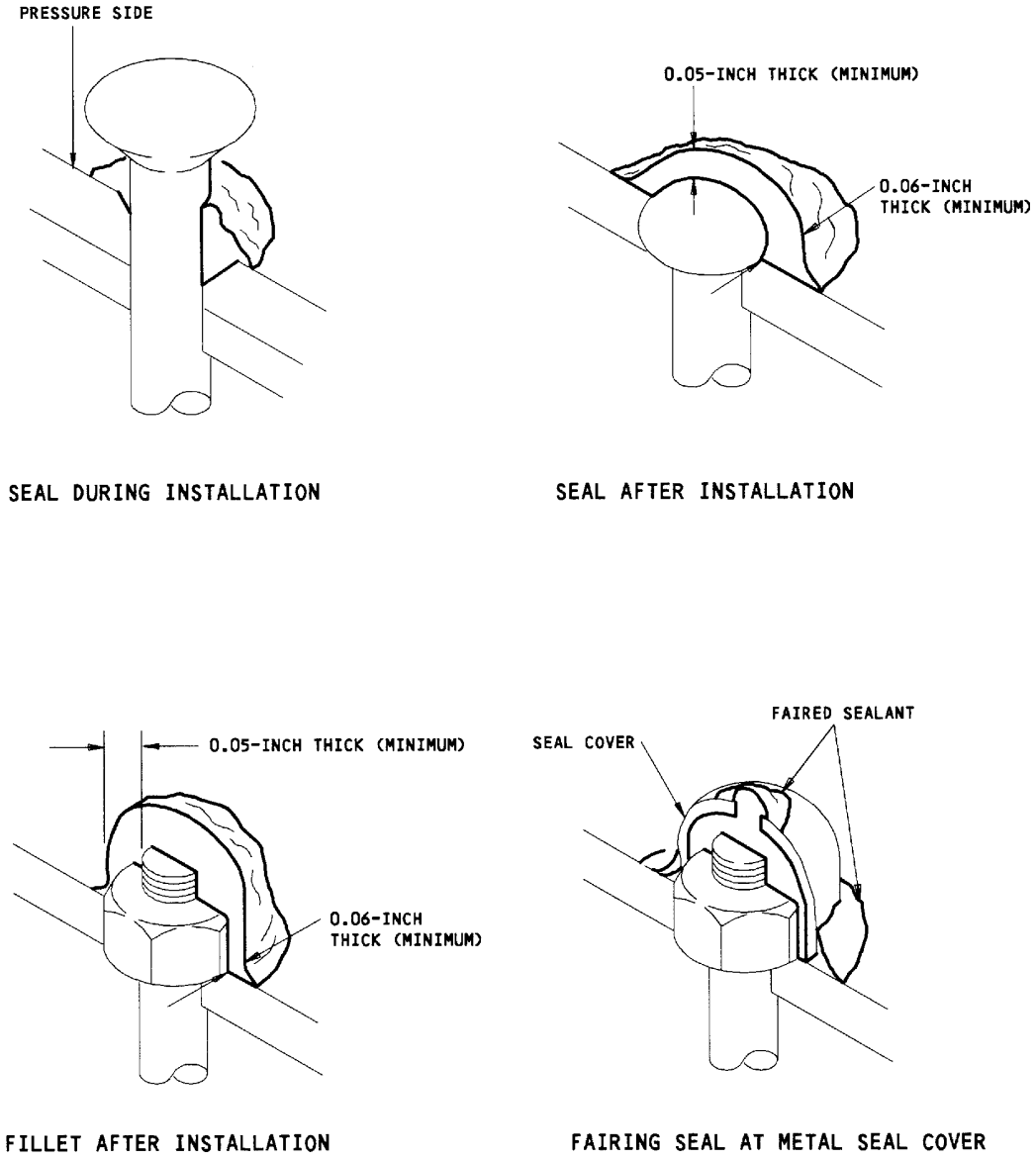


Figure 32 Fastener Seal

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ELECTRICAL SEALS

General

Where required, fillet seal electrical fittings in accordance with procedures described in the fillet sealing section.

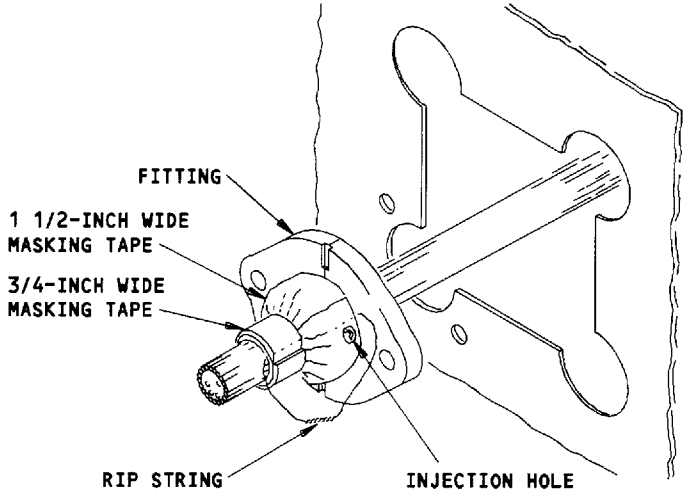
Procedure

- In wire bundle sealing, coat each individual wire with the specified sealant prior to installation.
- Installation must be completed within the sealant application time.
- Sealing of some wire bundles that pass through bulkhead fittings is done according to a special injection method.

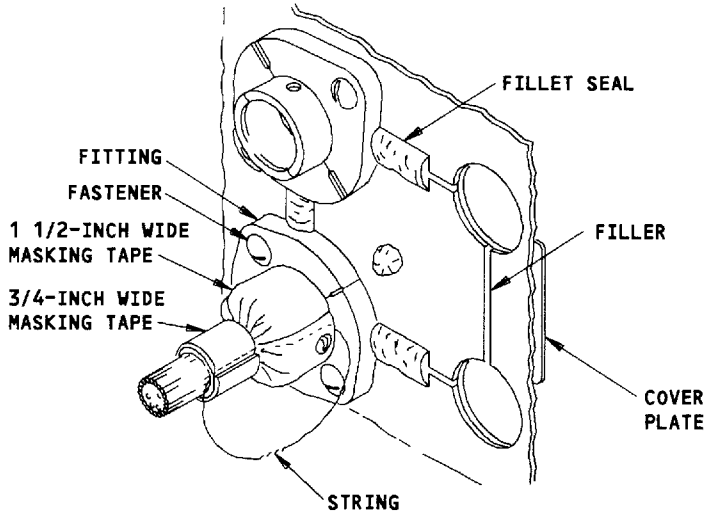
  Wire bundles that pass through bulkheads are routed through special fittings. The fittings and wires are sealed in accordance with manufacturer specifications to prevent leakage of cabin air pressure. The wires are encased in a mould made from tape. Sealant is then injected through a hole to completely encapsulate all the wires.

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BULKHEAD FITTING



INSTALLATION OF BULKHEAD FITTING

Figure 33 Electrical Seal

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Removal of Damaged Sealant

General

When removing damaged sealant it has to be ensured that the damaged area is removed completely. It has to be ensured that only sealant with a good adhesion remains on the structure.

Tools

Sealant removal or cutting tools should be made of hardwood, plastic or metal not harder than the aluminium structure to minimize the possibility of damaging the structure.

When working with aluminium structures, especially the aluminium skin of the fuselage, only cutting tools out of soft plastic are allowed.

Tools out of hard materials and hard metals (like steel) are not allowed due to a possible damaging of the structure (grooves)! Knifes, blades and metal spatulas must not be used.

Repair of damaged Sealing Compound

Remove all defective compound from the repair area and taper the remaining compound in order to produce a scarf joint. The tapered surface allows a good adhesion of the new sealing compound.

Before bringing on the new sealant the surface must be absolutely clean and degreased!

Attack by Expanding Agents

After paint stripping with stain, paint softeners or similar ”aggressive” expanding agents **all affected sealings in this area must** be renewed!

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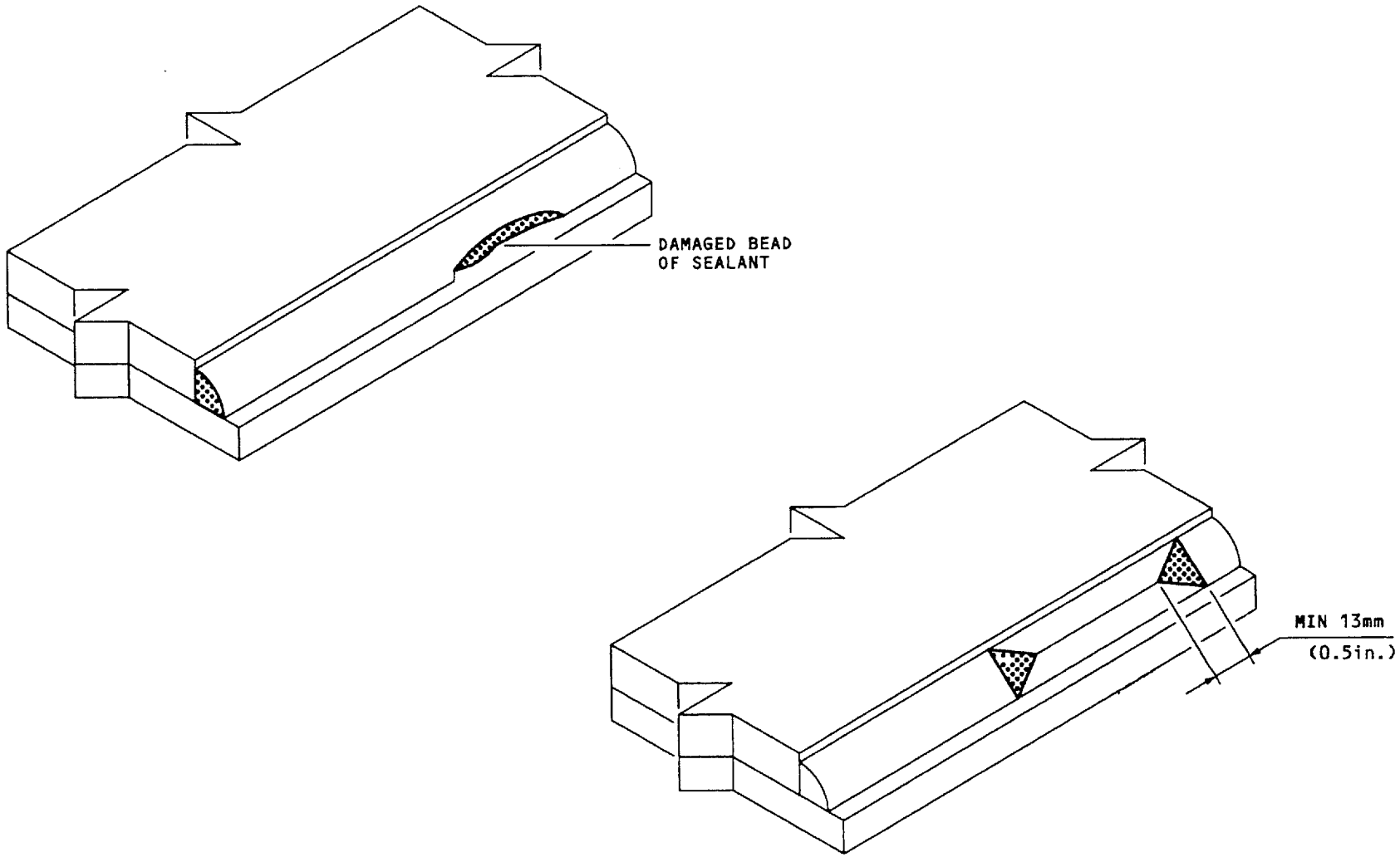


Figure 34 Removal of Damaged Sealing Compound

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Treatment and Safety Instructions for Handling Sealing Compounds and Solvents

General Treatment

Since a good adhesion of the sealer can only be achieved on dry surfaces it is one of the highest importance, that the cooled down aircraft is not treated immediately, but has time to adapt the environmental temperature because of possible condensation on the surface. This is also valid for the sealer.

After applying the sealer it has to be cured entirely before any coats or loads are applied on the sealing.

Environmental Temperatures and Humidity

If temperature and humidity is lower than normal the curing time is increased. If the temperature and the humidity is higher than normal the curing time is reduced.

The best curing results of most of the sealants are achieved at 25°C (+/- 1°C) with good ventilation.

If the temperature is lower than 10°C or higher than 60°C no sealing compound must be applied.

The relative humidity must always be known during curing the sealing compounds; it should be between 45% and 55% (+/-5%).

If the rel. humidity is less than 40% the curing time is increased in such a way, that it can be necessary to let humid warm air with a temperature of max. 50°C circulate around the treated surface and under some conditions to preheat the working area.

WARNING: THE USAGE OF WARM AIR CAN BE DANGEROUS IF THE SAFETY INSTRUCTIONS ARE NOT OBSERVED ENTIRELY. DO NOT TURN THE HOT-AIR BLOWER ON OR OFF IF THE INLET HOSE IS LOCATED IN A FUEL TANK!

SAFETY INSTRUCTIONS

General Safety Instructions

Generally all manufacturer advices have to be read attentively and followed entirely, since otherwise an endangering of persons and a degradation of the sealing function can occur.

Here general advices are described which have to be followed when working with sealing compounds:

- Cleaning agents with solvents have to be kept away from heat sources, fire or sparks, to prevent a possible explosion.
- Avoid contact of skin, eyes and clothes with solvents. Use eye protection and if needed mechanical ventilation.
- When suing solvents in closed rooms a respiratory protection is needed. The breathing of solvent fumes, skin and eye contact are dangerous.
- For cleaning, use only wiping cloths and solvents which are described in the particular process specifications or in the instructions in the maintenance manual.
- Mix the sealing compound in a well ventilated room. Do not mix sealing compounds inside the airplane. Avoid eye and skin contact with the sealing compound. Use rubber gloves and a respiratory protection. Sealing compounds are poisonous and can lead to personal injury.
- Parts of some sealing compounds are poisonous and can be absorbed by the skin. Skin contact must be avoided. If necessary, gloves must be worn. When skin contact with sealing compound does occur remove the sealant and wash the area. Never smooth sealing lines with the fingers but use always a tool.
- Most sealing compounds are highly flammable in the unmixed form.
- Cleaning and ventilation of the fuel tanks according to chapter 28 of the aircraft maintenance manual, before getting into the fuel tanks. Fuel fumes are dangerous and explosive.

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SPECIFICATION	CLASS	MATERIAL DESCRIPTION	USAGE	APPLICATION TIME (HOURS) [B]	SQUEEZE-OUT LIFE (HOURS) [B]	CURE TIME (HOURS) [B]	SUPPLIER DESIGNATION [D]
NONE	---	ONE-PART SILICONE SEALANT RESISTANT TO BMS 3-11 HYDRAULIC FLUID	FILLET SEALS	⇨		24	SILASTIC 731 RTV OR RTV 174
BMS 5-79 SUPERSEDED BY BMS 5-95 SEE FIG. 2	B-1/2	TWO-PART SEALANTS	FAYING, PREPACK, INJECTION, AND FILLET SEALS	1/2	1/2	24	PRO-SEAL 898 B-1/2 GC-414 B-1/2
	B-2		FAYING, PREPACK, INJECTION, FILLET, AND BRUSHABLE [A] SEALS	2	6	48	PRO-SEAL 898 B-2 GC-414 B-2
	B-4		FAYING, PREPACK INJECTION, AND FILLET SEALS	4		90	PRO-SEAL 898 B-4 GC-414 B-4
BMS 5-32	B-2	TWO-PART SEALANT	FAYING, PREPACK, INJECTION, AND FILLET SEALS	2		72	GC-502 PR 1224 CS3200 B-2

NOTES

[A] FOR BRUSHABLE SEALANT (CLASS A-2) ADD 12% MEK/TOLUENE (50%/50% BY VOLUME) MAX BY WEIGHT TO PREMIXED CLASS B-2 SEALANT.

⇨ [B] AT 77 ±2°F (25 ±1°C) AND 50 ±5% RELATIVE HUMIDITY

[C] CURE TIME AT 120 ±5°F (49 ±3°C) IS 4 HOURS.

[D] SEE 51-30-03 FOR SOURCES OF MATERIALS.

[E] 72 HRS AT 70°F (21.1°C) TO 90°F (32.2°C), 4 HRS AT 100°F (37.8°C), OR 1 HR AT 140°F (60°C)

[F] THE CURE OF BMS 5-63 IS INHIBITED BY BMS 10-11 AND BMS 10-20 PRIMERS AND BY BMS 5-26, BMS 5-79, AND BMS 5-95 SEALANTS.

[G] THE APPLIED PRIMER SHALL BE THICK ENOUGH TO HAVE A CHALKY SURFACE WHEN DRIED. ALLOW A MINIMUM OF 1 HOUR AND A MAXIMUM OF 2 HOURS FOR PRIMER TO DRY PRIOR TO APPLICATION OF SEALANT COMPOUND.

[H] USE PR-1826 ADHESION PROMOTER ON ALL SUBSTRATES. ALLOW THE PRIMER TO CURE FOR 1/2 TO 3 HOURS BEFORE APPLYING SEALANT.

[I] USE PR-186 ADHESION PROMOTER ON POLYSULFIDE SEALANTS. ALLOW THE PRIMER TO CURE FOR 1/2 TO 3 HOURS BEFORE APPLYING SEALANT.

Figure 35 Treatment Instructions e.g Temperature/Humidity

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Mixing of Sealant Compounds

General

Two-part sealants must be completely mixed. If sealant is completely mixed, color will be uniform throughout. A streaked appearance is evidence of incomplete mixing. Incomplete mixing may affect cure and performance properties of the sealant.

ATTENTION: Before starting the mixing process make sure that the activator and the base compound is not over-aged and from the same repair kit or batch.

Hand Mixing

For special jobs, it may occasionally be necessary to hand-mix a small quantity of sealant.

To hand-mix sealant kits, proceed as follows:

1. Check label to verify that you have the correct material and that the expiration data has not been exceeded.
2. Stir accelerator thoroughly until all solids are dispersed and a smooth, uniform material is obtained (accelerator may be either a liquid or a paste).
3. Add the entire accelerator to the base container and mix thorough, using a spatula or other suitable tool until a uniform blend with no evidence of streaking is obtained. Verify that there is no unmixed base or accelerator in the container.

Machine Mixing

The sealing compound can also be mixed by specialized machines. Machine mixing provides the most reliable, consistent material and is the only way that high-volume usage requirements can be met.

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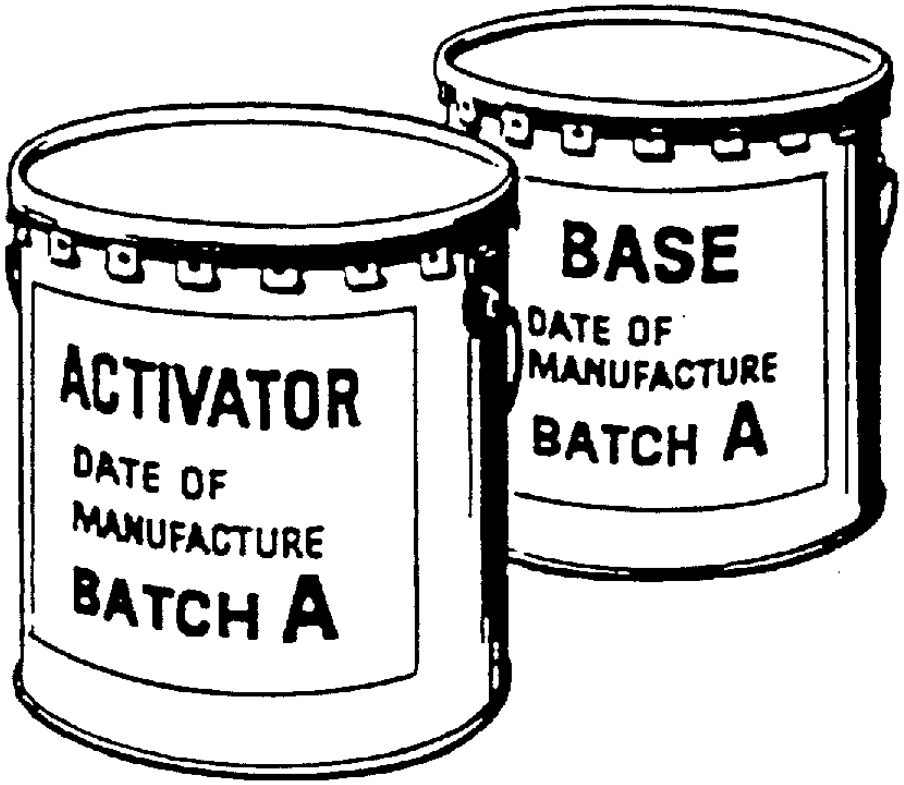


Figure 36 Mixing of Sealant Compounds

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MIXING OF SEALING COMPOUNDS (CONT'D)

Cartridge Hand Mixing

The following mixing instructions are only for the SEMKIT two-part material cartridge injection type.

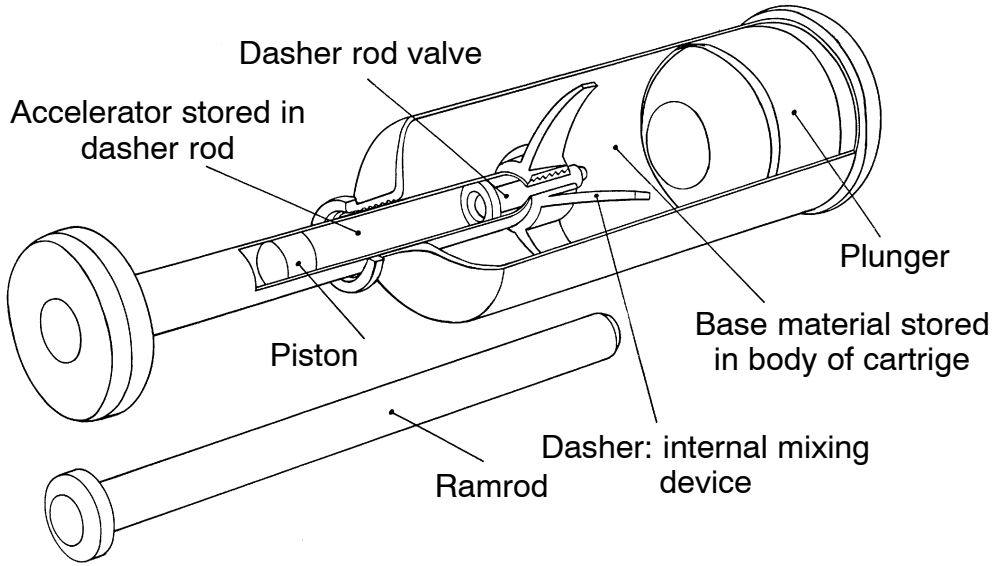
1. Wear safety glasses.
2. Hold cartridge, grasp dasher rod and pull back approximately one inch.
3. Insert ramrod into hollow of dasher rod, break piston loose and inject about 1/3 of the contents into the cartridge.

ATTENTION: Use even pressure, do not use force, tap, pound or jolt ramrod if piston does not break loose readily.

4. Repeat steps 2 and 3 until all of the contents of the rod are emptied into the cartridge. Then remove ramrod.
5. Hand mix: mix material for the total number of 50 strokes; a stroke is one complete in-and-out cycle. Hold cartridge and rotate dasher rod 90° in a spiral clockwise motion with each stroke.
6. Remove bottom cap.
7. Pull dasher rod back to neck of cartridge, grasp cartridge firmly at neck, unscrew dasher rod and remove.
8. Screw nozzle into cartridge, insert into Semco Extrusion Gun and use as required. For hand extrusion, press used dasher rod against plunger to force material from cartridge.

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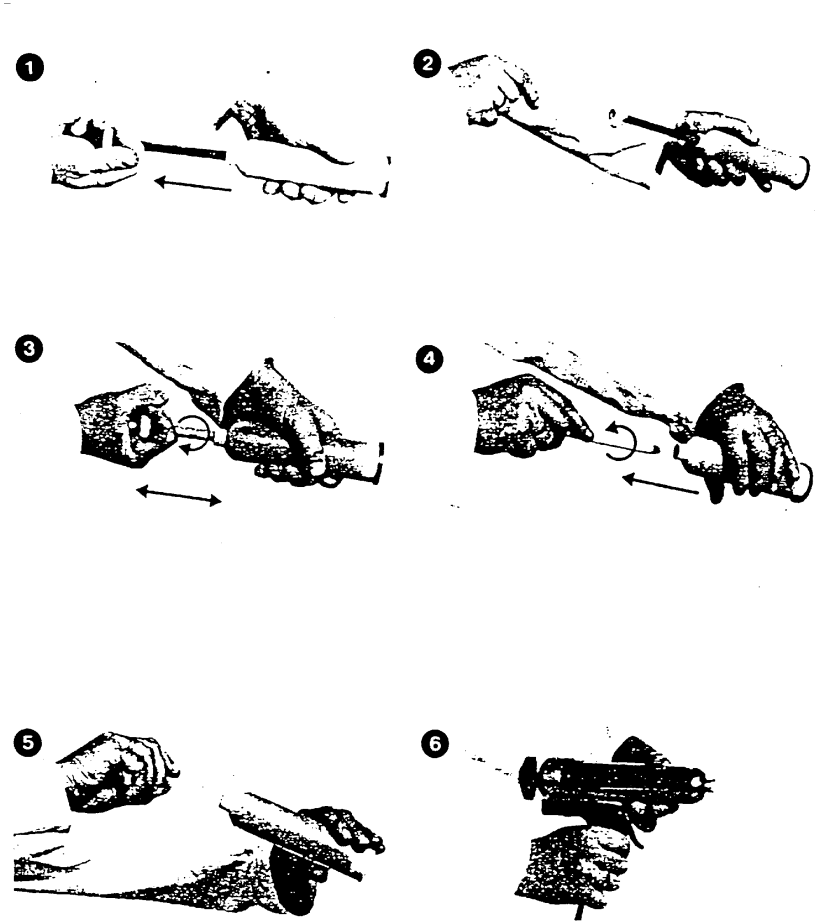


Figure 37 Semkit Cartridge and Mixing by Hand

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Cleaning Processes

General

The importance of cleaning cannot be over emphasized. Sealant will not adhere to any surface that is contaminated. It is made a difference between preliminary and final cleaning.

Preliminary Cleaning

The preliminary cleaning corresponds to the removal of possible heavy dirt like e.g. swarf and other loose material on the surface.

- Remove loose materials with a vacuum cleaner
- Remove all heavy soils and contaminants, using a stiff-bristled brush and solvent.
- Cheese-cloth or other approved wipers may be used if desired for light dirt instead of a brush.

Final Cleaning

The final cleaning has to be done directly prior to the application of the sealant.

- Dampen clean wiping material with solvent and wipe the area to be sealed.
- Before the solvent evaporates, wipe the area again with clean, dry wiping material. Repeat these steps until there is no visible contamination on the wipers.
- Ventilate the area until all solvent is evaporized.
- If the total area to be cleaned is large, do not try to clean it in one operation. This will allow the solvent to evaporate and wipers to become contaminated. Clean smaller areas progressively until the total area has been cleaned.

ATTENTION: For all cleaning operations, use only those wiping materials and solvents that are approved by the applicable process specification. Solvents are flammable and/or toxic.

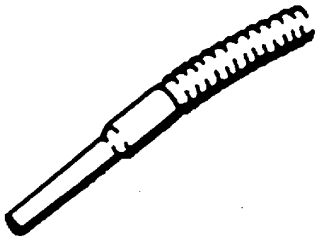
Cleaning Equipment

The most commonly-used cleaning equipment for sealant is as follows:

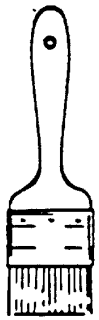
- **Vacuum Cleaner**. The vacuum cleaner removes aluminium swarf and other debris from areas to be sealed.
- **Brushes**. Brushes are used for removing loose material and for preliminary solvent cleaning to remove heavy soiling. Stencil brushes or trimmed paint brushes with short stiff bristles are best.
- **Cheese-Cloth** (or other approved wiping materials). Wipers are used for preliminary and final solvent cleaning of areas to be sealed.
- **Solvents**. These are used for cleaning structure prior to sealing. Solvents used for cleaning must be approved by the applicable sealing process specification.

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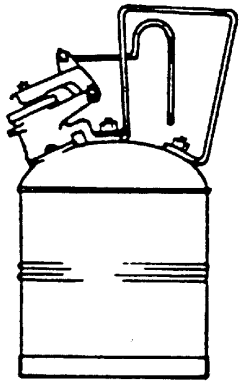
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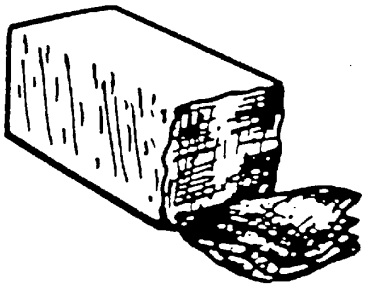
VACUUM CLEANER



BRUSHES



SOLVENT SAFETY CAN



CHEESE CLOTH



PLASTIC SQUEEZE BOOTLES

Figure 38 Cleaning Equipment

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Sealant Application Tools

Sealant Gun

Initial application of sealants is generally made with a standard air−operated sealant gun. A sealant-filled cartridge is inserted into the barrel of the gun. The sealant is contained by a plunger at the upper end of the cartridge and a cap at the reduced diameter lower end. After removal of the cap, a nozzle of the desired configuration is attached to the lower threaded end of the cartridge. Sealant is extruded when the trigger is depressed to open an air valve, allowing pressure to be applied against the plunger.

Nozzles

Nozzles are available in assorted sizes and shapes for various sealing requirements and are made of the same type of plastic as the cartridge. Some types of nozzles may be cut at the tip to provide a more convenient angle or diameter for application of sealant. Multiple-orifice nozzles are available for more rapid spreading of sealant over relatively large areas for faying surface sealing.

Rollers

Both metal and rubber rollers are available to spread sealants for faying surface sealing. Rubber rollers of approximately 50 Shore “A” durometer hardness are superior and recommended for use. These rollers do a better job of spreading the sealant and are effective in keeping it out of previously drilled fasteners holes.

Brushes

Brushes are available in different sizes and forms and are suitable for a continuous distribution and brushing of sealing compound in local application like e.g. fastener seals.

Scrapers

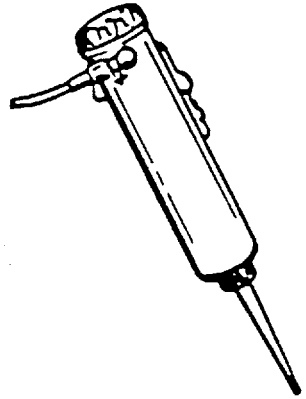
Plastic scrapers are also to spread sealant over a surface or to press the sealant into grooves and to smoothen it. Scrapers are available in different sizes and forms and are also recommended for situations where using a roller would be awkward because of access or other considerations.

Mirrors

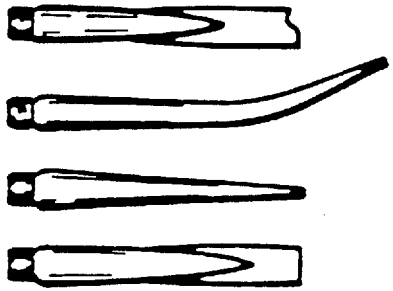
Occasionally, cleaning and sealing operations must be accomplished in areas that are out of direct line of sight. In such situations, a swivel-handled mirror provides the visibility needed to perform the job successfully.

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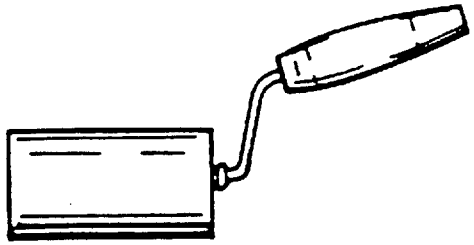
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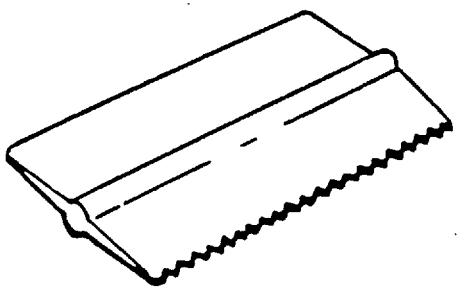
SEALANT GUN



NOZZLES



ROLLERS



SCRAPER

Figure 39 Sealant Application Tools

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GEN. REPAIR– & SRM METHODS, AGING–, FATIGUE–, CORROSION DETECTION

General Repair Techniques

Damage Classification

After cleaning and investigating the damage and surrounding area, it must be classified into one of the following categories:

- Allowable Damage
- Repairable Damage
- Non Repairable Damage

Allowable Damage

Allowable damage is defined as damage which is slight or of little significance, and is unlikely to be of sufficient severity to propagate further damage in the immediate vicinity.

ATTENTION: Allowable does not mean that repair is unnecessary. For example, scratches and burring are included in this category, and it is necessary to remove rough and sharp edges and smooth out the damage. Additionally, any damage to surface coatings and/or protective treatment must be repaired.

Repairable Damage

Damage which exceeds the limits must be repaired by removing the damaged area of a structural component and inserting or attaching a reinforcing piece. These specific repairs are to be found in each chapter of the SRM.

Non Repairable Damage

Non-repairable damage is defined as damage to structural components which cannot be repaired and where replacement of the complete component is recommended as a repair is not practical or economical.

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Structural Repair Manual (Boeing)

MANUALS GENERAL

Manual Introduction

The structuring of manuals is done according to **A**ir **T**ransport **A**ssociation of America (ATA) Specification No.100:

„Specifications for Manufacturers Technical Data“.

The manuals contain all necessary information for maintaining and repairing aircraft and aircraft components.

Customized Manuals

The manuals differ depending on the customers configuration, that means they are aircraft type and customer related (“Customized“), like e.g.:

- Aircraft Maintenance Manual (AMM)
- Wiring Diagram Manual (WDM)
- Illustrated Parts Catalogue (IPC)

Non Customized Manuals

Other manuals are universal, that means they are aircraft type but not customer related (“Non-Customized“), like e.g.:

- Structural Repair Manual (SRM)
- Fault Isolation Manual (FIM)

Manuals

Furthermore there are manuals, which are nor customer nor aircraft type related, like e.g.:

- Component Maintenance Manual (CMM)

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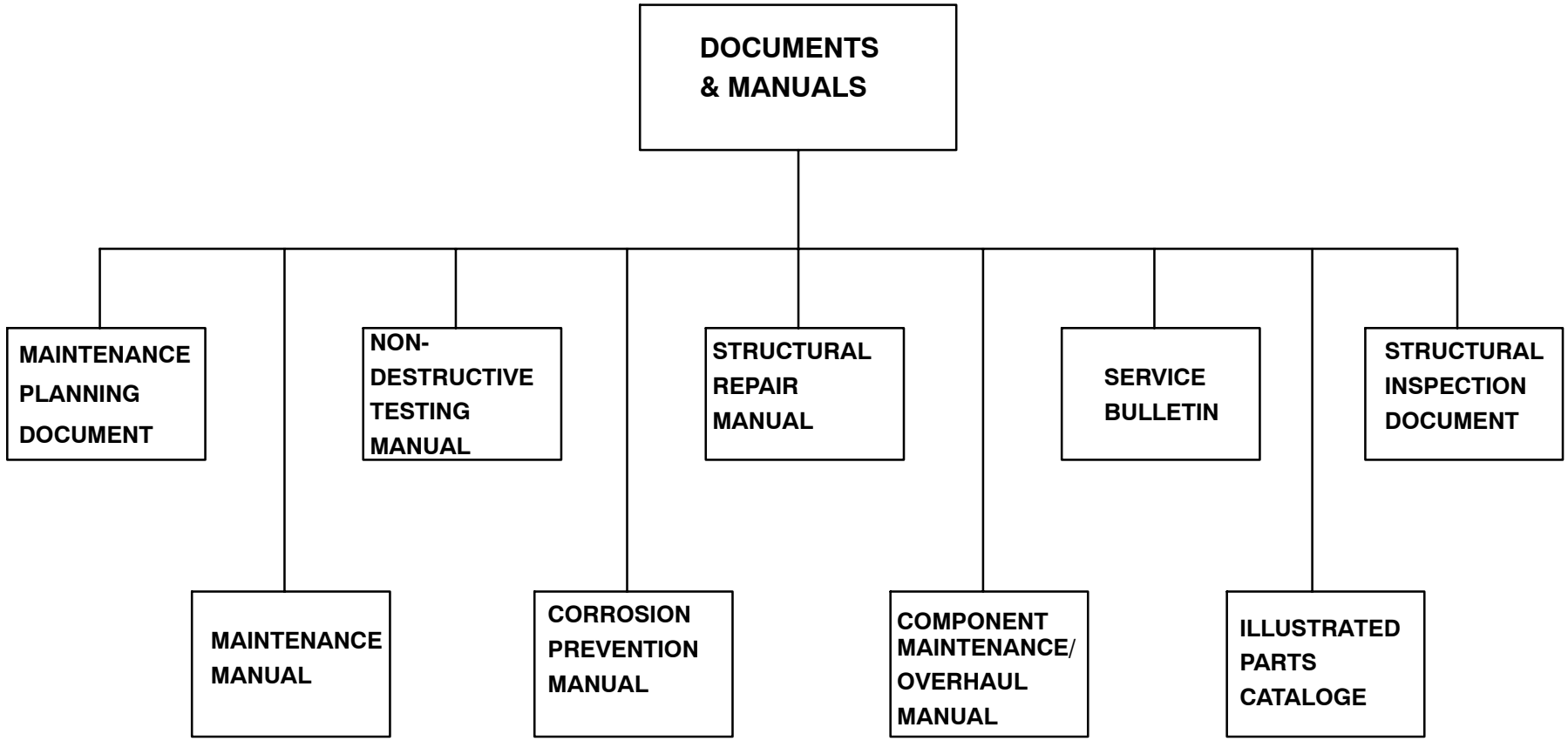


Figure 40 Manual Overview

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ATA Chapter Arrangement

General

For a clear overview the manuals are arranged in *chapters* and *groups of chapters*, to ensure an easy finding of the searched information:

- **Group** **Chapter-No.**
  - **General:** **Chapter 5 to 12**
  - **Systems:** **Chapter 20 to 49**
  - **Structure:** **Chapter 51 to 57**
  - **Engine:** **Chapter 71 to 80**

ATA 100 (Chapter-No. and Title)

AIRCRAFT

5 Time Limits
6 Dimensions and Areas
7 Lifting and Shoring
8 Leveling and Weighing
9 Towing and Taxing
10 Parking and Mooring
11 Required Placards
12 Servicing
13 Processes And Procedures

AIRFRAME SYSTEMS

20 Standard Practices Airframe
21 Air Conditioning
22 Autopilot
23 Communications
24 Electrical Power
25 Equipment and Furnishings
26 Fire Protection
27 Flight Controls
28 Fuel
29 Hydraulic Power
30 Ice And Rain Protection
31 Instruments
32 Landing Gear
33 Lights
34 Navigation
35 Oxygen
36 Pneumatic
37 Vacuum
38 Water and Waste
39 Electronic Panels And Multipurpose
49 Airborne Aux. Power

STRUCTURES

51 Structure General
52 Doors
53 Fuselage
54 Nacelles and Pylons
55 Stabilizers
56 Windows
57 Wings

PROPELLERS/ROTOR

60 Propellers and Rotors Standard Practice
61 Propellers
65 Rotors

POWER PLANT

70 Engine Standard Practices
71 Power Plant General
72 Engines
73 Engine and Fuel Control

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74 Ignition
75 Air
76 Engine Controls
77 Engine Indicating
78 Exhaust
79 Oil
80 Starting
81 Turbines

Manual Revisions

Determination of Revision Status

Directives and Instructions normally consist out of several pages. The document can be present as:

- Loose page portfolio,
- Microfilm
- digital format (CD or intranet/internet)

These documents are revised in certain periods - generally all 3 or 6 months.

The actual revision number can in case of a portfolio or a microfilm be derived from the overview list of the record of revisions (generally in an extra folder). If a manual is released prior to the publishing of the overview list always the highest revision number is valid.

- The revision number inside the manual can be found in the front, prior to every ATA chapters in the section:
  - „FRONT MATTER“ under „TRANSMITTAL LETTER“.

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BOEING

747-400
STRUCTURAL REPAIR MANUAL

Revision No. 60
Feb 20/2005

To: All holders of this Boeing Document D634U102

Attached is the current revision to the Boeing 747-400 Structural Repair Manual.

The Structural Repair Manual (SRM) is furnished either as a printed manual, on microfilm, or digital products, or any combination of the three. This revision replaces all previous microfilm cartridges or digital products. All microfilm and digital products are reissued with all obsolete data deleted and all updated pages added.

For printed manuals, changes are indicated on the List of Effective Pages (LEP). The pages which are revised will be identified on the LEP by an R (Revised), A (Added), O (Overflow, i.e. changes to the document structure and/or page layout), or D (Deleted). Each page in the LEP is identified by Chapter-Section-Subject number, page number and page date.

Pages replaced or made obsolete by this revision should be removed and destroyed.

ATTENTION

IF YOU RECEIVE PRINTED REVISIONS, PLEASE VERIFY THAT YOU HAVE RECEIVED AND FILED THE PREVIOUS REVISION. BOEING MUST BE NOTIFIED WITHIN 30 DAYS IF YOU HAVE NOT RECEIVED THE PREVIOUS REVISION. REQUESTS FOR REVISIONS OTHER THAN THE PREVIOUS REVISION WILL REQUIRE A COMPLETE MANUAL REPRINT SUBJECT TO REPRINT CHARGES SHOWN IN THE DATA AND SERVICES CATALOG.

TRANSMITTAL LETTER

Page 1
Feb 20/2005

D634U102

Figure 41 Transmittal Letter

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Temporary Revisions

General

Important revisions which have to be in effect between the normal revision intervals, are published as Temporary Revisions.

They are attached to the documentation or in case of a microfilm provided in an extra folder (yellow page).

Generally there are overview lists concerning temporary revisions of a document.

- Is there one temporary revision for a work task, the revision is the effective document for the accomplishment of the work.
- Is there no temporary revision, the common documentation must be used.

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BOEING
747-400
STRUCTURAL REPAIR MANUAL
AFT CARGO DOOR CUTOUT - SKIN PANEL AND BEAR STRAP CRACK REPAIR
AT THE FORWARD UPPER CORNER

TEMPORARY REVISION 53-51

FILING INSTRUCTIONS

For the printed manual, file this temporary revision adjacent to the page(s) affected. Record the filing of this temporary revision in the Temporary Revision Record.

For the microfilm supplement, file this temporary revision in sequence by ATA number. Mark the microfilm cartridge to indicate that it has been changed by temporary revision(s).

This Temporary Revision will be incorporated in the revision dated Oct 20/03.

Revision reason: Added Alternative Method of Compliance data and added chamfer on repair doublers.

This temporary revision furnishes an advance copy of the following page(s) which supersede any previously issued page(s). The information thereon is to be used until this temporary revision is either incorporated or rescinded.

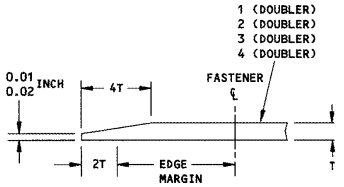
Chapter-Section-Subject	Page No.	Date	Code
53-60-01	209-213, 216-218	Oct 20/03	400.1

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W52488

53-60-01
Page 1 of 9
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BOEING
747-400
STRUCTURAL REPAIR MANUAL



DETAIL IV [G]

CATEGORY B INSPECTION REQUIREMENTS			
INSPECTION THRESHOLD	REPEAT INSPECTIONS		
	METHOD	INTERVAL	REFERENCE
15,000 FLIGHT CYCLES AFTER REPAIR INSTALLATION	DETAILED VISUAL	3,000 FLIGHT CYCLES	
NOTE: DETAILED VISUAL INSPECT THE SKIN PANEL, BEAR STRAP, STA 1810 EDGE FRAME OUTER CHORD AND UPPER SILL OUTER CHORD FROM THE INSIDE OF THE REPAIR AREA. DETAILED VISUAL INSPECT THE REPAIR PARTS AND THE SKIN AT THE EDGE OF THE REPAIR PARTS FROM THE OUTSIDE OF THE REPAIR AREA.			

TABLE III

Aft Cargo Door Cutout - Skin Panel and Bear Strap Crack
Repair at the Forward Upper Corner
Figure 204 (Sheet 10)

52496

53-60-01
400.1 Page 218
Oct 20/03

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TR 53-51 Page 9 of 9 Aug 15/03

Figure 42 Temporary Revisions

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Applicability

Determination of Effective Pages

Every page of the document has a publishing date in the lower right edge. Every page is individually mentioned in the list of effective pages of the particular document.

For checking the effectivity of a page the publishing date of the particular page has to be compared with the publishing date that is written down in the list of effective pages for the particular side.

- Both dates must be the same, only then the particular page is effective!
  - The list of effective pages for the B747−400 SRM can be found prior to the corresponding ATA chapter, just as well as prior to the „Front Matter“ in the section „EFFECTIVE PAGES“.

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BOEING

747-400
STRUCTURAL REPAIR MANUAL

CHAPTER 52
DOORS

Subject/Page	Date	Subject/Page	Date	Subject/Page	Date
52-30-02 ALLOWABLE DAMAGE 1		52-40-01 IDENTIFICATION 3		52-40-01 REPAIR 2	
101	Oct 20/2004	1	Oct 20/2004	201	Oct 20/2004
102	Oct 20/2004	2	BLANK	202	Oct 20/2004
103	Oct 20/2004	52-40-01 IDENTIFICATION 4		52-40-01 REPAIR 3	
104	Oct 20/2004	1	Oct 20/2004	201	Oct 20/2004
105	Oct 20/2004	2	BLANK	202	Oct 20/2004
106	Oct 20/2004	52-40-01 IDENTIFICATION 5		52-40-01 REPAIR 4	
107	Oct 20/2004	1	Oct 20/2004	201	Oct 20/2004
108	BLANK	2	BLANK	202	Oct 20/2004
52-30-02 REPAIR 1		52-40-01 ALLOWABLE DAMAGE 1		52-40-01 REPAIR 5	
201	Oct 20/2004	101	Oct 20/2004	201	Oct 20/2004
202	Oct 20/2004	102	Oct 20/2004	202	Oct 20/2004
203	Oct 20/2004	103	Oct 20/2004	203	Oct 20/2004
204	Oct 20/2004	104	Oct 20/2004	204	BLANK
205	Oct 20/2004	52-40-01 ALLOWABLE DAMAGE 2		52-40-01 REPAIR 6	
206	BLANK	101	Oct 20/2004	201	Dec 20/2004
52-30-90 IDENTIFICATION 1		102	Oct 20/2004	202	Dec 20/2004
1	Oct 20/2004	103	Oct 20/2004	203	Dec 20/2004
2	Oct 20/2004	104	Oct 20/2004	204	Dec 20/2004
52-30-90 IDENTIFICATION 2		52-40-01 ALLOWABLE DAMAGE 3		52-40-02 IDENTIFICATION 1	
1	Oct 20/2004	101	Oct 20/2004	1	Oct 20/2004
2	BLANK	102	Oct 20/2004	2	BLANK
52-30-90 IDENTIFICATION 3		103	Oct 20/2004	52-40-02 IDENTIFICATION 2	
1	Oct 20/2004	104	Oct 20/2004	1	Oct 20/2004
2	BLANK	52-40-01 ALLOWABLE DAMAGE 4		2	BLANK
52-30-90 ALLOWABLE DAMAGE 1		101	Oct 20/2004	52-40-02 IDENTIFICATION 3	
101	Oct 20/2004	102	Oct 20/2004	1	Oct 20/2004
102	Oct 20/2004	103	Oct 20/2004	2	BLANK
103	Oct 20/2004	104	Oct 20/2004	52-40-02 IDENTIFICATION 4	
104	Oct 20/2004	52-40-01 ALLOWABLE DAMAGE 5		1	Oct 20/2004
105	Oct 20/2004	101	Oct 20/2004	2	BLANK
106	Oct 20/2004	102	Oct 20/2004	52-40-02 IDENTIFICATION 5	
107	Oct 20/2004	103	Oct 20/2004	1	Oct 20/2004
108	BLANK	104	Oct 20/2004	2	BLANK
52-40-01 IDENTIFICATION 1		52-40-01 REPAIR GENERAL		52-40-02 IDENTIFICATION 6	
1	Oct 20/2004	O 201	Feb 20/2005	1	Oct 20/2004
2	BLANK	202	BLANK	2	BLANK
52-40-01 IDENTIFICATION 2		52-40-01 REPAIR 1		52-40-02 ALLOWABLE DAMAGE 1	
1	Oct 20/2004	201	Oct 20/2004	101	Oct 20/2004
2	BLANK	202	Oct 20/2004	102	Oct 20/2004

A = Added, R = Revised, O = Overflow, D = Deleted

52-EFFECTIVE PAGES

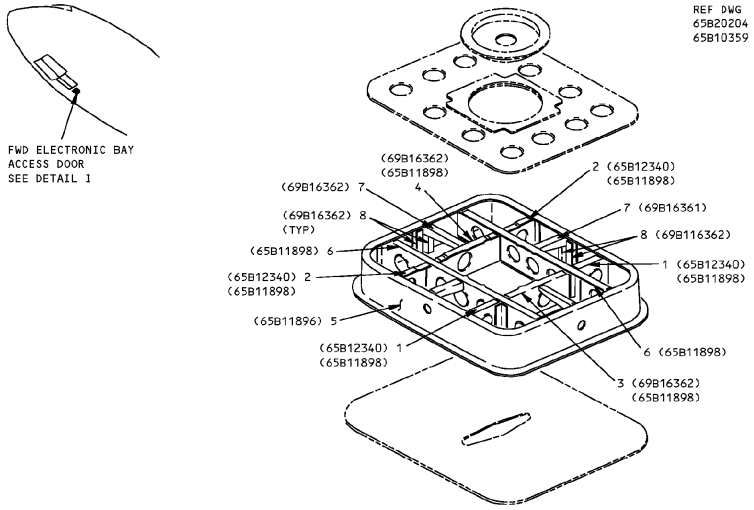
Page 3
Feb 20/2005

D634U102

BOEING

747-400
STRUCTURAL REPAIR MANUAL

IDENTIFICATION 1 - FORWARD ELECTRONIC BAY ACCESS DOOR STRUCTURE



DETAIL I

ITEM	DESCRIPTION	GAGE	MATERIAL	EFFECTIVITY
1	BEAM			
	CHORD		BAC1489-43 CLAD 2024-T42	
	WEB	0.032	2024-T42	
2	BEAM			
	CHORD		BAC1489-64 CLAD 2024-T42	
	WEB	0.032	CLAD 2024-T42	
3	BEAM			
	CHORD		BAC1489-89 CLAD 2024-T42	
	WEB	0.032	CLAD 204-T42	
4	BEAM			
	CHORD		BAC1489-235 CLAD 2024-T42	
	WEB	0.032	CLAD 2024-T42	
5	FRAME	0.050	CLAD 2024-T42	
6	BEAM			
	CHORD	0.032	CLAD 2024-T42	
	WEB	0.032	CLAD 2024-T42	
7	CHANNEL		BAC1493-131 CLAD 2024-T3	
8	CHANNEL		BAC1493-481 CLAD 2024-T3	

LIST OF MATERIALS FOR DETAIL I

Forward Electronic Bay Access Door Structure Identification
Figure 1

IDENTIFICATION 1
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Figure 43 Effective Pages

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Aircraft Effectivity

General

Aircraft and aircraft components of the same aircraft type can be in different modification states.

With the help of comparing the effectivity it must be ensured that the present document is applicable for the concerned aircraft and/or aircraft modification state at all.

- This comparison must be done *prior* to any work!

SRM Effective Aircraft

In the prefix of the documentation in the section „FRONT MATTER“ a reference list can be found under „EFFECTIVE AIRCRAFT“ which lists all aircraft for which the present manual is effective.

This list sets a reference between aircraft sign, line number (also known as ’CUM LINE NUMBER’) and aircraft version.

These data are needed at a later date again.

SRM Effectivity

The checking of the effectivity inside the Boeing structural repair manual is done via the (Cum) LINE NUMBER or via the differentiation between the different versions, in the case of the B747−400 e.g.:

- **B**-Version for
  - **Basic** Version
- **BC**-Version for
  - **Basic Combi** Version.

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BOEING

747-400
STRUCTURAL REPAIR MANUAL

Model-Series	Operator		Manufacturer			Registration Number
	Identification Code	Effectivity Code	Block Number	Serial Number	Line Number	
747-475B	ACN	381	RT701	24883	823	C-GMWW
747-446B	JAL	079	RT649	24885	824	JA8079
747-446B	JAL	080	RT650	24886	825	JA8080
747-438B	QAN	OJI	RT559	24887	826	VH-OJI
747-444B	SAA	001	RT781	24976	827	ZS-SAV
747-436B	BAB	NLP	RT486	24058	828	G-BNLP
747-436B	BAB	NLR	RT487	24447	829	G-BNLR
747-4B5B	KAL	004	RT574	24621	830	HL7481
747-412B	SIA	008	RT508	24227	831	9V-SMH
747-481B	ANA	026	RT776	24920	832	JA8096
747-4D7B	TII	003	RT693	24993	833	HS-TGK
747-467B	CAT	HOU	RT456	24925	834	B-HOU
747-438B	QAN	OJJ	RT560	24974	835	VH-OJJ
747-428B	AFA	201	RT711	24969	836	F-GITA
747-475B	ACN	382	RT702	24895	837	N895NC
747-412B	SIA	009	RT509	24975	838	N223BA
747-47CB	JAG	002	RT682	24731	839	20-1102
747-433BC	ACN	341	RT101	24998	840	C-GAGL
747-436B	BAB	NLS	RT488	24629	841	G-BNLS
747-436B	BAB	NLT	RT489	24630	842	G-BNLT
747-428B	AFA	202	RT712	24990	843	F-GITB
747-446D	JAL	083	RU801	25213	844	JA8083
747-430B	DLH	007	RT437	25045	845	D-ABVH
747-430BC	DLH	105	RT045	24966	846	D-ABTE
747-430B	DLH	008	RT438	25046	847	D-ABVK
747-430BC	DLH	106	RT046	24967	848	D-ABTF
747-467B	CAT	HOV	RT457	25082	849	B-HOV
747-406BC	KLM	030	RT006	25086	850	PH-BFI
747-446B	JAL	081	RT651	25064	851	JA8081
747-412B	SIA	010	RT510	25068	852	9V-SMJ
747-4B5B	KAL	005	RT575	25205	853	HL7482
747-406BC	KLM	031	RT007	25087	854	PH-BFK
747-430BC	DLH	107	RT047	25047	856	D-ABTH

EFFECTIVE AIRCRAFT

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Figure 44 Effective Aircraft List

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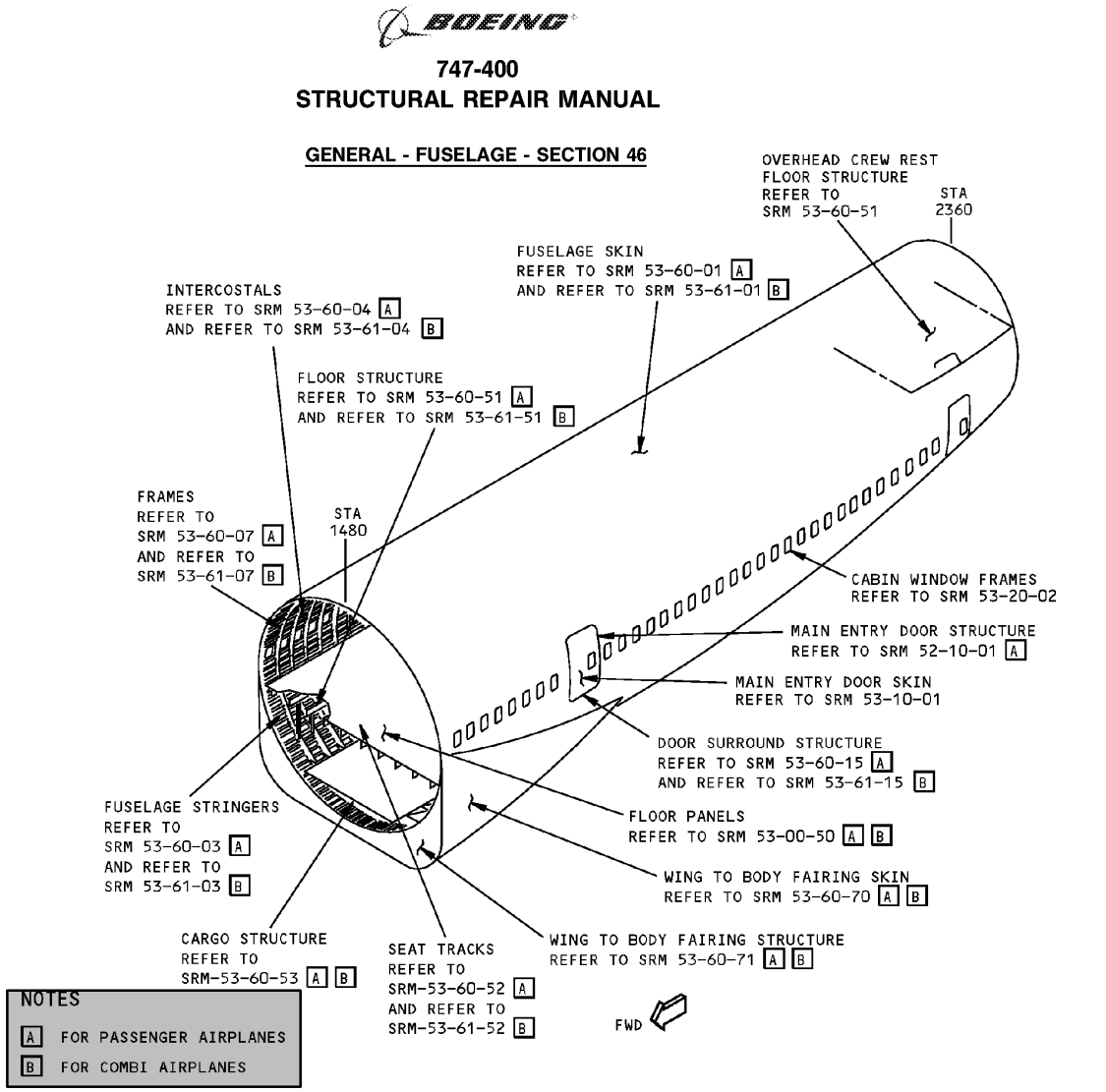


Figure 45 Effectivity by A/C-Version

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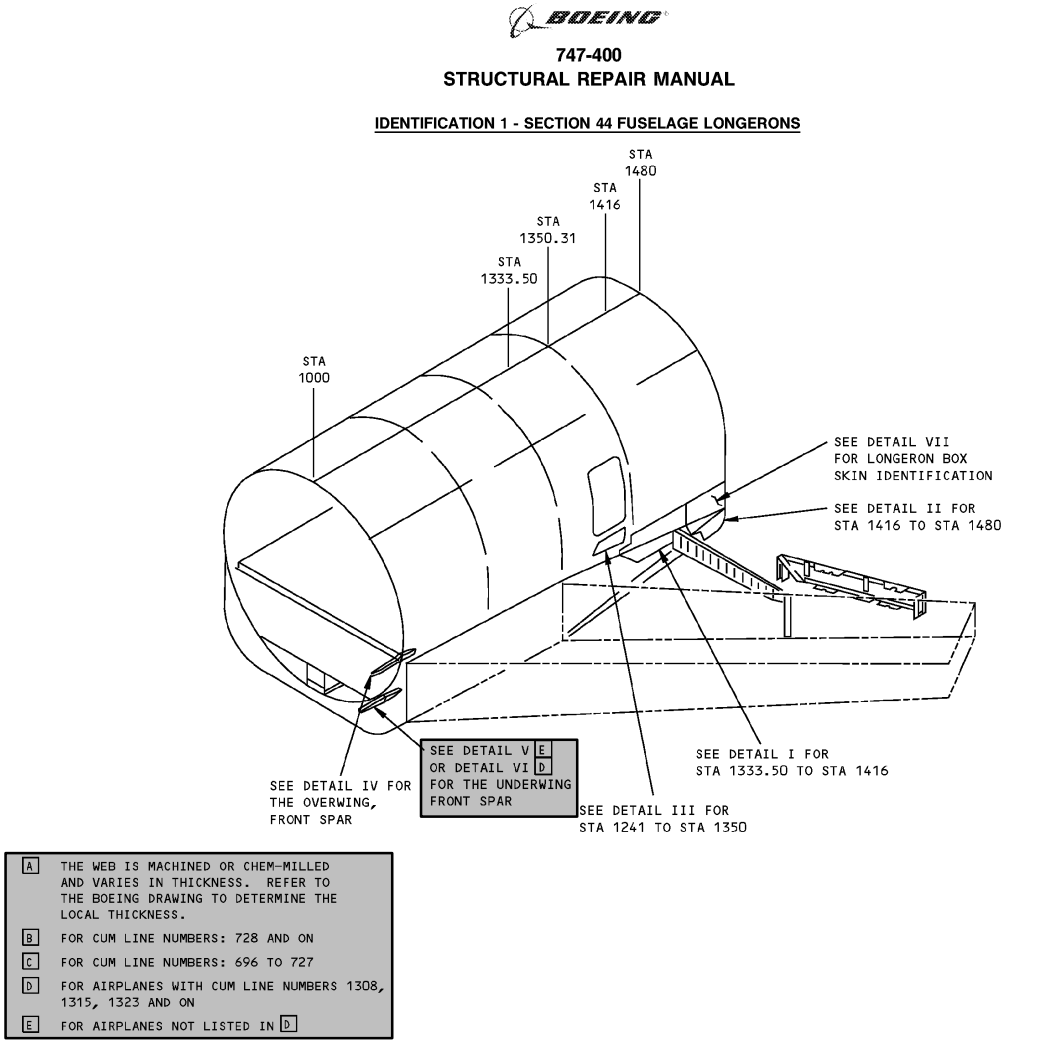


Figure 46 Effectivity by Cum Line Number

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SRM Build Up

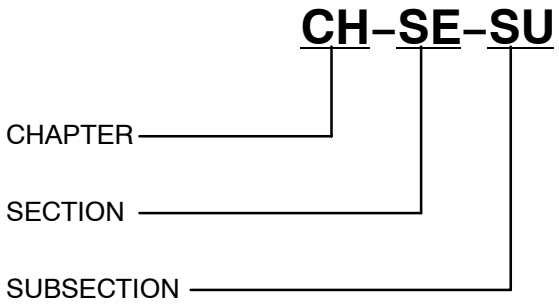
ATA Main Chapters

The content of the SRM is divided into seven chapters:

51 - Structures/General
52 - Doors
53 - Fuselage
54 - Pylons/Nacelles
55 - Stabilizers
56 - Windows
57 - Wings

Arrangement in Sections and Subsections

All of these ATA chapters are divided again in sections and subsections.



Page Blocks

Furthermore there is a special page attribution for different topics, the so called Page Block Allocation.

Page Block Allocation for ATA chapter 52 to 57

Page:	Topic:
1 - 99	Structural Identification
101- 199	Allowable Damage
201- 999	Repairs

Page Block Allocation for ATA chapter 51

Since there is no page block „Identification” in ATA chapter 51 the page block 1 to 99 is used for the topic „Description”.

Additional Information

The structural repair manual can be divided into two groups.

- On the one hand the ATA chapter 51 Structures/General,
- On the other hand the ATA chapters 52 to 57.

In ATA chapter 51 general information is contained that means it is information which is applicable for several other ATA chapters. For example that is information about fasteners, surface protection or standard repairs.

Unlike to ATA chapter 51 the ATA chapters 52 to 57 contain no general information, but special information about particular structural components.

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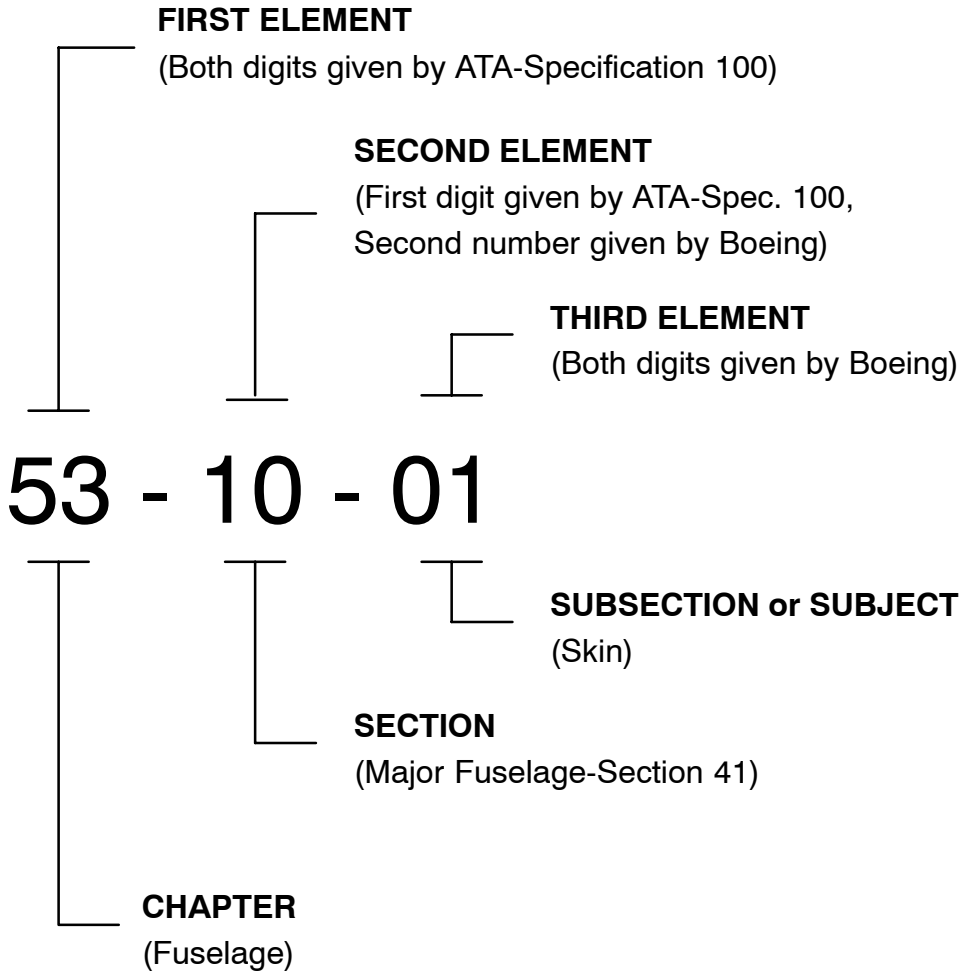


Figure 47 Standard Numbering System

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Section Arrangement

Section arrangement of ATA chapter 53 for the Boeing 747–400

The arrangement of the sections starts in every ATA chapter with section 00.

The 00 stands for general as the further arrangement in even 10th steps allows, like shown in the example below, the arrangement in main sections.

ATA CHAPTER and SECTION	CONTENT
53	**Fuselage**
53–**0**0	**General**
53–**1**0	SECTION 4**1** – Nose Fuselage
53–**2**0	SECTION 4**2** – Forward Intermediate Fuselage
53–**4**0	SECTION 4**4** – Centre Fuselage
53–**6**0	SECTION 4**6** – Aft Intermediate Fuselage
53–**8**0	SECTION 4**8** – Aft Fuselage

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SUBSECTION Numbers for the ATA–CHAPTERS 52 to 57 for Boeing 747–400			
SUB–SECTION	**CONTENT**	**SUB–SECTION**	**CONTENT**
5X–XX–00	GENERAL	5X–XX–16	EDGE MEMBERS
–01	SKINS AND PLATES	–17 bis –29	NOT USED
–02	STRUCTURE COMPLETE	–30	AUXILIARY
–03	STRINGERS AND SKIN STIFFENERS	–31 bis –49	NOT USED
–04	INTERCOSTALS	–50	FLOOR PANELS
–05	LONGERONS	–51	FLOOR STRUCTURE
–06	FORMERS	–52	SEAT TRACKS
–07	FRAMES	–53	CARGO COMPARTMENT SPECIAL STRUCTURE
–08	BULKHEADS	–54	EQUIPMENT BAY SPECIAL STRUCTURE
–09	RIBS	–55 bis –69	NOT USED
–10	SPARS	–70	FILLETS AND FAIRINGS, SKINS AND PLATING
–11	INTERMEDIATE, AUXILIARY AND SUBSPARS	–71	FILLETS AND FAIRINGS, STRUCTURE
–12	KEEL STRUCTURE	–72	RADOMES AND ANTENNA FAIRINGS
–13	BEAMS	–73 bis –89	NOT USED
–14	LANDING GEAR SUPPORT STRUCTURE	–90	ATTACHMENT FITTINGS
–15	DOOR SURROUND STRUCTURE	–91 bis –99	NOT USED

SRM-ATA Chapter 51 Structures General

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General

The general information listed in ATA chapter 51 is valid for several other ATA chapters. As examples information about fastener, surface protection or common repairs can be mentioned.

Arrangement of ATA chapter 51

In the following an overview about the content and the arrangement of the *ATA chapter 51 of the Boeing 747–400* will be given.

It has to be considered that the manual arrangement (section arrangement and page block allocation) of the older aircraft of the manufacturer Airbus (A300) and Boeing (B707, B727, B737–100, -200, B747–100, -200, -300) differs from the one of the B747–400!

Section Arrangement ATA 51 Structures General

Section Arrangement ATA 51

The ATA chapter 51 of the Boeing 747–400 is divided into different sections: At the beginning 00 for structures general and in the following the classification in main sections which can be identified by even 10th steps.

SECTION Numbers for the **ATA CHAPTER 51 for Boeing 747–400**

SECTION	CONTENT
51–**00**–XX	STRUCTURES-GENERAL
51–**10**–XX	INVESTIGATION AND CLEANUP OF DAMAGE AND AERODYNAMIC SMOOTHNESS
51–**20**–XX	PROCESSES AND PROCEDURES
51–**30**–XX	MATERIALS
51–**40**–XX	FASTENERS
51–**50**–XX	SUPPORT OF AIRPLANE FOR REPAIR AND ALIGNMENT CHECK
51–**60**–XX	CONTROL SURFACE BALANCING
51–**70**–XX	REPAIRS

51–00 Structures General

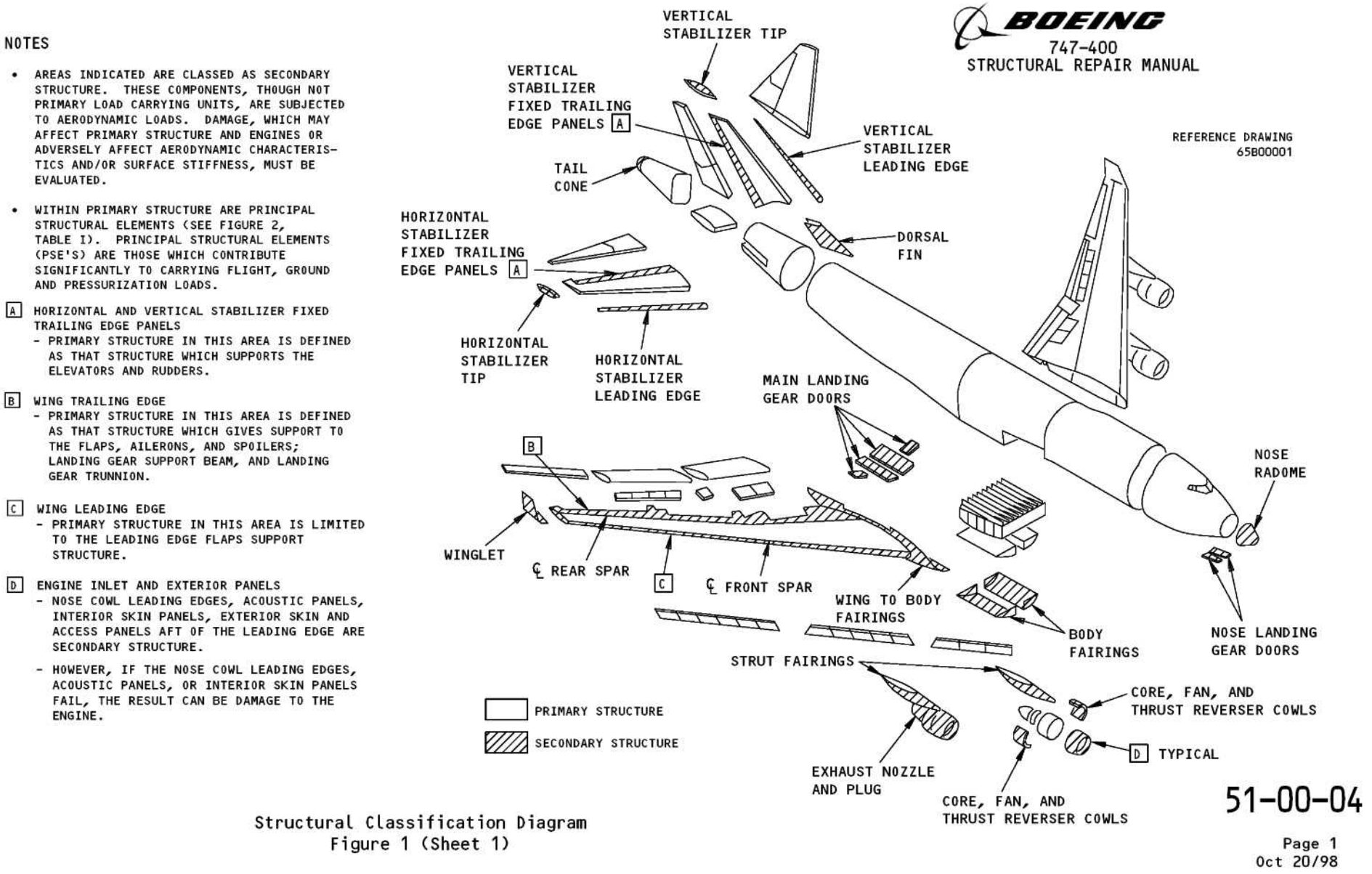
General

In ATA 51–00 *general* topics are noticed which are related to the structure. Examples are:

- Abbreviations used in the manual and their definitions (like e.g. BBL, RBL, LBL, WBL etc.)
- Main assemblies
- Aircraft dimensions
- Allocation of the structure in primary-/secondary-structure, PSE's and SSI's
- References to other documents
- General repair definitions (like e.g. different categories, permanent-, interim-, time-limited repairs etc.)

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Structural Classification Diagram
Figure 1 (Sheet 1)

Figure 48 51-00 Structural Classification

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51–1x Aerodynamic Smoothness, Investigation and Clean Up

General

In ATA 51–1X *special* structural topics are noticed like e.g.:

- Aerodynamic Smoothness
- Damage Inspection
- Damage Classification
- Damage Removal

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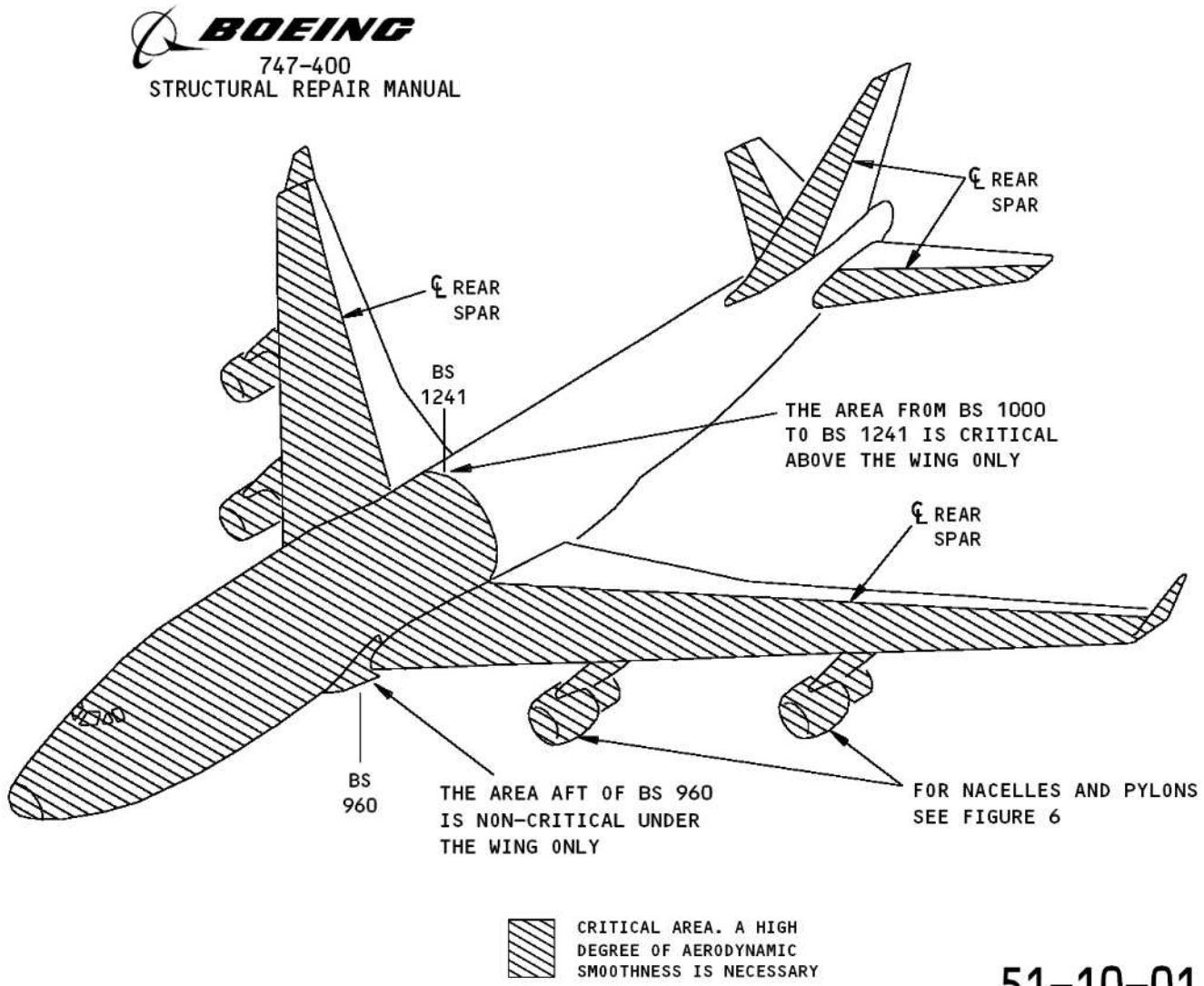


Figure 49 51-10 Aerodynamic Smoothness

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51–2X Processes and Procedures

General

In ATA 51–2X processes and procedures are described, like e.g.:

- Surface treatment of materials (e.g. CCC or cadmium plating)
- Hardness testing and test value tables
- Sealing repairs
- Shot peening
- Freeze plug installation
- Inspection and installation of shims

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BOEING SPECIFI-CATION	CLASS	MATERIAL DESCRIPTION	USAGE	APPLICA-TION TIME (HOURS) [B]	SQUEEZE-OUT LIFE (HOURS) [B]	CURE TIME (HOURS) [B]	SUPPLIER DESIGNATION [D]
BMS 5-26, TYPE II	A-2, GRADE 1	TWO-PART FUEL-RESISTANT SEALANTS	PRECOATING (BRUSHABLE)	2		72	PRO-SEAL 890 A-2 PR1440 A-2
	A-2, GRADE 2			2		48	PRO-SEAL 890M A-2
	B-2		FAYING, PREPACK, INJECTION AND FILLET SEAL	2	6	48 [C]	PRO-SEAL 890 B-2 PR1440 B-2
	C-24		FAYING SEAL		24	168	PRO-SEAL 890 C-24
NONE	B-1/2 B-1/4	TWO-PART FUEL-RESISTANT SEALANTS [J]	FAYING, PREPACK, INJECTION AND FILLET SEAL FOR FAST CURES AND AT LOWER TEMPERATURES	1/2 1/4		3 2	PR-1826 B-1/2 PR-1826 B-1/4
		REQUIRES A PRIMER [H]	NOT FOR USES ON BARE CLAD ALUMINUM				
NONE	B-1/2 B-1/4	TWO-PART FUEL-RESISTANT SEALANTS [I] [J]	FAYING, PREPACK, INJECTION AND FILLET SEAL FOR FAST CURES AND AT LOWER TEMPERATURES	1/2 1/4		3 2	PR-1828 B-1/2 PR-1828 B-1/4
BMS 5-95	B-1/2	TWO-PART SEALANTS, CONTAINING CHROMATES TO ASSIST IN INHIBITING CORROSION	FAYING, PREPACK, INJECTION AND FILLET SEAL	1/2	1/2	20 [C]	PRO-SEAL 870 B-1/2
	B-2		FAYING, PREPACK, INJECTION, FILLET AND BRUSHABLE SEALS [A]	2	6	48 [C]	PRO-SEAL 870 B-2
	C-20		FAYING SEALS	12	20	160	PRO-SEAL 870 C-20
BMS 5-63, TYPE I [E]	B-4	TWO-PART SILICONE FIREWALL SEALANT RESISTANT TO BMS 3-11 HYDRAULIC FLUID	FAYING, FILLET, INJECTION, AND PREPACK SEALS	4	6	48 [C]	DAPCO 18-4 DAPCO 18-4F
		PRIMER FOR BMS 5-63, TYPE I	PRECOATING (BRUSHABLE)			1 [G]	DAPCO 1-100

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NOTES

[A] FOR BRUSHABLE SEALANT (CLASS A-2) ADD 12% MEK/TOLUENE (50%/50% BY VOLUME) MAXIMUM BY WEIGHT TO PREMIXED CLASS B-2 SEALANT.

[B] TEMPERATURE AND HUMIDITY CAN CHANGE THE CURE TIME. THE CURE TIME THAT IS SHOWN IS FOR 75°F (24°C) AND 50% HUMIDITY. HIGHER TEMPERATURE AND/OR HUMIDITY WILL INCREASE THE CURE TIME.

[C] REFER TO FIGURE 3 FOR FILLET AND FAYING SURFACE SEALANT CURE PROPERTIES.

[D] REFER TO SRM 51-30-03 FOR SOURCES OF MATERIALS.

[E] THE CURE OF BMS 5-63 IS INHIBITED BY BMS 10-11 AND BMS 10-20 PRIMERS AND BY BMS 5-26, AND BMS 5-95 SEALANTS.

[F] CURE TIME AT 120 ±5°F (49 ±3°C) IS 4 HOURS.

[G] THE APPLIED PRIMER SHALL BE THICK ENOUGH TO HAVE A CHALKY SURFACE WHEN DRIED. ALLOW A MINIMUM OF 1 HOUR AND A MAXIMUM OF 2 HOURS FOR PRIMER TO DRY PRIOR TO APPLICATION OF SEALANT COMPOUND.

[H] USE PR-1826 ADHESION PROMOTER ON ALL SUBSTRATES. ALLOW THE PRIMER TO CURE FOR 1/2 TO 3 HOURS BEFORE APPLYING SEALANT.

[I] USE PR-1826 ADHESION PROMOTER ON POLYSULFIDE SEALANTS. ALLOW THE PRIMER TO CURE FOR 1/2 TO 3 HOURS BEFORE APPLYING SEALANT.

[J] DO NOT APPLY PR-1826 OR PR-1828 ON OR ADJACENT TO ACRYLIC WINDOWS OR OTHER ACRYLIC COMPONENTS.

[K] ALLOW PRIMER TO DRY 30 MINUTES MINIMUM TO A MAXIMUM OF 16 HOURS BEFORE SEALANT APPLICATION

Sealant Materials
Figure 1 (Sheet 1)

51-20-05

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Figure 50 Sealant Materials

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51–3x Repair Materials

General

In ATA 51–3X the most common repair materials (incl. characteristics, recognition features and handling, like e.g. minimum bend radii) and the most common tools are listed, which can be applied for the B747–400:

- Sheet Metal Materials
- Metallic Materials
- Nonmetallic Materials
- Equipment and Tools for Repairs
- Order Data for Composite Repairs
- Extrusions and Formed Sections

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MINIMUM INNER BEND RADII					
GAGE	ALUMINUM				
	2024-0 5052-H34	2024-T3/T4	5052-0	7178-0 7075-0	7178-T6 7075-T6
[A]	0.03	0.06	0.03	0.03	0.09
0.016	0.03	0.06	0.03	0.03	0.09
0.018	0.03	0.06	0.03	0.03	0.12
0.020	0.03	0.06	0.03	0.03	0.12
0.022	0.06	0.09	0.03	0.06	0.12
0.025	0.06	0.09	0.03	0.06	0.12
0.028	0.06	0.09	0.03	0.06	0.16
0.032	0.06	0.12	0.03	0.06	0.16
0.036	0.06	0.16	0.06	0.06	0.19
0.040	0.06	0.16	0.06	0.06	0.19
0.045	0.09	0.19	0.06	0.09	0.25
0.050	0.09	0.19	0.06	0.09	0.25
0.056	0.12	0.22	0.06	0.12	0.28
0.063	0.12	0.22	0.06	0.12	0.31
0.071	0.12	0.28	0.09	0.12	0.38
0.080	0.16	0.34	0.09	0.19	0.44
0.090	0.19	0.38	0.09	0.19	0.50
0.100	0.22	0.44	0.12	0.22	0.62
0.112	0.25	0.50	0.12	0.28	0.75
0.125	0.25	0.56	0.12	0.28	0.88
0.140	0.34	0.62	0.12	0.38	1.00
0.160	0.38	0.75	0.16	0.44	1.12
0.180	0.44	0.88	0.19	0.50	1.25
0.190	0.50	0.88	0.19	0.56	1.25

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NOTES

[A] ALL GAGES BELOW 0.016

Minimum Inner Radii for Straight Line Bends in Aluminum Sheet
Figure 3

51-30-01

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Figure 51 Minimum-Bend Radii

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51–4x Fasteners

General

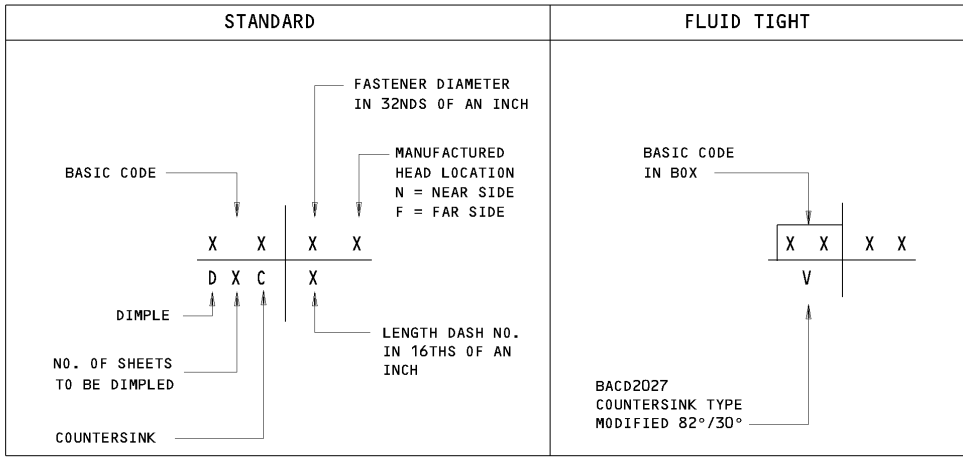
In ATA 51–4X fasteners are treated. Here information about the following points can be found:

- Fastener-Types
- Fastener Installation and Removal
- Fastener Substitution
- Torque Values
- Fastener Hole-Sizes
- Fastener Edge Margins
- Strength of Fasteners
- Countersinking
- Cold Working of Holes for Fatigue Improvement

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YNE | 6N
C |
BACR15FV6KE RIVET
120° MODIFIED SHEAR HEAD
3/16 DIAMETER
7050-T73
COUNTERSINK, NEAR SIDE

RL | 5
BACR1398D BLIND RIVET
5/32 DIAMETER
2017-T4

XFV | 8
DC |
BACB30GY LOCKBOLT
100° SHEAR HEAD
1/4 DIAMETER
STEEL, WITH BACC30K COLLAR
DIMPLED SKIN
COUNTERSINK STRUCTURE

XCZ | 8
|
BACB30FM HEX-DRIVE BOLT
1/4 DIAMETER
STEEL, WITH BACC30M COLLAR

YKJ | 4N
C | 12
BACB30PT4K12L BOLT
70° RADIUS LEAD-IN HEAD
EXTENDED THREAD LENGTH
1/8 DIAMETER
3/4 GRIP LENGTH
6AL-4V TITANIUM
WITH BACN10WM ALUMINUM COATED NUT
COUNTERSINK, NEAR SIDE

EXAMPLES

Fastener Symbols
Figure 1

51-40-01

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Figure 52 Fastener Code

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51–5x Support of Airplane for Repair and Alignment Check

General

In ATA chapter 51–5x information and instructions can be found which concern:

- Aircraft Jacking Points
- Aircraft Fuselage Station Points
  - Landing Gear Station Points
  - Engine Station Points
  - Stabilizer Station Points
- Aircraft Fuselage Support
  - Airfoil Support

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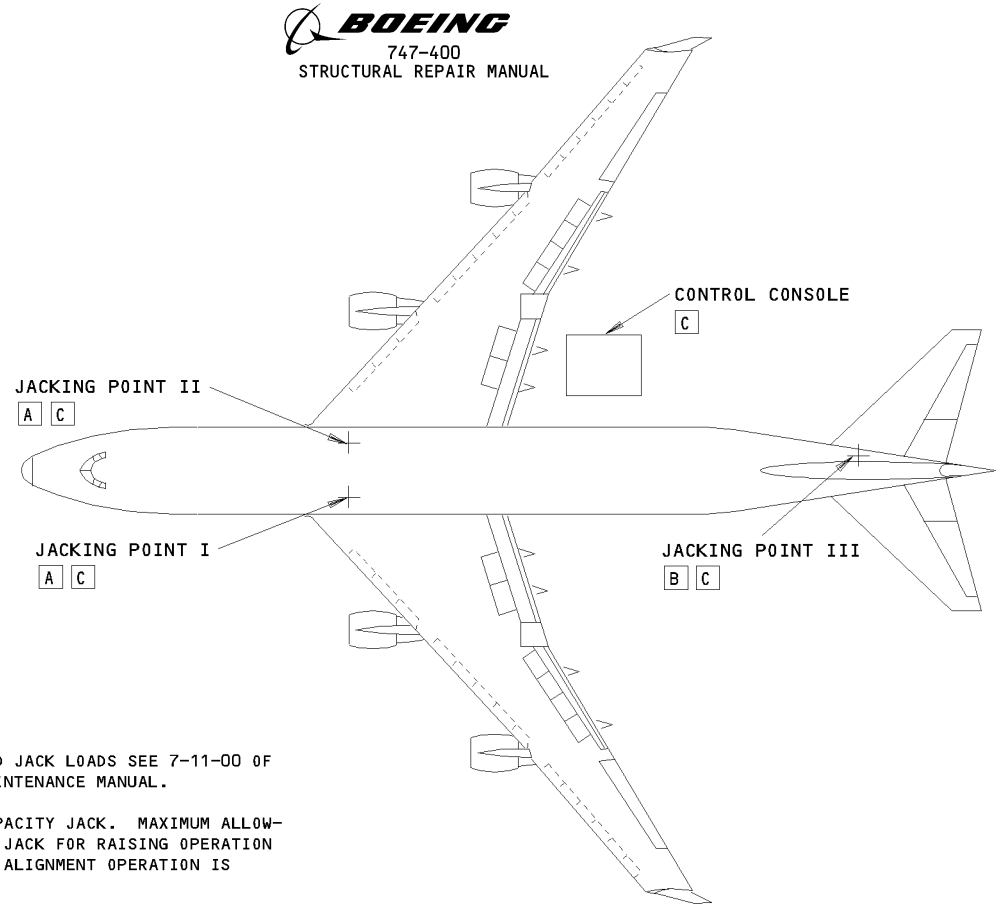


Figure 53 Support of Airplane for Repair/Check

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51–60 Control Surface Balancing

General

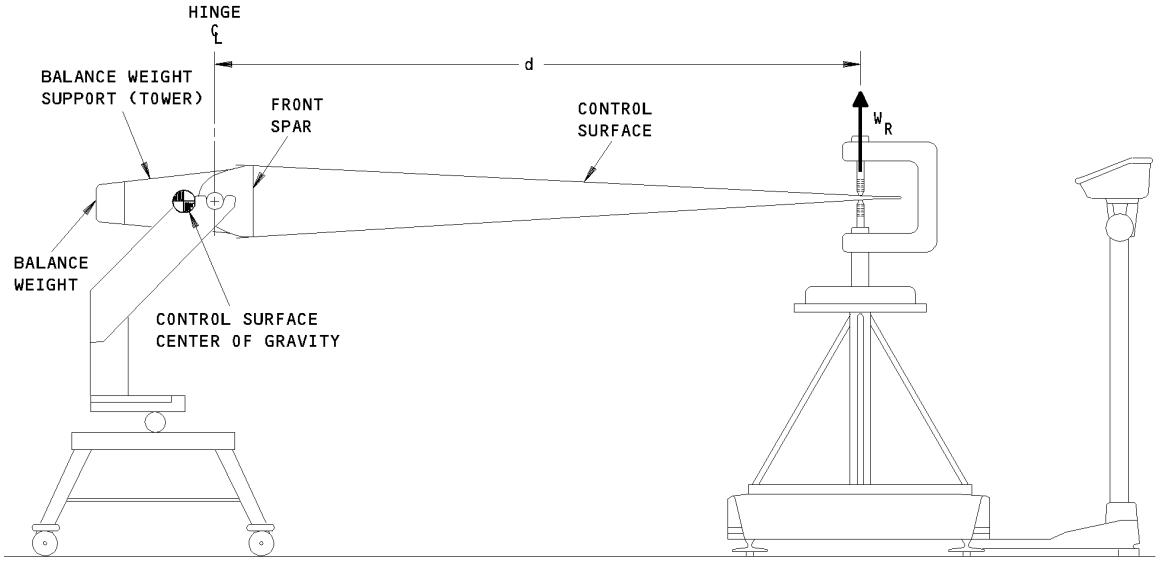
The ATA 51–6x contains information and procedures concerning the static balancing of B747 control surfaces (in this case Outbd. Ailerons and Outbd. Elevators).

The control surfaces have so called Operational Balance Limits, which make a balancing after a repair or a paint job necessary.

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ARRANGEMENT OF EQUIPMENT TO MEASURE THE
STATIC BALANCE MOMENT OF A CONTROL SURFACE
DETAIL I

NOTES

- THE ACTUAL STATIC BALANCE MOMENT IS COMPARED WITH THE OPERATIONAL LIMIT FOR THE CONTROL SURFACE. IF NECESSARY, MAKE AN ADJUSTMENT TO THE MASS BALANCE TO MAKE THE STATIC BALANCE MOMENT (M) BE LESS THAN OR EQUAL TO THE OPERATIONAL LIMITS.

[A] W_R = THE SCALE READING MINUS THE WEIGHT OF THE TOOL STAND. THE UPWARD FORCE IS NEGATIVE.

[B] THE DISTANCES FORWARD OF THE HINGE CENTERLINE ARE NEGATIVE. THE DISTANCES AFT OF THE HINGE CENTERLINE ARE POSITIVE.

SAMPLE CALCULATION (MOMENT): $M = W_R \times d$

SCALE READING	= 7.5 POUNDS
WEIGHT OF THE TOOL STAND	= 10.0 POUNDS
WEIGHT REACTION (W_R)	= 7.5-10.0 = +2.5 POUNDS [A]
MOMENT ARM (d)	= 21.3 INCHES [B]
STATIC BALANCE MOMENT (M)	= -2.5 x 21.3 = -53.3 POUND INCHES

Over-Balanced Control Surface Sample Calculation
Figure 2

51-60-00
400 Page 10
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Figure 54 Control Surface Balancing

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51–7x Typical Repairs

General

In ATA chapter 51–7X typical repairs also called standard repairs are described, which can be applied on the whole aircraft if these are no special notes in the particular repair description.

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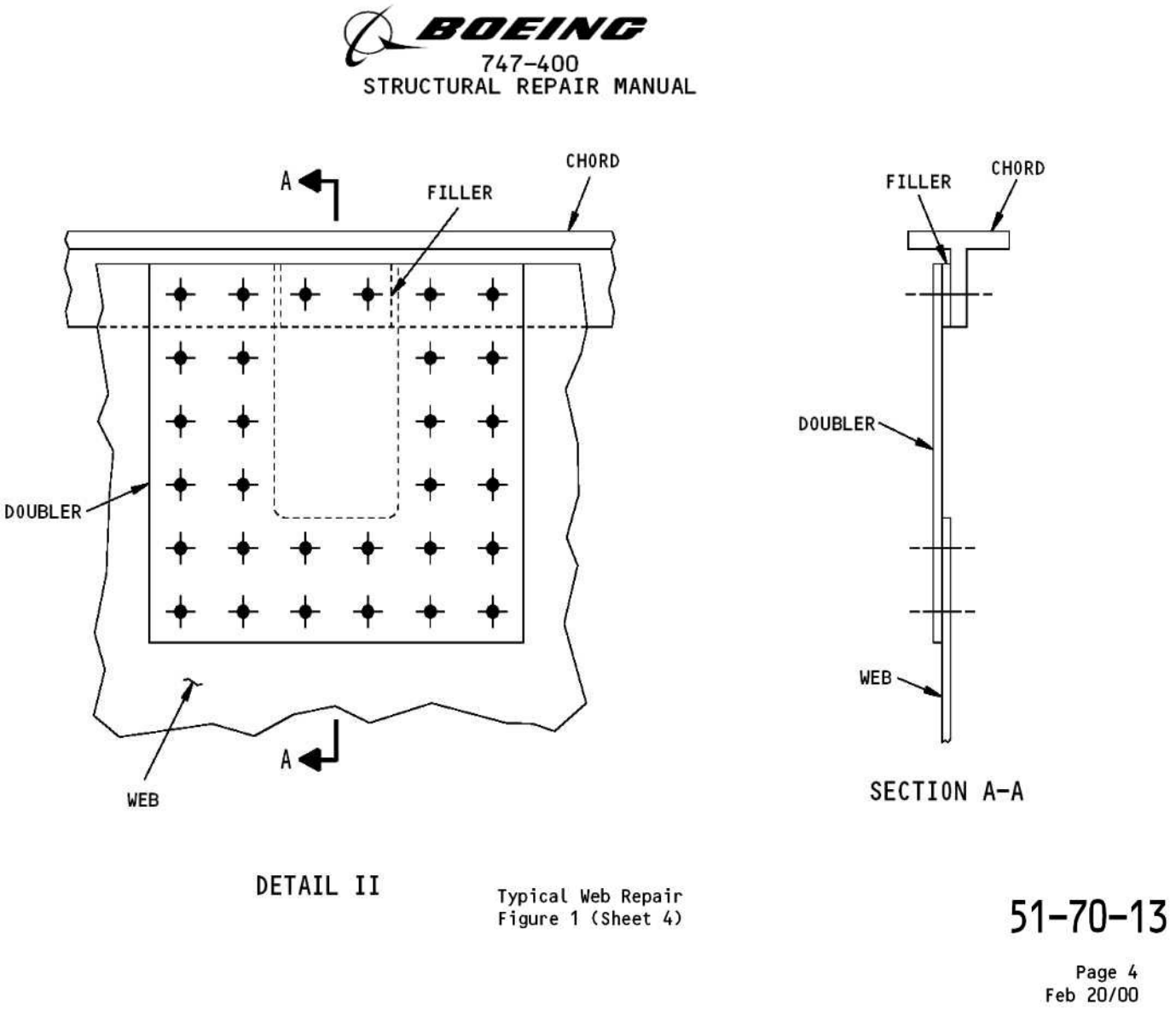


Figure 55 Typical Web Repair/Repair Sketch

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Application of the Manual

Page Blocks

The structural repair manual (ATA 52 to 57) is divided into three page blocks:

- Identification Page 1 - 99
- Allowable Damage Page 101 - 199
- Repairs Page 201 - 999

The page blocks can be identified by the page numbers and by the adapted figure numbers and are depicted on the following page.

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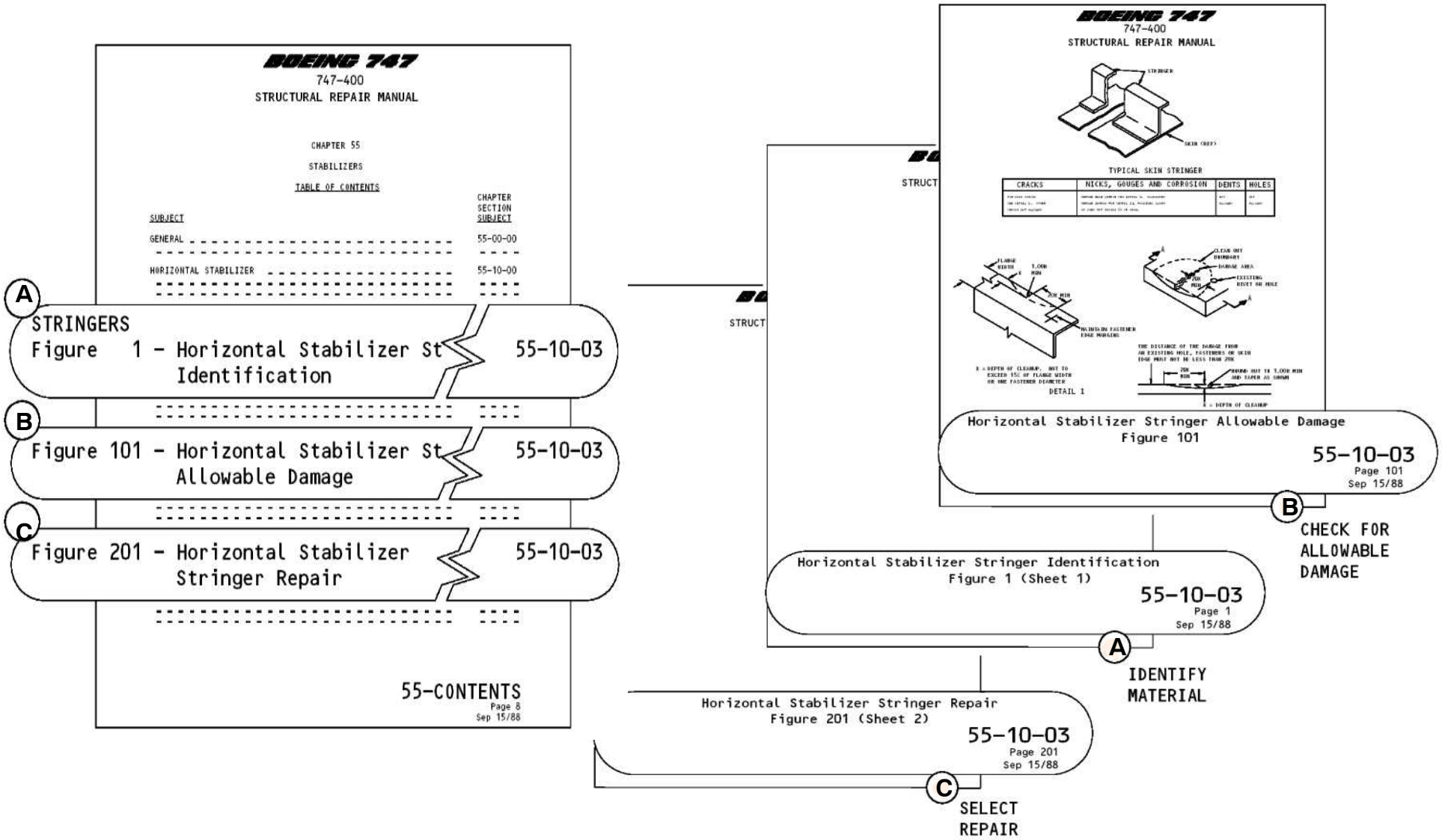


Figure 56 SRM Usage

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How can i get to the Effective Repair?

Procedure

The procedure for the treatment of damages with the help of the SRM can be divided into five steps:

- Location
- Effectivity
- Identification
- Allowable Damage
- Repair.

Exact Damage Description

In order to judge damages at all, information about the following points is needed:

- Location of Damage
- Type of Damage
- Size of Damage

To make sure that there are no mix-ups the exact airplane, the exact location of damage, the type of damage and the concerning component have to be defined.

Example of a Damage Description

The simplest method is the denomination of structural elements, e.g.:

- Groove in the fuselage outer skin between station 620 and station 640, between stringer 41 LH and stringer 42 LH.
- Length of groove: 18mm, max. depth: 0,4mm (do not take it into the findings!)
- Concerned A/C: B747-400, registration: D-ABTD

Definition Structural Damage

The denomination „Damage“ is valid for every enduring deformation and every enduring change of a structural part, e.g. caused by mechanical, chemical or thermal reasons.

An exact definition of the different damage types can be found in ATA chapter 51 of the SRM.

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Manual Effectivity

General

The check of manual effectivity is the review of the effectivity of the SRM procedure at hand for a certain aircraft serial number (CUM LINE NUMBERS or LINE NUMBERS).

- Only if the aircraft is listed in the introduction part of the manual the document is effectual!
  - Attention: Before using the manual the actual revision status of the document must be checked!

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CURR OPER	MODEL-SERIES	VARIABLE NO.	LINE NO.	OMNI NO.	MANUF S/N	REGISTRY NO.	ENGINE NO.
DLH	LUFTHANSA GERMAN AIRLINES						(CONTINUED)
	-430B	RM004	1261	R6679	29869	D-ABVY	RQ702
	-430B	RM005	1264	R6681	29870	D-ABVZ	RQ705
	-430B	RM006	1293	R6699	29871	D-ABTK	RQ722
	-430B	RM007	1299	R6702	29872	D-ABTL	RQ724
	-430B	RT431	700	R2402	23817	D-ABVB	RV831
	-430B	RT432	723	R2409	23816	D-ABVA	RV832
	-430B	RT433	757	R2432	24288	D-ABVC	RV843
	-430B	RT434	786	R2454	24740	D-ABVD	RV856
	-430B	RT435	787	R2455	24741	D-ABVE	RV857
	-430B	RT436	796	R2462	24761	D-ABVF	RV858
	-430B	RT437	845	R2505	25045	D-ABVH	RV876
	-430B	RT438	847	R2506	25046	D-ABVK	RV878
	-430B	RT439	898	R2541	26425	D-ABVL	RV903
	-430B	RT441	915	R2555	26427	D-ABVN	RV914
	-430B	RT442	1080	R2677	28086	D-ABVO	RV983
	-430B	RT443	1103	R2695	28284	D-ABVP	RV990
	-430B	RT444	1106	R2697	28285	D-ABVR	RV991
	-430B	RT445	1109	R2700	28286	D-ABVS	RV992
	-430B	RT446	1110	R2701	28287	D-ABVT	RV993
	-430B	RT447	1143	R2725	29101	D-ABVM	RW513
	-430BC	RT041	747	R2006	24285	D-ABTA	RV840
	-430BC	RT042	749	R2007	24286	D-ABTB	RV841
	-430BC	RT043	754	R2008	24287	D-ABTC	RV842
	-430BC	RT044	785	R2013	24715	D-ABTD	RV855
	-430BC	RT045	846	R2017	24966	D-ABTE	RV877
	-430BC	RT046	848	R2018	24967	D-ABTF	RV879
	-430BC	RT047	856	R2021	25047	D-ABTH	RV884
ELA	EL AL ISRAEL AIRLINES						
	-458B	RM091	1215	R6658	29328	4X-ELD	RQ523
	-458B	RU081	1027	R2640	26055	4X-ELA	RW303
	-458B	RU082	1032	R2644	26056	4X-ELB	RW305
	-458B	RU083	1062	R2666	27915	4X-ELC	RW319
EVA	EVA AIR						
	-45EB	RM116	1151	R6607	29111	B-16411	RQ651
	-45EB	RM117	1159	R6615	29112	B-16412	RQ654
	-45EB	RT951	942	R2576	27062	B-16401	RV925
	-45EB	RT952	947	R2580	27063	B-16402	RV928
	-45EB	RT953	976	R2602	27141	B-16403	RV941
	-45EB	RT954	982	R2607	27142	B-16405	RV945

Airplane Effectivities
Figure 2 (Sheet 6)

INTRODUCTION

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Figure 57 Airplane Effectivity

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Structure Identification

General

After checking the effectivity of the manual the structure identification is done with the help of the particular ATA chapter.

In this example: ATA chapter 53, Page Block 1–99.

Identification of Damage Location

Since from the data it is not clear in which fuselage section the damage is located the first step is done with the help of the station plan.

So it is possible to locate the damage exactly and to identify to affected fuselage section.

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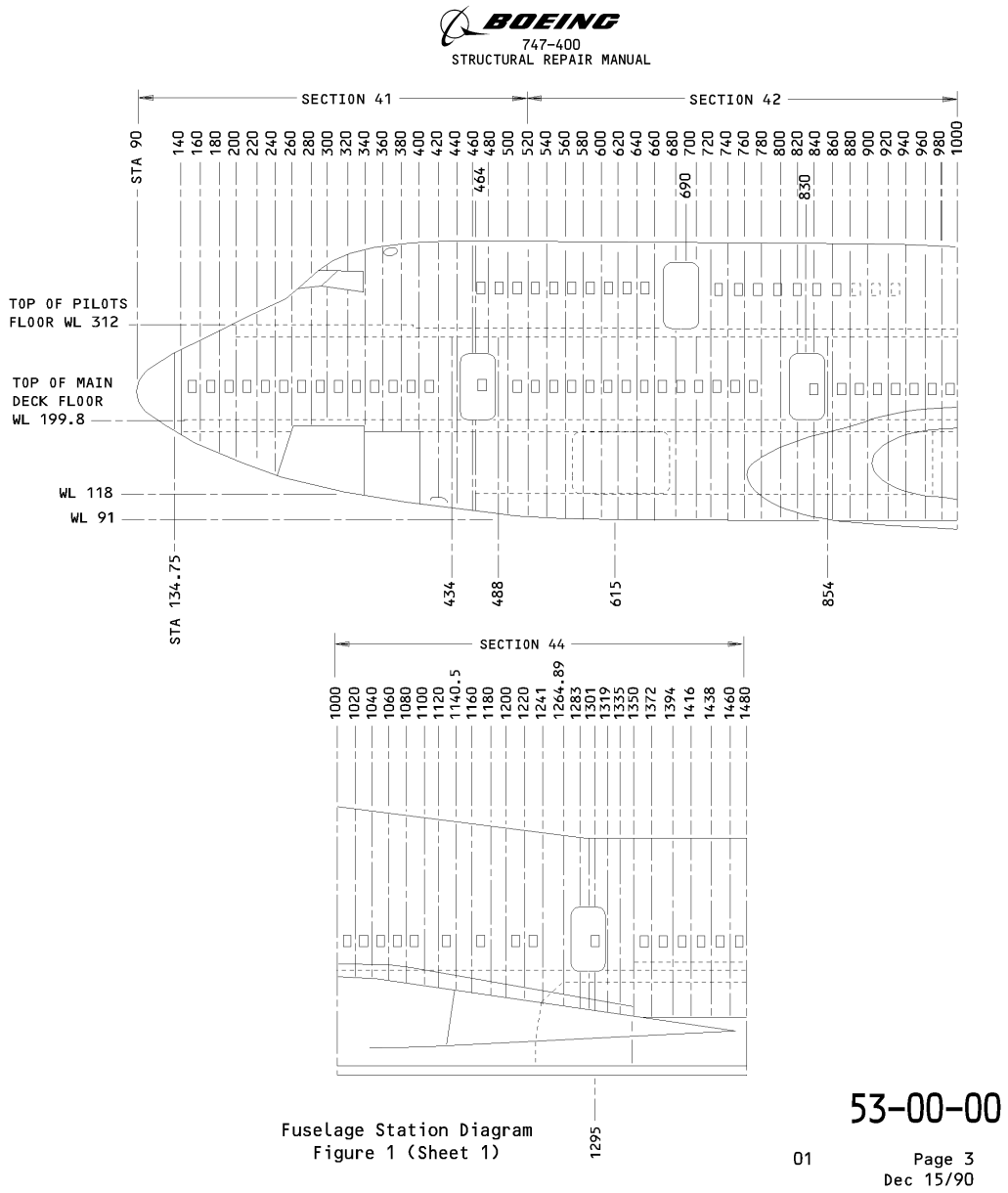


Figure 58 Structure Identification (1)

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STRUCTURE IDENTIFICATION (CONT'D)

Entrance into the damaged Section

After identifying the concerned fuselage section the start can begin at the corresponding section in the SRM chapter 53.

In this example:

- 53–**20**–01.
  - The subsection for skin is the '01' for the B747–400.

Effectivity Consideration of different A/C Versions

For doing the effectivity check for the particular component in the Boeing SRM besides the information/illustration notes with (CUM) LINE NUMBER or denomination of the version are given, like:

- PASSENGER
- COMBI
- FREIGHTER
- LINE NO.696 THRU 932
- -100, -200, -300, SP (older manuals)
- SF

There are other denominations possible.

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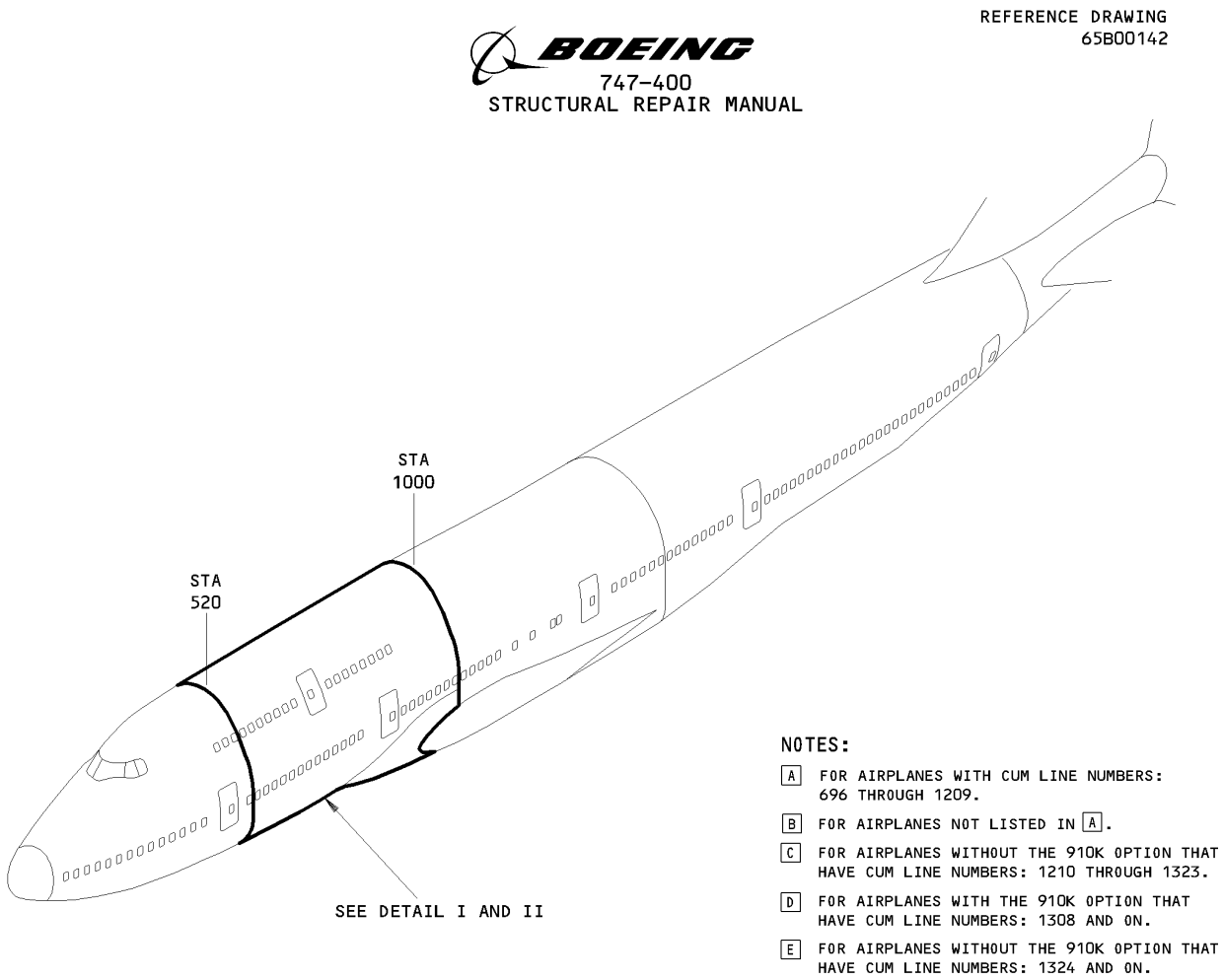


Figure 59 Structure Identification (2)

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STRUCTURE IDENTIFICATION (CONT'D)

Identification of the Damaged Component

To judge the amount of damage accurately the type and thickness of the damaged structural part must be determined.

This can mostly be done by looking at the SRM's.

- There is the section Structure Identification in the Page Block 1 – 99 for every structural area in ATA chapter 52 – 57.

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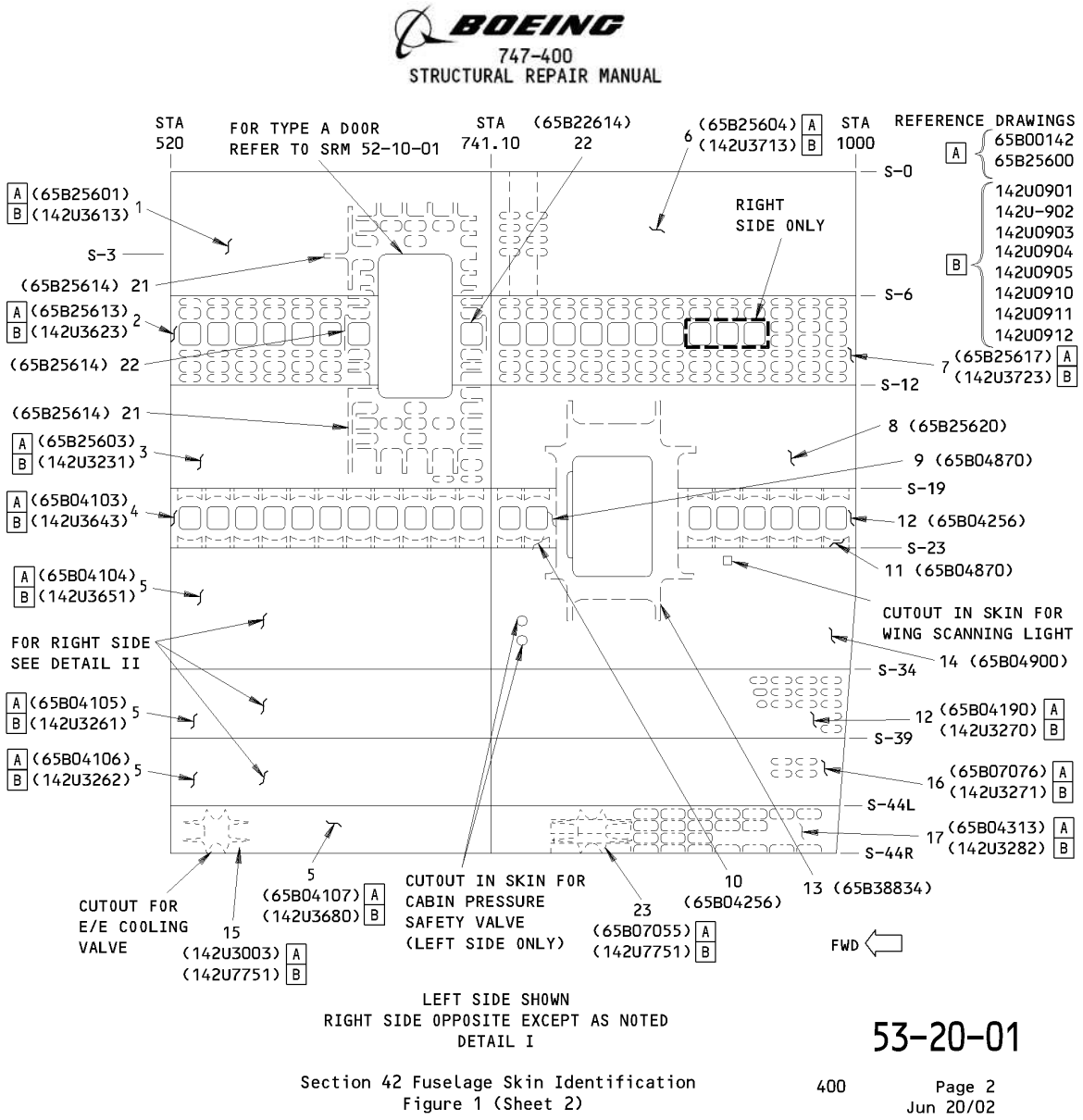


Figure 60 Structure Identification (3)

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STRUCTURE IDENTIFICATION (CONT'D)

Identification of Material Type, -Number, -Thickness via Partslist

Besides the drawing of the particular structure in the structure identification a corresponding parts list can be found from which material and/or material number and most of the time also the material thickness can be derived.

If this should not be the case there is the possibility to get into the set of drawings via the assy drawing number in order to get the desired information (dimensions, fastener, etc.) from the manufacturing drawing.

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ITEM	DESCRIPTION	GAGE	MATERIAL	EFFECTIVITY
1	BONDED SKIN PANEL			
	SKIN	0.056	CLAD 2024-T3	
	DOUBLER	0.063	CLAD 2024-T3 (CHEM-MILLED TO 0.032 MINIMUM)	
2	BONDED PANEL ASSY			
	SKIN	0.125	CLAD 2024-T3 (CHEM-MILLED TO 0.063 MINIMUM)	
	DOUBLER	0.080	CLAD 2024-T3	
3	SKIN PANEL	0.125	CLAD 2024-T3 (CHEM-MILLED TO 0.063 MINIMUM)	
4	BONDED PANEL ASSEMBLY			
	SKIN	0.071	CLAD 2024-T3	
	DOUBLER	0.071	2024-T3	
	TRIPLER	0.056	CLAD 2024-T3	
5	SKIN PANEL	0.062	CLAD 2024-T3	
6	BONDED SKIN PANEL			
	SKIN	0.090	CLAD 2024-T3 (CHEM-MILLED TO 0.062 MINIMUM)	
	FWD DOUBLER	0.016	CLAD 2024-T3	
	AFT DOUBLER	0.032	CLAD 2024-T3	
7	PANEL ASSEMBLY			
	SKIN	0.080	CLAD 2024-T3 (CHEM-MILLED TO 0.025 MINIMUM)	
	DOUBLER	0.050	CLAD 2024-T3	
	TRIPLER	0.080	CLAD 2024-T3	
8	SKIN PANEL	0.250	CLAD 2024-T351 (MACHINED TO 0.071 MINIMUM)	
9	FWD BONDED SKIN-TAPERED	0.100	CLAD 2024-T3 (MACHINED TO 0.071 MINIMUM)	
10	FWD BONDED DOUBLER	0.100	2024-T3 (MACHINED TO 0.071 MINIMUM)	
11	AFT BONDED SKIN - TAPERED	0.170	CLAD 2024-T3 (MACHINED TO 0.092 MINIMUM)	
12	AFT BONDED DOUBLER	0.143	CLAD 2024-T3 (MACHINED TO 0.092 MINIMUM)	A C D E
	MACHINED SKIN	0.250	2024-T3 (MACHINED TO 0.092 MINIMUM)	
13	DOOR STRAP	0.250	2024-T351 PLATE	
14	SKIN PANEL	0.250	CLAD 2024-T351 (MACHINED TO 0.063 MINIMUM)	
15	DOUBLER	0.100	2024-T3 (STRAIGHT TAPER 0.10 TO 0.02)	
16	BONDED SKIN PANEL	0.115	CLAD 2024-T3 (MACHINED TO 0.063 MINIMUM)	A C D E
	SKIN PANEL	0.143	CLAD 2024-T3 (MACHINED TO 0.063 MINIMUM)	
		0.125	CLAD 2024-T3 (MACHINED TO 0.063 MINIMUM)	
17	SKIN PANEL	0.160	CLAD 2024-T3 (MACHINED TO 0.063 MINIMUM)	
18	DOOR STRAP	0.190	2024-T3	
19	FWD & AFT SKIN PANEL	0.100	CLAD 2024-T3 (CHEM-MILLED TO 0.063 MINIMUM)	
20	SKIN PANEL	0.100	CLAD 2024-T3 (CHEM-MILLED TO 0.063 MINIMUM)	
21	TRIPLER - DOOR SURROUND	0.080	CLAD 2024-T3 (CHEM-MILLED TO 0.040 MINIMUM)	
22	TRIPLER - DOOR SURROUND	0.080	CLAD 2024-T3 (CHEM-MILLED TO 0.025 MINIMUM)	
23	STRAP	0.071	CLAD 2024-T3 OR 2024-T3	

LIST OF MATERIALS FOR DETAILS I AND II

53-20-01

Section 42 Fuselage Skin Identification
Figure 1 (Sheet 3)

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Page 3
Jun 20/02

Figure 61 Structure Identification (4)

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Allowable Damage

General

With the help of the section „Allowable Damage, which is in the ATA chapter 51 and in the chapters ATA 52–57 in Page Block 101–199, the particular limits of damages can be determined.

The information which is given in ATA 51 relate to the whole fuselage structure. The information in the Allowable Damage section in ATA 52 to 57 is only effective for special areas of the fuselage.

With the help of this data it is determined if the damage is an **„Allowable Damage“, „Repairable Damage“** or a **„Non Repairable Damage“**.

„Allowable Damage“ does not mean that the damage can stay as it is!

Here the instructions of the SRM have to be complied, e.g. „Restoration of surface protection“, „Blendout“ or NDT-Testing.

If there is no section „Allowable Damage“ and there is also no replacement of the part instructed at another place the aircraft manufacturer has to be informed.

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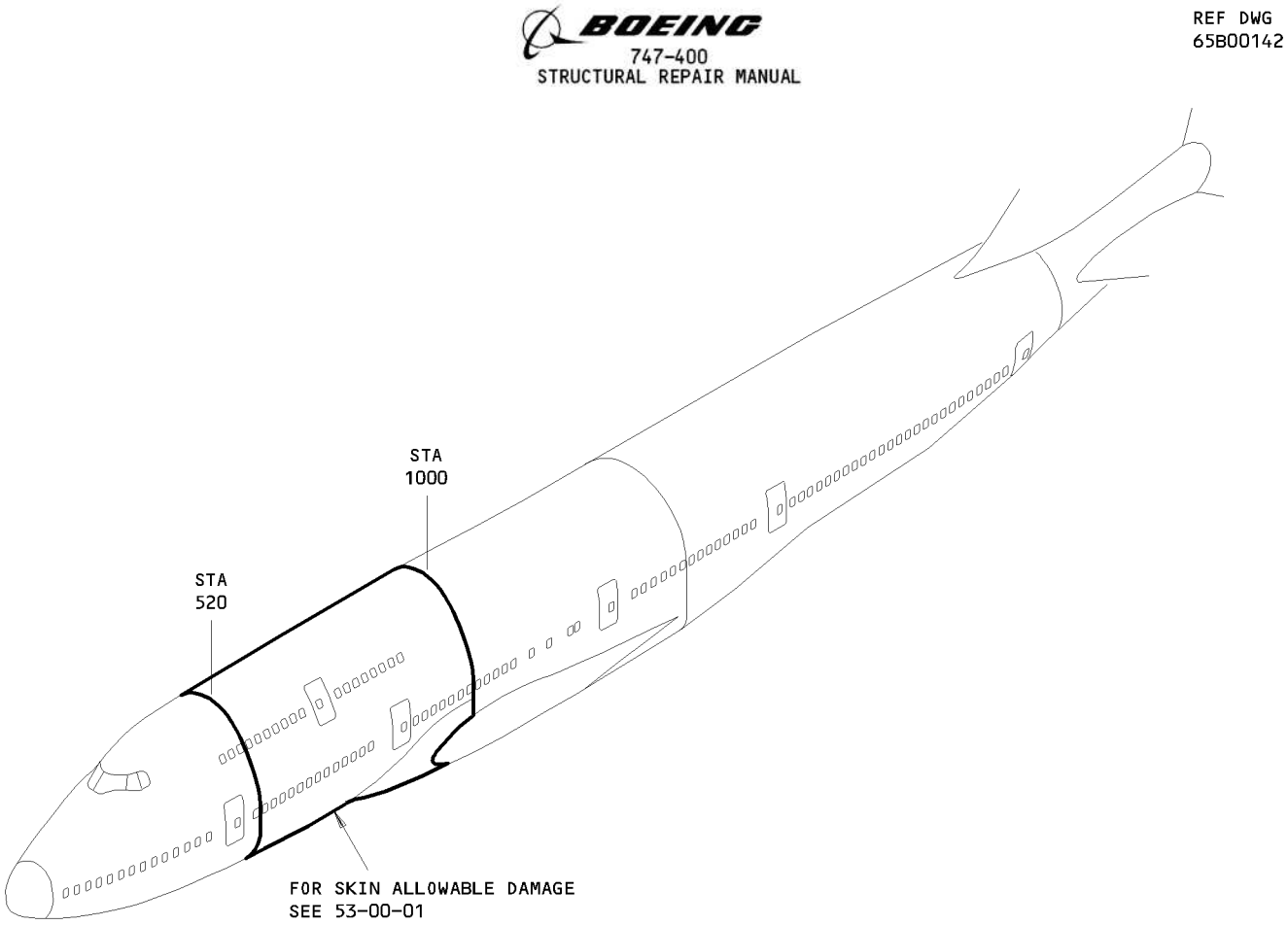


Figure 62 Allowable Damage (1)

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ALLOWABLE DAMAGE (CONT'D)

References within the Allowable Damage Page Blocks

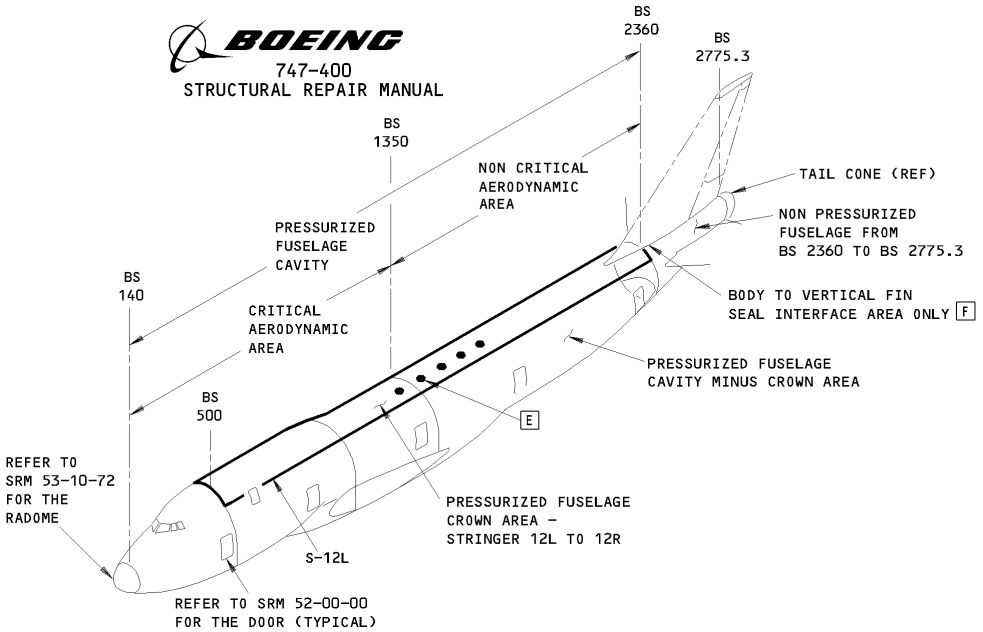
In the case of the example, a damage of the skin, a reference is given in the particular page block 101 of the section 42 (so in 53–20–01, Page Block 101) to the SRM chapter 53–**00**–01, page block 101.

This approach is very common inside the SRM. The aircraft manufacturer saves himself to list the complete „Allowable Damage“ for the skin in every section concerning the fuselage.

That is why general damages are described in the prior chapter 53–**00**–01.

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AREA	CRACKS C	NICKS, GOUGES AND CORROSION C	DENTS	HOLES C	WRINKLES OR BUCKLES	LIGHTENING STRIKE E
PRESSURIZED FUSELAGE CAVITY MINUS CROWN AREA H	FOR EDGE CRACKS SEE DETAIL I A. OTHER CRACKS ARE NOT PERMITTED	FOR EDGE DAMAGE SEE DETAIL I A FOR OTHER DAMAGE SEE DETAILS II, IV, V AND VI	SEE DETAIL III B D G J	NOT PERMITTED E	--	REFER TO TABLE II
PRESSURIZED FUSELAGE CROWN AREA (S-12L TO S-12R)	FOR EDGE CRACKS SEE DETAIL I A. OTHER CRACKS ARE NOT PERMITTED	FOR EDGE DAMAGE SEE DETAIL I A FOR OTHER DAMAGE SEE DETAILS II, IV, V AND VI	SEE DETAIL III B G	NOT PERMITTED E	--	REFER TO TABLE II
NON PRESSURIZED FUSELAGE FROM BS 2360 TO BS 2775.3	FOR EDGE CRACKS SEE DETAIL I. OTHER CRACKS ARE NOT PERMITTED	FOR EDGE DAMAGE SEE DETAIL I. FOR OTHER DAMAGE SEE DETAILS II, IV, V AND VI	SEE DETAIL III B G J	HOLES CLEANED UP TO 0.25 INCH DIAMETER PLUG WITH A BACR15BB()D() OR MS20470D()-() RIVET. DISTANCE TO OTHER FASTENERS MUST BE 4 TIMES FASTENER DIAMETER OR MORE	I	REFER TO TABLE II

Allowable Damage - Fuselage Skin
Figure 101 (Sheet 1)

53-00-01

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Figure 63 Allowable Damage (2)

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NOTES

- REFER TO SRM 51-10-00 FOR INVESTIGATION AND CLEANUP OF DAMAGE.
- REFER TO SRM 51-20-01 FOR PROTECTIVE TREATMENT OF METAL.
- REFER TO NDT PART 6, 51-00-00, FIG. 4 FOR EDDY CURRENT INSPECTION PROCEDURES.
- THE ALLOWABLE DAMAGE LIMITS HAVE FAA APPROVAL CONTINGENT ON ACCOMPLISHMENT OF INSPECTIONS AT THE INTERVALS CONTAINED HEREIN.

[A] EDGE GAPS MUST BE FILLED WITH AERODYNAMIC SMOOTHER PER SRM 51-10-01 FORWARD OF BS 1350.

[B] REFER TO SRM 51-10-01 FOR AERODYNAMIC SMOOTHNESS REQUIREMENTS.

[C] REFER TO FIGURE 102 FOR THE FUSELAGE SKIN OPERATING LIMITS AFTER DAMAGE HAS BEEN REMOVED.

[D] REFER TO SRM 51-10-01 FOR LIMITATIONS IN THE VICINITY OF THE STATIC PORTS AND PITOT-STATIC PROBES.

[E] FOR REPAIR OF LIGHTNING STRIKES AND SMALL DAMAGE, REFER TO FIG. 209.

[F] FOR THE BODY TO VERTICAL SEAL INTERFACE AREA, THE MAXIMUM ALLOWABLE REWORK DEPTH IS:

- 0.020 INCH AFT OF STA 2360 (IN THE NON-PRESSURIZED AREA)
- 0.012 INCH OR [K] FORWARD OF STA 2360

DO THE REWORK AS SHOWN IN DETAIL II, SECTION A-A AND:

- APPLY A CHEMICAL CONVERSION COATING AS GIVEN IN SRM 51-20-01.
- APPLY BMS 10-79, TYPE III PRIMER (REFER TO SOPM 20-44-04), OR AS AN ALTERNATIVE, APPLY BMS 10-79, TYPE II PRIMER (REFER TO SOPM 20-44-04), OR BMS 10-11, PRIMER REFER TO SOPM 20-41-02)
- APPLY BMS 10-86, TYPE I OR II COLOR BAC 707 (GRAY) OR BAC 700 (WHITE), ABRASION RESISTANT TEFLON COATING ALONG THE TOTAL LENGTH OF THE SEAL CONTACT AREA (APPROXIMATELY 4.0 INCHES WIDE). REFER TO SOPM 20-44-01.

[G] IF THE DENT DAMAGE IS MORE THAN THE LIMITS SHOWN IN DETAIL III, THE AIRPLANE IS PERMITTED TO OPERATE IF YOU:

- DO AN INITIAL DETAILED VISUAL INSPECTION OF ALL ADJACENT STRUCTURE IN A 20 INCH RADIUS. MAKE SURE THERE IS NO DAMAGE TO ANY FRAME, STRINGER, INTERIOR OR EXTERIOR DOUBLER, OR TEAR STRAP. IF THERE IS DAMAGE TO ANY STRUCTURE OTHER THAN THE SKIN, MAKE THE REPAIRS IMMEDIATELY.
- MAKE SURE THE DENT IS SMOOTH AND FREE FROM SHARP CREASES AND GOUGES.
- MAKE SURE THERE ARE NO FASTENERS IN THE DENT AREA AND THERE IS NO EVIDENCE OF SHEARED OR LOOSE FASTENERS ADJACENT TO THE DENT. MAKE SURE THERE ARE NO ELONGATED FASTENER HOLES ADJACENT TO THE DENT.
- MAKE SURE THE DENT IS A MINIMUM OF 10.0 INCHES AWAY FROM A SKIN SPLICE OR CUTOUT, AND 1.0 INCH AWAY FROM A STRINGER, TEAR STRAP OR SKIN DOUBLER.
- MAKE SURE YOU CAN INSPECT THE DENT. DO NOT FILL THE DENT WITH BODY PUTTY.
- MAKE SURE THERE IS NO UNREPAIRED DAMAGE EXCEEDING ALLOWABLE DAMAGE LIMITS, INCLUDING OTHER DENT DAMAGE IN THE SKIN PANEL'S ADJACENT FRAME BAYS FORWARD AND AFT OF THE DENT. MULTIPLE DENTS EXCEEDING ALLOWABLE DAMAGE LIMITS ARE ALLOWED IN THE SAME FRAME BAY.
- DO INSPECTIONS OF THE DENT WITH ONE OF THE PROCEDURES THAT FOLLOW:

1. DO AN INITIAL HFEC INSPECTION FOR CRACKS. IF NO CRACKS ARE FOUND, DO SUBSEQUENT HFEC INSPECTIONS FOR CRACKS OR CORROSION EVERY 1,500 FLIGHT CYCLES OR LESS. IF CRACKS OR CORROSION ARE FOUND, MAKE A PERMANENT REPAIR.
2. DO AN INITIAL DETAIL VISUAL INSPECTION FOR CRACKS. IF NO CRACKS ARE FOUND, DO SUBSEQUENT DETAILED VISUAL INSPECTIONS EVERY 250 FLIGHT CYCLES FOR CRACKS OR CORROSION UNTIL AN HFEC INSPECTION CAN BE DONE. ONCE AN HFEC INSPECTION IS DONE (AND NO CRACKS OR CORROSION ARE FOUND), DO SUBSEQUENT DETAIL VISUAL INSPECTIONS FOR CRACKS AND CORROSION EVERY 250 FLIGHT CYCLES OR LESS. ALTERNATELY, ONCE AN HFEC INSPECTION IS DONE (AND NO CRACKS OR CORROSION ARE FOUND), DO SUBSEQUENT HFEC INSPECTIONS FOR CRACKS AND CORROSION EVERY 1500 FLIGHT CYCLES OR LESS. IF CRACKS OR CORROSION ARE FOUND, MAKE A PERMANENT REPAIR.

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[H] FOR REDUCED VERTICAL SEPARATION MINIMUM (RVSM) CERTIFIED AIRPLANES, REFER TO SRM 51-10-03, FIG. 101, FOR LIMITATIONS IN THE VICINITY OF THE PITOT-STATIC PROBES.

[I] WRINKLES ARE PERMITTED IN THE AFT FUSELAGE IF:

- THEY ARE NOT ADJACENT TO CUTOUTS,
- THERE IS NO EVIDENCE OF CRACKS,
- THERE ARE NO LOOSE OR DAMAGED FASTENERS,
- THERE ARE NO SHARP CREASES,
- THERE ARE NO WRINKLES THAT GO INTO OR THROUGH FASTENER ROWS.

YOU MUST REPAIR FUSELAGE SKINS THAT HAVE:

- CRACKS
- LOOSE OR DAMAGED FASTENERS
- SHARP CREASES
- WRINKLES THAT GO INTO OR THROUGH FASTENER ROWS

AND YOU MUST DO INSPECTIONS OF THE ADJACENT STRUCTURE AS GIVEN IN AMM 05-51.

[J] DENT DAMAGE THAT IS APPLICABLE TO THE LIMITS GIVEN IN DETAIL III CAN BE REWORKED OR FILLED. REFER TO SRM 51-70-01.

[K] 0.015 INCH IF THE DAMAGE IS A MAXIMUM OF 10 INCHES IN LENGTH IN A 20 INCH BY 20 INCH SQUARE.

[L] AFTER YOU REMOVE THE DAMAGE ON ALUMINUM PARTS:

- MAKE SURE THE SURFACE FINISH OF THE BLENDED AREA IS 125 MICROINCHES OR BETTER.
- DO A DETAIL VISUAL INSPECTION OF THE BLENDED AREA TO MAKE SURE ALL THE DAMAGE IS REMOVED.
- APPLY A CHEMICAL CONVERSION COATING. REFER TO SRM 51-20-01.
- APPLY 1 LAYER OF BMS 10-79, TYPE III PRIMER OR EQUIVALENT TO THE EXTERNAL NON-POLISHED SURFACES. REFER TO SOPM 20-44-04.
- APPLY 2 LAYERS OF BMS 10-11, TYPE I PRIMER OR EQUIVALENT TO THE INTERNAL SURFACES. REFER TO SOPM 20-41-02.
- APPLY THE DECORATIVE FINISH TO THE REWORKED AREAS AS NECESSARY. REFER TO AMM 51-21.

Figure 64 Allowable Damage (3)

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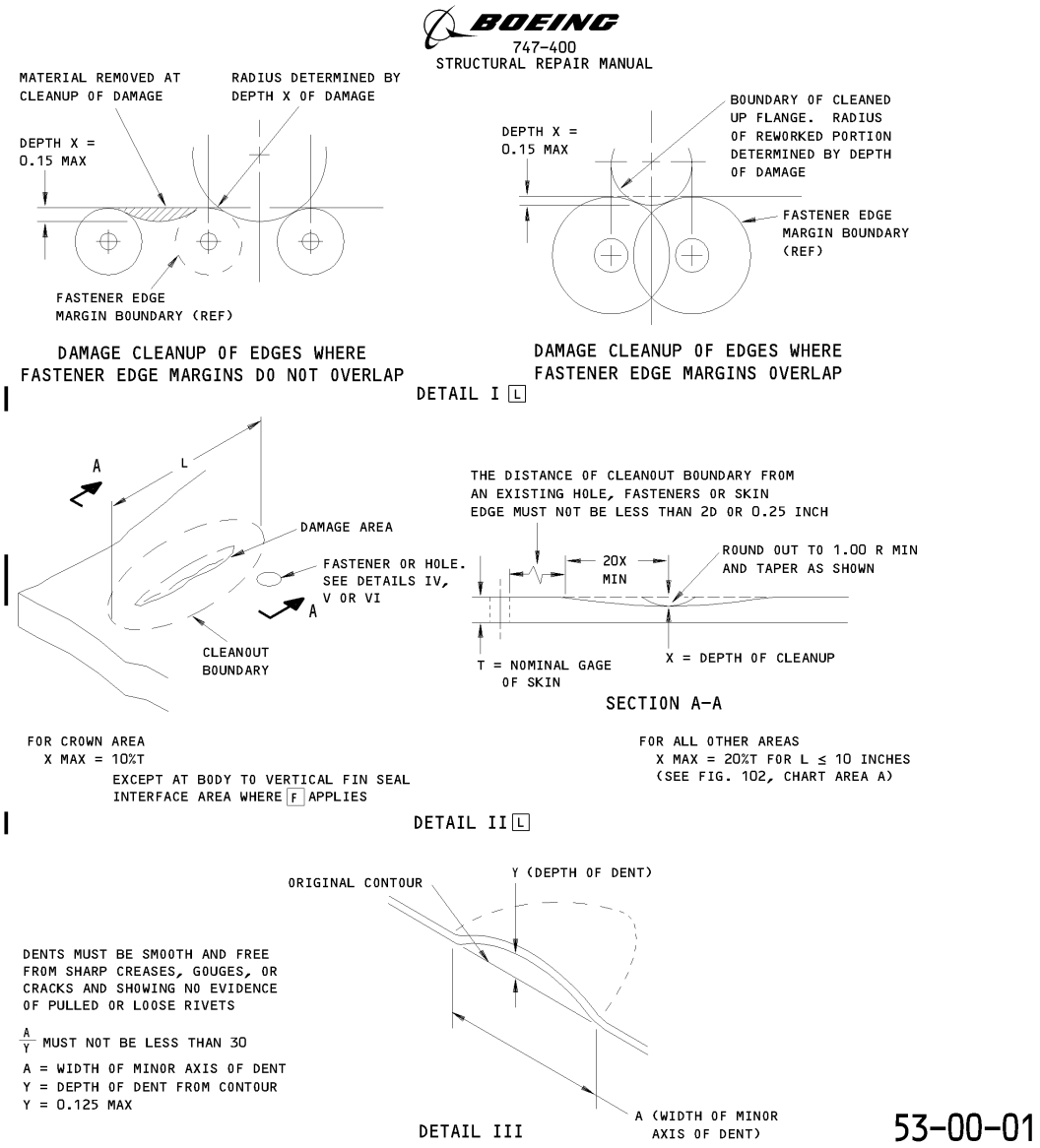


Figure 65 Allowable Damage (4)

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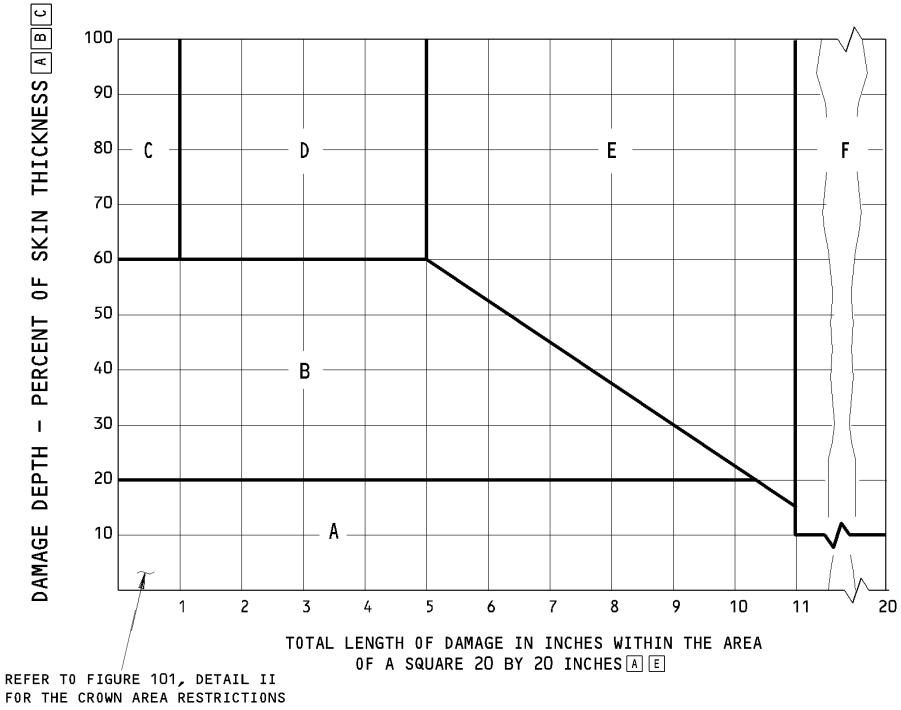
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NOTES

A DAMAGE INCLUDES CRACKS, NICKS, GOUGES, SCRATCHES, CORROSION, HOLES, AND PUNCTURES.

DAMAGE DOES NOT INCLUDE DENTS.

B THE SKIN THICKNESS DOES NOT INCLUDE THE THICKNESS OF ANY DOUBLERS, TRIPLERS OR STRAPS.

C THE PERCENT OF SKIN THICKNESS IS CALCULATED FROM THE NOMINAL THICKNESS GIVEN ON THE PRODUCTION DRAWING FOR THE SKIN. DO NOT USE THE "MINIMUM DRAWING THICKNESS" TO CALCULATE THE PERCENT OF SKIN THICKNESS.

D CABIN PRESSURE LIMITS ARE FOR SKIN DAMAGE TO THE PRESSURIZED FUSELAGE SKIN ONLY

E FOR DAMAGE AROUND FASTENERS, AT EDGE, LAP AND BUTT SPLICES, REFER TO FIGURE 101, DETAILS IV THRU VI.

Operating Limits for Fuselage Skin
Figure 102 (Sheet 1)

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CHART AREA	DAMAGE TREATMENT	ALLOWABLE AIRPLANE OPERATIONS
A	CLEAN UP AS SPECIFIED IN FIGURE 101	NO FLIGHT RESTRICTIONS E
B	CLEAN UP AS SPECIFIED IN FIGURE 101 TO DAMAGE DEPTH.	LIMITED TO 50 FLIGHT CYCLES INCLUDING REVENUE FLIGHTS.
	DO AN APPLICABLE REPAIR AS GIVEN IN SRM 53-00-01	REFER TO THE APPLICABLE REPAIR FOR THE LIMITS.
C	CLEAN UP AS SPECIFIED IN FIGURE 101 TO DAMAGE DEPTH. STOP DRILL 0.25 INCH DIAMETER HOLES AT THE ENDS OF CRACKS.	A NON-REVENUE FLIGHT TO A REPAIR STATION IS PERMITTED IF THE APPLICABLE REGULATORY AUTHORITY GIVES APPROVAL BEFORE THE FLIGHT. IT IS RECOMMENDED THAT THE PROPOSED REPAIR PROCEDURE BE GIVEN TO BOEING. THE MAXIMUM CABIN PRESSURE DIFFERENTIAL D IS LIMITED TO 5.8 PSIG UNLESS THE SKIN IS REPAIRED.
	DO AN APPLICABLE REPAIR AS GIVEN IN SRM 53-00-01.	REFER TO THE APPLICABLE REPAIR FOR THE LIMITS.
D	CLEAN UP AS SPECIFIED IN FIGURE 101 TO DAMAGE DEPTH. STOP DRILL 0.25 INCH DIAMETER HOLES AT THE ENDS OF CRACKS.	A NON-REVENUE FLIGHT TO A REPAIR STATION IS PERMITTED IF THE APPLICABLE REGULATORY AUTHORITY GIVES APPROVAL BEFORE THE FLIGHT. IT IS RECOMMENDED THAT THE PROPOSED REPAIR PROCEDURE BE GIVEN TO BOEING. THE MAXIMUM CABIN PRESSURE DIFFERENTIAL D IS LIMITED TO 5.8 PSIG UNLESS THE SKIN IS REPAIRED.
	DO AN APPLICABLE REPAIR AS GIVEN IN SRM 53-00-01.	REFER TO THE APPLICABLE REPAIR FOR THE LIMITS.
E	CLEAN UP AS SPECIFIED IN FIGURE 101 TO DAMAGE DEPTH. STOP DRILL 0.25 INCH DIAMETER HOLES AT THE ENDS OF CRACKS.	A NON-REVENUE FLIGHT TO A REPAIR STATION IS PERMITTED IF THE APPLICABLE REGULATORY AUTHORITY GIVES APPROVAL BEFORE THE FLIGHT. IT IS RECOMMENDED THAT THE PROPOSED REPAIR PROCEDURE BE GIVEN TO BOEING. THE MAXIMUM CABIN PRESSURE DIFFERENTIAL D IS LIMITED TO ZERO PSIG.
	DO AN APPLICABLE REPAIR AS GIVEN IN SRM 53-00-01.	REFER TO THE APPLICABLE REPAIR FOR THE LIMITS.
F	CLEAN UP AS SPECIFIED IN FIGURE 101 TO DAMAGE DEPTH. STOP DRILL 0.25 INCH DIAMETER HOLES AT THE ENDS OF CRACKS.	OPERATION IS NOT PERMITTED BEFORE BOEING AND APPLICABLE REGULATORS AUTHORITY GIVES APPROVAL.
	DO AN APPLICABLE REPAIR AS GIVEN IN SRM 53-00-01.	REFER TO THE APPLICABLE REPAIR FOR THE LIMITS.

Operating Limits for Fuselage Skin
Figure 102 (Sheet 2)

53-00-01
400.1 Page 113
Oct 20/03

Figure 66 Allowable Damage (5)

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Repairs

General

Within the ATA chapter 52 to 57 of the SRM special repairs for the here installed structural parts can be found in Page Block 201 - 999.

”Standard Repairs” however, like e.g. composite repairs, can be found in ATA chapter 51.

If there is no repair instructed at both places of the manual it means that the particular structure is not repairable.

It means that there was no reason for developing a standard repair for this part since there has not been a need to due to the operational experience.

In this case either a special repair is developed by the Boeing engineering or a replacement of the part is carried out.

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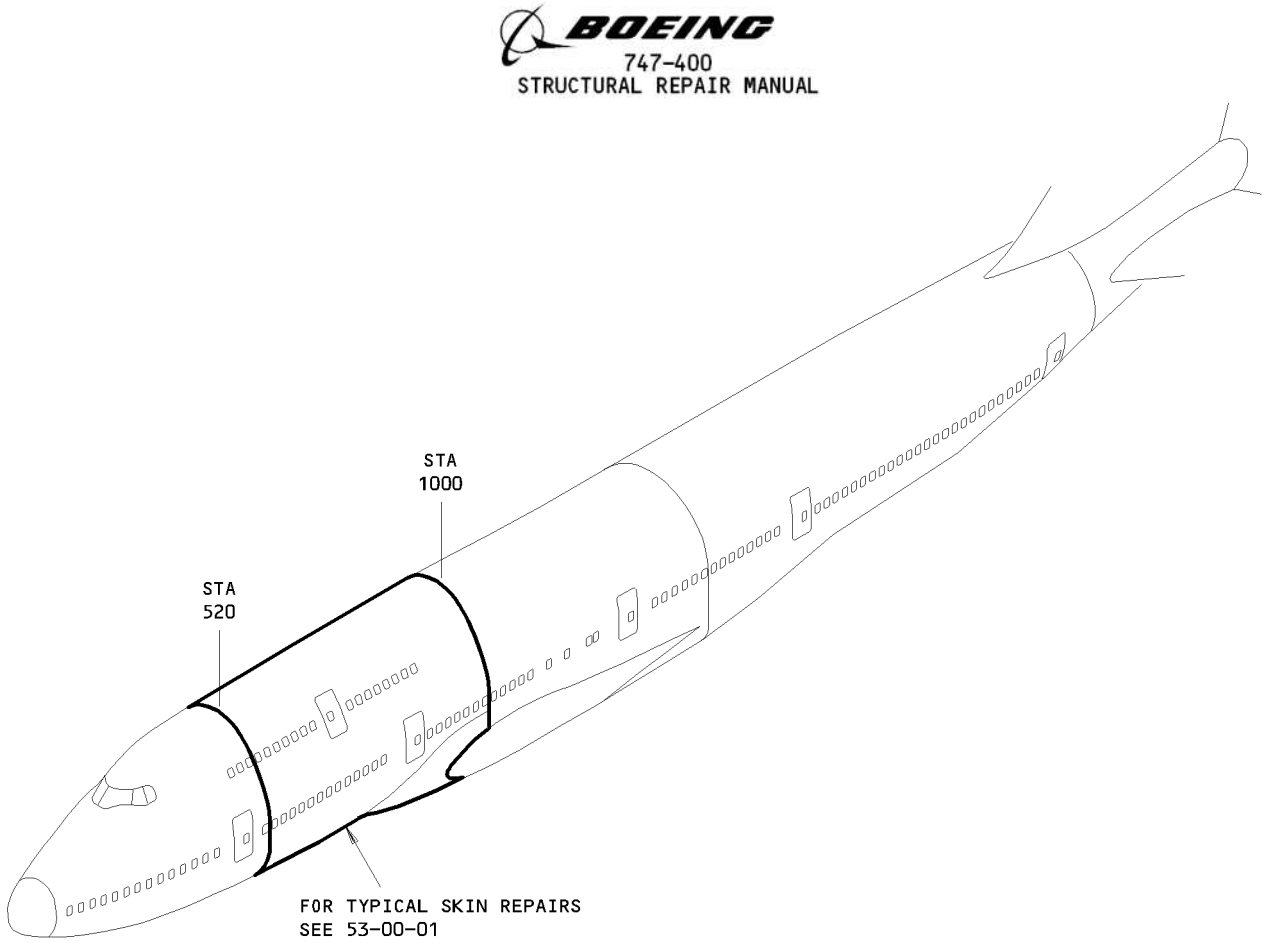


Figure 67 Repairs (1)

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REPAIRS (CONT'D)

References within the Repair Page Blocks

In the case of the example of the damaged skin, a reference is given in the corresponding page block 201 of the section 42 (so in 53–20–01, page block 201) back to the SRM chapter 53–**00**–01, page block 201.

Also here the aircraft manufacturer saves itself to describe the entire repair for every section of the fuselage.

General repairs are one again described in the prior chapter 53–**00**–01.

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BOEING
747-400
STRUCTURAL REPAIR MANUAL

REPAIR INSTRUCTIONS

1. Cut and remove the damaged portion of the skin.
2. Make the repair parts.
3. Assemble the repair parts and drill the fastener holes.
4. Remove the repair parts.
5. Break the sharp edges of the initial and repair parts to 0.015R to 0.030R.
6. Remove all nicks, scratches, burrs, sharp edges and corners from the initial and repair parts.
7. Apply a chemical conversion coating to the repair parts and bare edges of the initial parts. Refer to SRM 51-20-01.
8. Apply one coat of BMS 10-11, type 1 primer to all of part 2 and to the inner surface of part 1, and the bare edges of existing skin and part 1. Refer to SOPM 20-41-02.
9. Install the repair parts, making a faying surface seal with BMS 5-95 sealant. Install the hex-drive bolts wet with BMS 5-95. Refer to SRM 51-20-05.
10. Fill the gap between parts with aerodynamic smoother.
11. Restore the exterior and interior finish. Refer to AMM 51-21.

NOTES

- THE SOLID FASTENER REPAIR IS CATEGORY A AND NO SUPPLEMENTAL INSPECTIONS ARE NECESSARY IF THE FOLLOWING CONDITIONS ARE MET:
  a) THE LENGTH OF THE REPAIR DOUBLER IS LESS THAN OR EQUAL TO 17 INCHES.
  b) THE EXTERNAL VISUAL INSPECTIONS SPECIFIED IN THE BASELINE ZONAL INSPECTION PROGRAM (BZI) ARE DONE EVERY:
     - 2,400 FLIGHT CYCLES FOR THE UPPER LOBE (ABOVE THE MAIN DECK FLOOR)
     - 1,200 FLIGHT CYCLES FOR THE LOWER LOBE (BELOW THE MAIN DECK FLOOR).

  IF THIS REPAIR IS NOT CATEGORY A, THEN IT IS CATEGORY B. THE CATEGORY B REPAIR HAS FAA APPROVAL IF YOU DO THE SUPPLEMENTAL INSPECTIONS GIVEN IN TABLE III, OR THE REPAIR ASSESSMENT GUIDELINES, D6-36181. THE DAMAGE TOLERANCE ASSESSMENT OF THE REPAIR CAN BE DONE WITHIN THE TIME LIMIT SPECIFIED IN THE REPAIR ASSESSMENT GUIDELINES AFTER YOU RELEASE THE AIRCRAFT TO SERVICE. REFER TO SRM 51-00-06 FOR GENERAL DATA ABOUT THE REPAIR ASSESSMENT PROGRAM. REFER TO DETAIL II FOR THE INSPECTION AREA.
- THIS REPAIR WILL HAVE AN EFFECT ON THE INSPECTION OF THE STRUCTURAL SIGNIFICANT ITEM (SSI):
  - NUMBERS F-25K, L, AND M WHEN INSTALLED IN A LONGITUDINAL LAP SPLICE AREA, BUT THE EXTERNAL INSPECTION ALTERNATIVE FOR F-25K IS STILL APPLICABLE. CONTACT BOEING FOR INSPECTION ALTERNATIVES FOR F-25L AND M.

  DO THE EXTERNAL LOW FREQUENCY EDDY CURRENT (LFEC) INSPECTION FOR F-25K, AT THE SUBSEQUENT SUPPLEMENTAL STRUCTURAL INSPECTION DOCUMENT (SSID) INSPECTION ON THIS AIRPLANE. REFER TO SRM 51-00-04, FIGURE 3 FOR THE APPLICABLE SSI DATA.
- ALL DIMENSIONS ARE IN INCHES.
- IN SOME AREAS TWO LAYERS OF SCOTCH BRAND TYPE Y-436 PRESSURE SENSITIVE TAPE ARE INSTALLED ON INNER SKIN SURFACE FOR VIBRATION DAMPENING. THIS SHOULD BE REMOVED OVER THE AREA INVOLVED
- WHERE THIS REPAIR IS BEING USED IN A MACHINED SKIN, SHIMS MAY BE USED BETWEEN DOUBLER AND SKIN TO MAKE UP VARIATIONS IN THICKNESS
- WHEN YOU USE THIS REPAIR REFER TO:
  - AMM 51-21 FOR INTERIOR AND EXTERIOR FINISHES
  - SOPM 20-41-02 FOR APPLICATION OF CHEMICAL AND SOLVENT RESISTANT FINISHES
  - SRM 51-00-06 FOR REPAIR CATEGORIES, DEFINITIONS AND REPAIR ASSESSMENT PROGRAM DATA
  - SRM 51-10-01 FOR AERODYNAMIC SMOOTHNESS REQUIREMENTS
  - SRM 51-10-02 FOR INSPECTION AND REMOVAL OF DAMAGE AND ZERO-TIMING PROCEDURE
  - SRM 51-20-01 FOR PROTECTIVE TREATMENT OF METAL
  - SRM 51-20-05 FOR SEALING OF REPAIRS
  - SRM 51-40 FOR FASTENER CODE, REMOVAL, INSTALLATION, HOLE SIZES AND EDGE MARGINS

BOEING
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STRUCTURAL REPAIR MANUAL

NOTES (CONTINUED)

[A] SAME MATERIAL, ONE GAGE THICKER THAN THE GREATEST THICKNESS OF SKIN REMOVED

[B] IF POSSIBLE, DO NOT END THE REPAIR DOUBLER ON AN INITIAL FASTENER ROW. [C]

[C] IF ONE OF THE CRITICAL FASTENER ROWS HAS MORE THAN THREE INITIAL FASTENER HOLES, IN A SEQUENCE, THE THRESHOLD STARTS:
- FROM THE TIME THE REPAIR WAS INSTALLED, IF ALL THE INITIAL FASTENER HOLES IN THE CRITICAL ROW HAVE BEEN ZERO-TIMED
- FROM THE TIME THE AIRPLANE WAS DELIVERED, IF ALL THE INITIAL FASTENER HOLES IN THE CRITICAL ROW HAVE NOT BEEN ZERO-TIMED. IF THE TOTAL NUMBER OF AIRFRAME FLIGHT CYCLES IS MORE THAN THE THRESHOLD, THEN THE INSPECTION THRESHOLD IS 1,200 FLIGHT CYCLES AFTER THE REPAIR IS INSTALLED.

[D] SERVICE BULLETIN REQUIREMENTS SUPERSEDE THE SRM IF THEY ARE MORE CONSERVATIVE IN INTERVAL OR THRESHOLD FOR THE AREAS INSPECTED IN THE SRM.

[E] FOR ADDITIONAL BENEFITS IN INTERVALS, REFER TO REPAIR ASSESSMENT GUIDELINES, D6-36181.

FASTENER SYMBOLS

- REFERENCE FASTENER LOCATION
- REPAIR FASTENER LOCATION. SEE TABLE II FOR TYPE AND DIAMETER
- REPAIR FASTENER LOCATION. SEE TABLE II FOR TYPE AND DIAMETER

REPAIR MATERIAL			
PART		QTY	MATERIAL
1	FILLER	1	SAME MATERIAL AND GAGE AS INITIAL SKIN
2	DOUBLER	1	[A]

TABLE I

INITIAL SKIN GAGE	REPAIR FASTENERS	HORIZONTAL AND VERTICAL FASTENER SPACING	t TAPERED EDGE
0.040 TO 0.050	1	1.00 TO 1.20	0.03
0.056 TO 0.063	2	1.30 TO 1.35	0.04
0.071 TO 0.080	3	1.40 TO 1.50	0.05
0.090 TO 0.190	4	1.40 TO 1.50	5

TABLE II

1. BACR15BB5D RIVETS AT ALL REPAIR FASTENER LOCATIONS.
   OPTION: BACR15BB5D RIVETS AT LOCATIONS AND BACR15FV5KE RIVETS AT LOCATIONS FOR SKIN GAGE 0.050 ONLY
2. BACR15FV6KE RIVETS AT ALL REPAIR FASTENER LOCATIONS.
   OPTION: BACR15BB6D RIVETS AT LOCATIONS AND BACR15CE6D RIVETS AT LOCATIONS
3. BACR15FV8KE RIVETS AT ALL REPAIR FASTENER LOCATIONS.
   OPTION: BACR15BB8D RIVETS AT LOCATIONS AND BACR15CE8D RIVETS AT LOCATIONS
4. BACB30MY8K HEX DRIVE FASTENERS WITH BACC30M COLLARS AT LOCATIONS AND BACB30VU8K HEX DRIVE FASTENERS WITH BACC30BL COLLARS OR BACB30NW8K HEX DRIVE FASTENERS WITH BACC30M COLLARS AT LOCATIONS
5. t TAPERED EDGE = (1/2 X T DOUBLER) ±0.01

Figure 68 Repairs (2)

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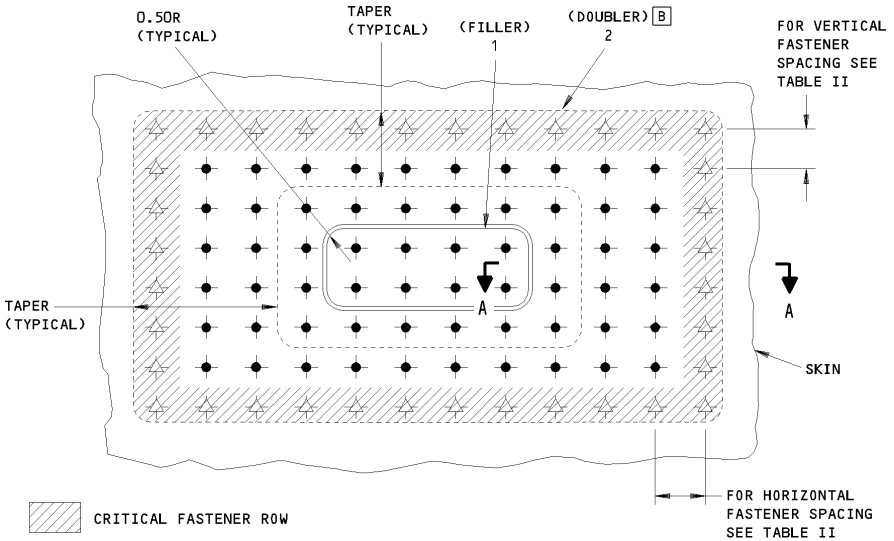
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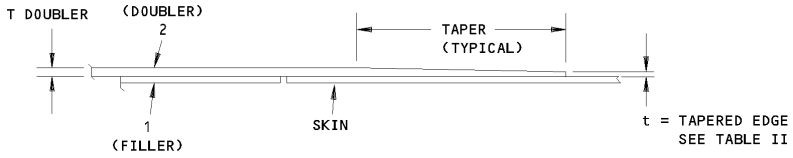
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SUBSEQUENT INSPECTIONS ARE NECESSARY FOR CATEGORY B REPAIRS. REFER TO TABLE III FOR INSPECTION REQUIREMENTS

DETAIL I



SECTION A-A

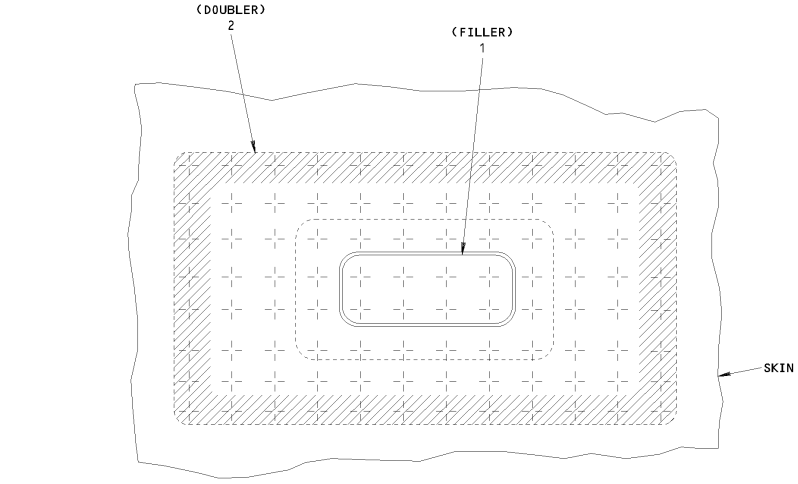
Fuselage Skin - Flush Repair Between Stringers
Figure 202 (Sheet 3)

53-00-01

400 Page 218
Jun 20/03

CATEGORY B REPAIR INSPECTION REQUIREMENTS D			
	REPEAT INSPECTION ALTERNATIVES		
	METHOD	INTERVAL E	REFERENCE
15,000 FLIGHT CYCLES C	EXTERNAL HIGH FREQUENCY EDDY CURRENT (HFEC)	6,000 FLIGHT CYCLES	NDT, PART 6, 51-00-00 FIGURE 4
	EXTERNAL DETAILED VISUAL	1,000 FLIGHT CYCLES	
NOTE: INSPECT THE SKIN AROUND THE FIRST ROW OF FASTENERS ALONG THE EDGE OF THE DOUBLER AS SHOWN IN DETAIL II. USE ONE OF THE ABOVE INSPECTION ALTERNATIVES.			

TABLE III



DETAIL II

Fuselage Skin - Flush Repair Between Stringers
Figure 202 (Sheet 4)

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Figure 69 Repairs (3)

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Ageing, Fatigue and Corrosion Control Programmes

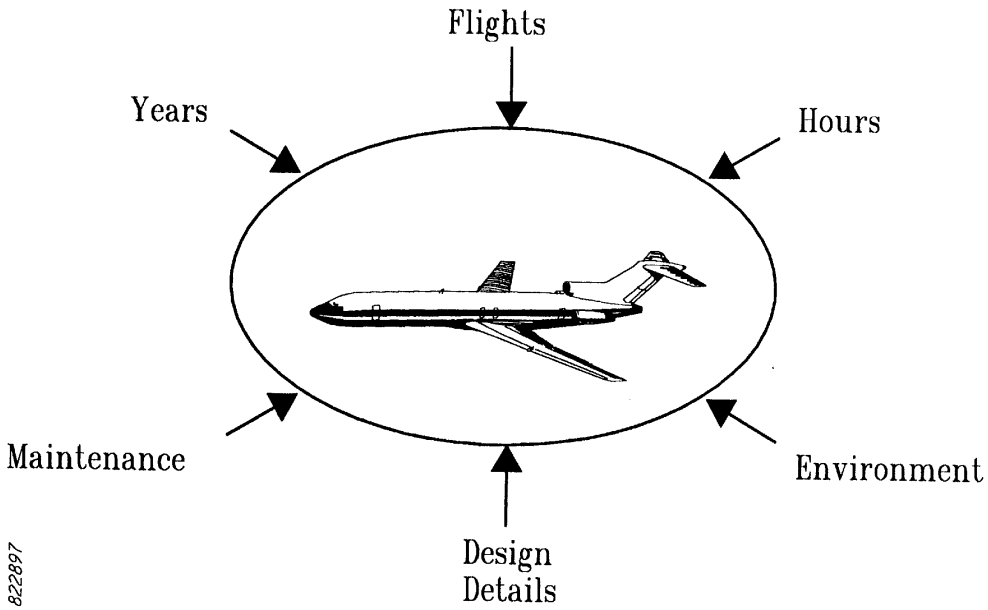
Ageing Aircraft/Fatigue

Many factors have influence on the structural strength and so the life of an aircraft. In a civil aircraft the main factor for fatigue is the number of flights, which every single aircraft makes. The characteristic of fatigue of many materials is very well investigated and can be forecast and proofed by tests quite exactly. But the structural strength is also influenced by many other effects, like e.g.:

- **Accidental damage**
- **Special Construction Details**
- **Maintenance Practices**
- **Repair Practices**

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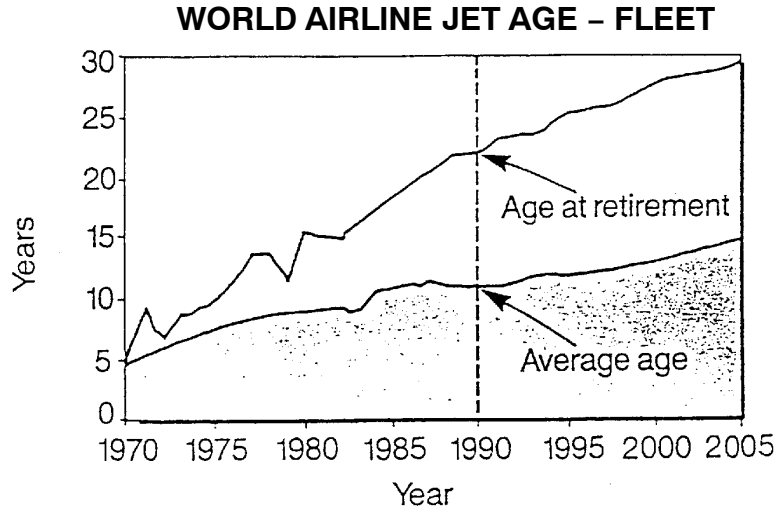


Figure 70 World Airline Jet Age-Fleet

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Fatigue Damage

Introduction

Structural parts are designed according to static and dynamical aspects in such a way that they can withstand certain loads without any permanent deformation or cracking.

The parts must not only withstand these loads one time, but over a period of many years with a number of 1000 to 2500 flights a year.

In this period the parts swing, tension or vibrate many million times, which causes very small cracks in an firstly entirely undamaged part. If these incipient cracks occur they widen steadily up under the recurrent loads. This phenomenon is called fatigue.

This weakening of structural parts can be accelerated by other damage types, like e.g. corrosion, drastically.

Detection of Fatigue Damages

When checking for fatigue, it is very important to recognize signs of incipient cracks. Especially in the early states it is very difficult to recognize fatigue by visual inspection. So especially for important structural parts periodical NDT inspections are specified. The applied method normally depends on the type of structural and the particular material.

In most of the cases fatigue damages can be recognized by small fissure or small cracks.

The structural parts at which fatigue damages can occur are determined through construction calculations, tests and operational experience. The time periods are defined in the particular documentation and specify the testing or even the replacement of the parts. These periods are normally defined according to the number of landings or to the measurement of the load recording instruments. Some materials and structural parts need a calendrical renewal or sample of testing.

Influencing Factors

It is important to know that structural parts underlie fatigue ahead of time if the parts are prestressed by unanticipated causes like damages or installation stresses. Also areas in which a concentration of stress does occur, like e.g. at fastener holes, component crossovers, cut-outs etc. can be places of early fatigue.

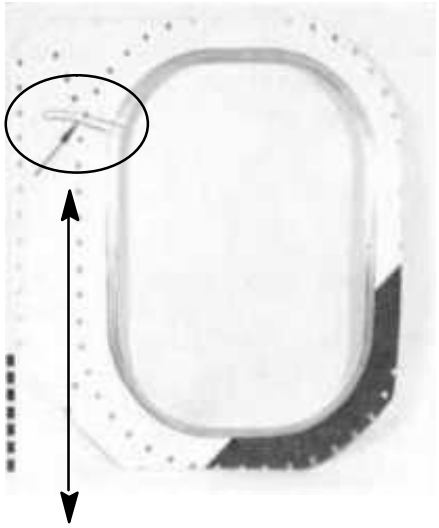
This is also valid for areas with slots like gouges, scratches, dents, corrosion, wear-outs etc., since also here stress concentration does occur.

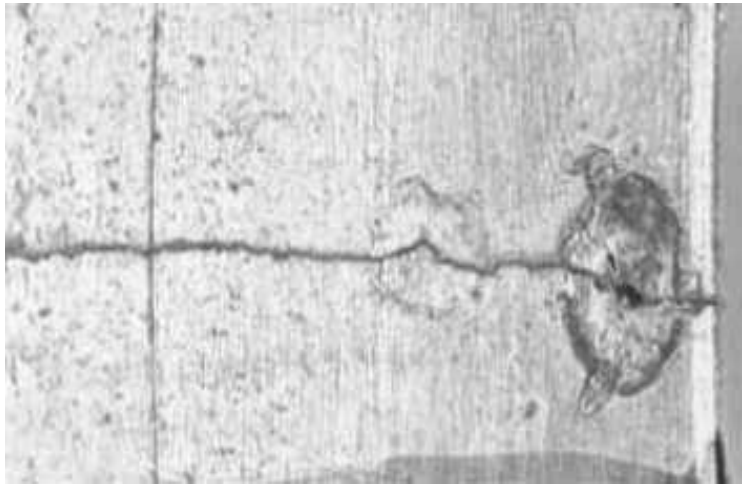
CAUTION: INCORRECT INSTALLATION CAN DECREASE THE FATIGUE LIMITS DRASTICALLY. DURING TESTS IT WAS FOUND THAT A STRUT WITHSTANDS ONLY A FRACTION OF HIS NORMAL LIFETIME IF A STRESS CONCENTRATION IS EXISTENT WHICH WAS CAUSED BY A TOOL SCRATCH IN A FASTENER HOLE. THE SCRATCH ACCELERATES THE FATIGUE IN THE STRESSED PART CLEARLY.

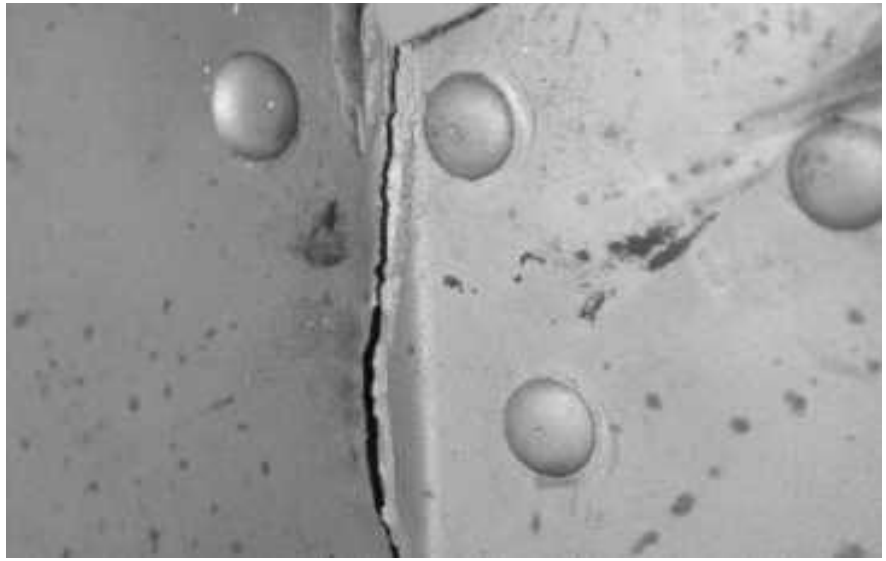
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Crack emanating from lightning strike







Stress Cracking

Figure 71 Defect Examples

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Dynamic Loads

Fatigue Stress

Most of the parts in the aircraft are stressed with changing loads. The load swings between two constant limits, the so called fatigue stress.

The general case is an absolutely irregular changing load.

So most of the breakage of structural parts are not fast fractures with their typical signs (lateral contraction and so on), but fatigue fractures without deformation and under loads which are in the limits of the maximum load.

The fatigue fracture, a process which takes a longer time until complete breakage, begins with a loosening of the grains' cohesion at the highest stressed location, caused by changing loads. Initially a small finite fissure does emerge, which causes local stress concentration due to the notch effect. So the crack starts to widen step by step until the remaining section can not withstand the static load and the process is ended by a fast fracture.

Emerging of a Fatigue Fracture

Due to stress peaks in some locations, plastic deformation with cold work hardening and brittleness does occur. It starts at the surface because the grains there:

- underlie higher stresses,
- are easier deformable than grains inside the material,
- can maybe chemically react with the environment.

Possible Starting Points for a Fissure can be

- Defects in the material (inclusions)
- Surface damages (scratches, dents, machining score,...)
- Designed notches (slots, holes,...)

Alternating Load Tests

over a long period give information about the dynamic strength of a material. In these tests a part of the material is exposed to permanently changing loads.

The S/N Curve

The characteristic of fatigue can be explained the easiest way with the S/N curve. Therefore this will be divided into two areas:

- **Fatigue Strength for Finite Life:**

  The stress is so high that the material breaks after a certain number of load alternations.

- **Fatigue Strength for Infinite Life:**

  The stress is so small that the material can withstand theoretically infinite load alternations.

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S/N Curve for Aluminium-Zinc Alloy. 3.4364-T62 / 7075-T62

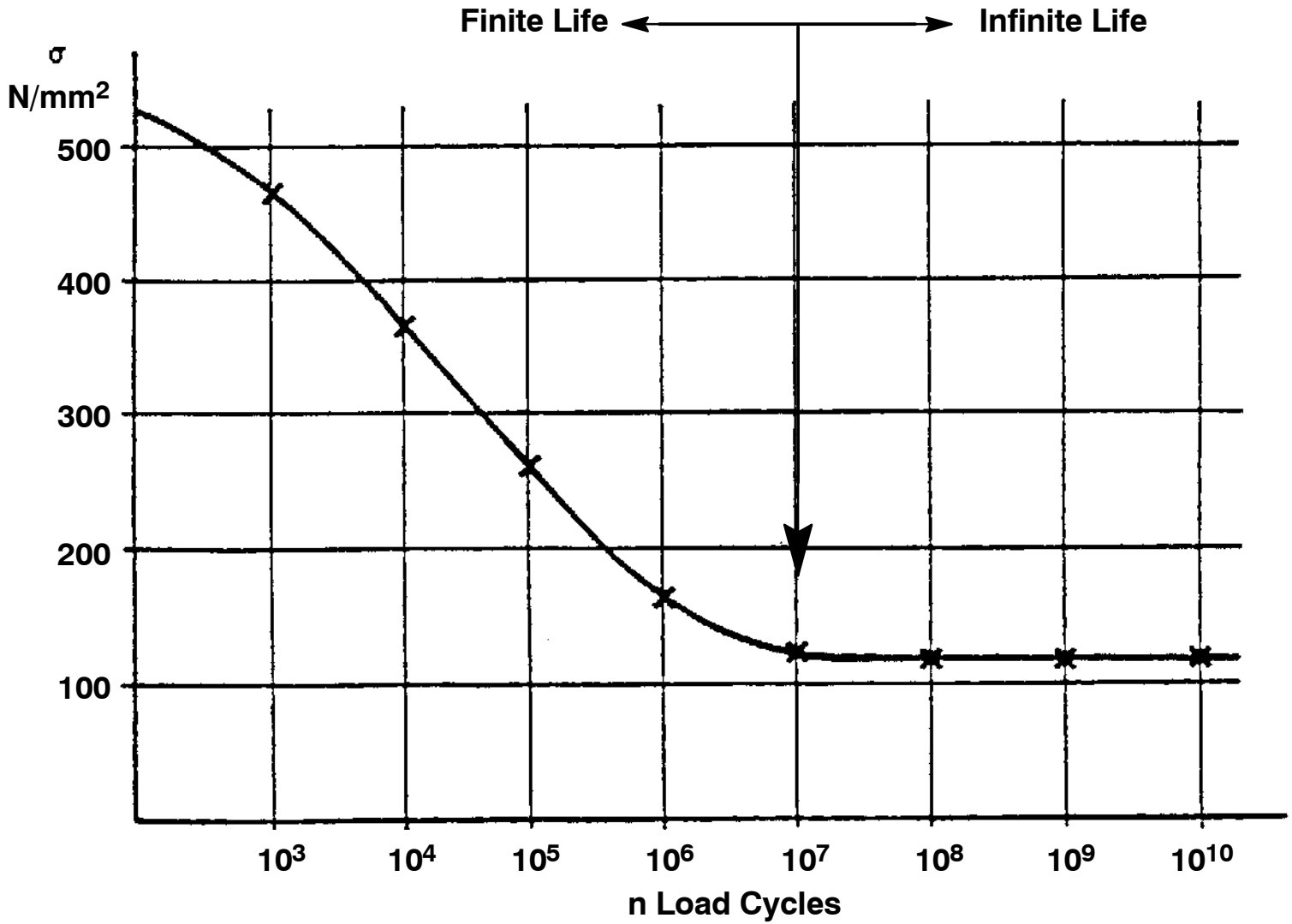


Figure 72 S-N-Curve

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Crack Propagation

Crack Propagation and Crack Propagation Resistance

In modern aircraft the lifetime of the structure is very important. An emerging crack should be widening up preferably slow to detect it in time during a check.

Influence of the Material State on the Crack Progagation

The higher the ductility of the material, the higher is the resistance against crack propagation. A crack grows in a sheet of 7075 material with the triple higher speed than in a sheet of 2024.

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Crack Propagation

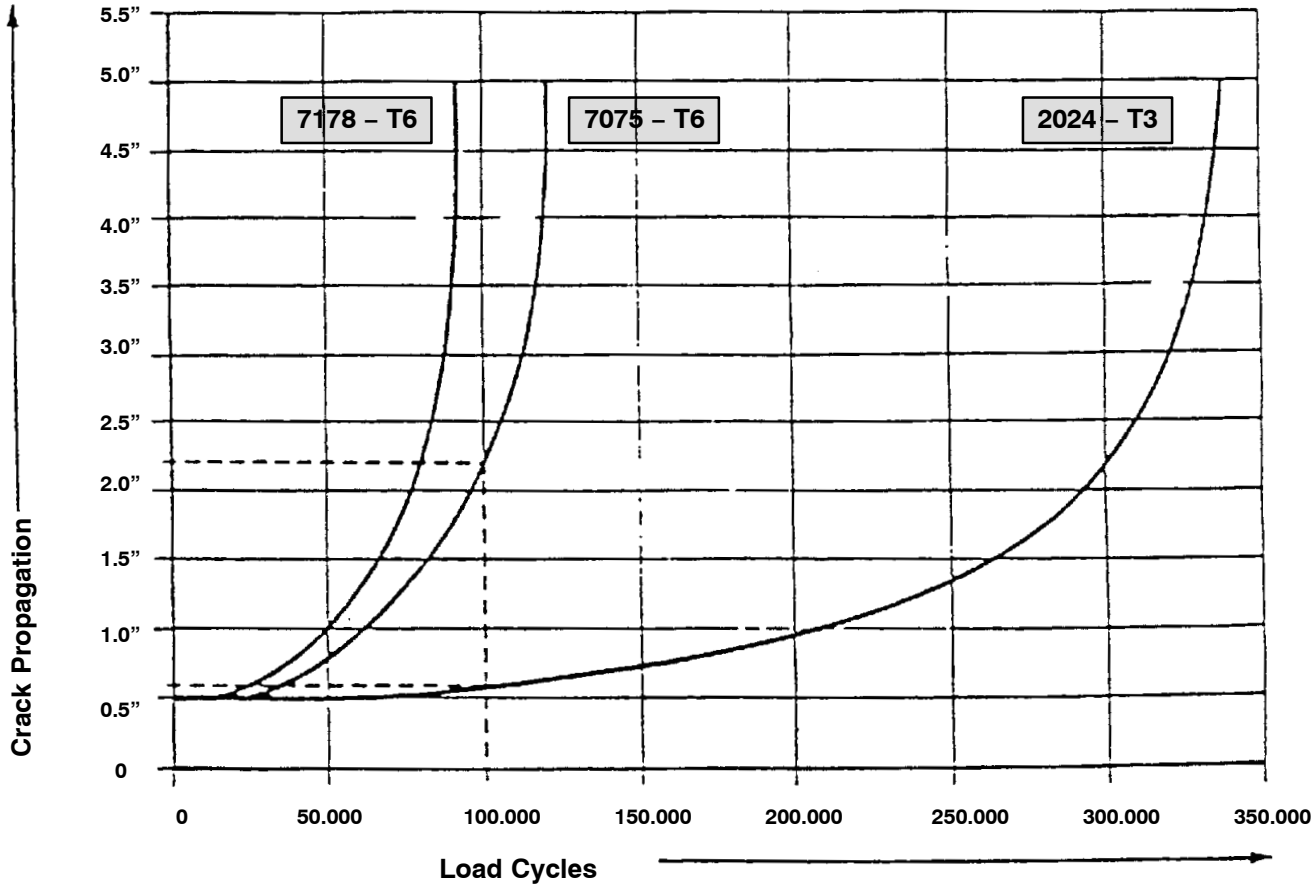


Figure 73 Crack Propagation

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Improvement of Fatigue Strength

General

In the following paragraphs different methods for increasing the fatigue strength are listed. These methods are already partially applied in the aircraft production process, but sometimes only in a repair case.

The effect of these methods does always intend to counteract the tensile stresses in the critical areas, which lead to fatigue cracks, with compression stresses in a well defined magnitude. If the particular procedure is well applied the fatigue limit can be increased enormously. In the case of cold work hardening of holes the factor is 20!

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FATIGUE PERFORMANCE
7075 – T6 ALUMINIUM TEST SPECIMENS

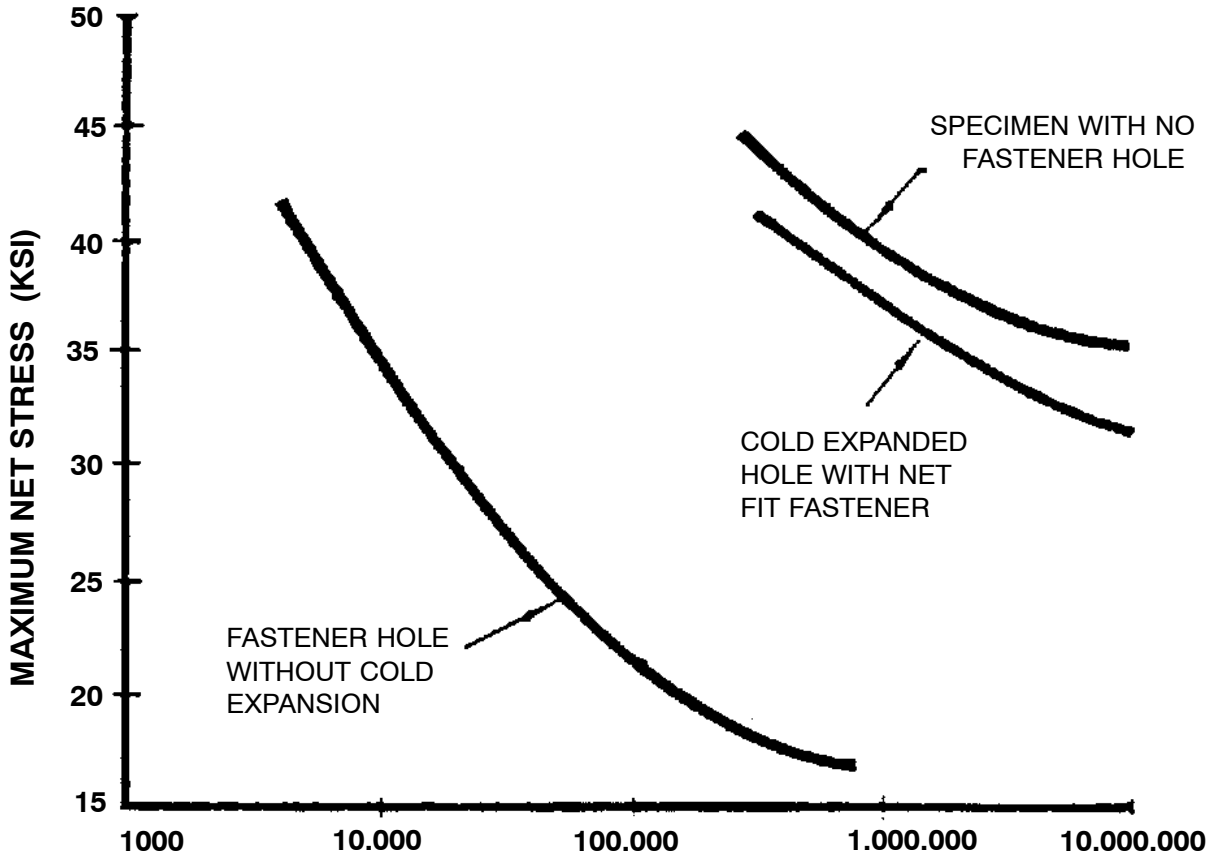


Figure 74 Fatigue Performance (7075–T6)

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IMPROVEMENT OF FATIGUE STRENGTH (CONT'D)

Taper Loks

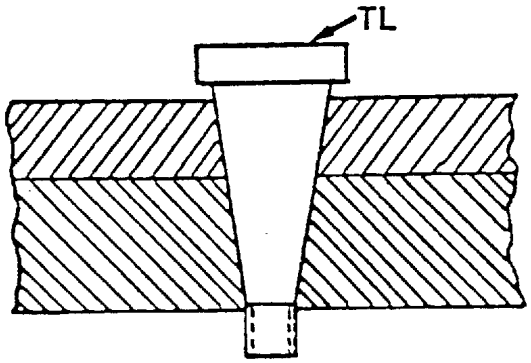
The hoop stress in the hole's wall increases the fatigue limit, the hole is elastically expanded.

This elastic compressive prestressing should be larger than the tensile stress caused by operational loads. In this case the installation area stays free of deformation and fatigue.

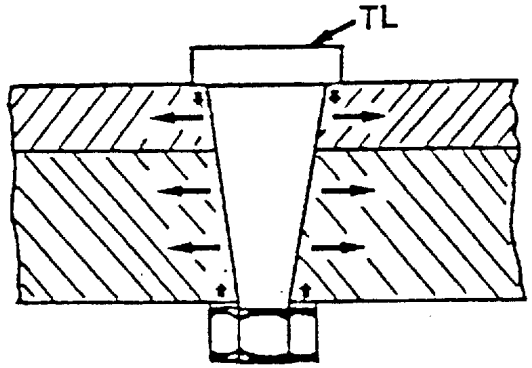
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Taper Lok is only put into the hole



Taper Lok is torqued



Hoop stress (compressive stress) in the hole wall

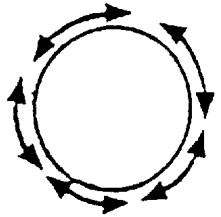


Figure 75 Fatigue Improvement Methods

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IMPROVEMENT OF FATIGUE STRENGTH (CONT'D)

Cold Work Hardening of Holes (Enlarging with Mandrel)

Cold work hardening of holes improves the lifetime of metal structures by pretensioning the metal in the border area of critical fastener holes.

With the help of a tensile mandrel a permanent compressive stress is created in the hole's wall. This is done by a ductile enlargement of the hole.

The introduced compressive stresses reach from the hole wall over an area which is about half the hole diameter into the material. During drifting the hole size is increased about 3–5%.

The introduced compressive stresses must firstly be exceeded by the operational loads to create fatigue critical tensile stresses. If the method is applied the right way a hole that is enlarged by a mandrel is far more resistant against alternating loads.

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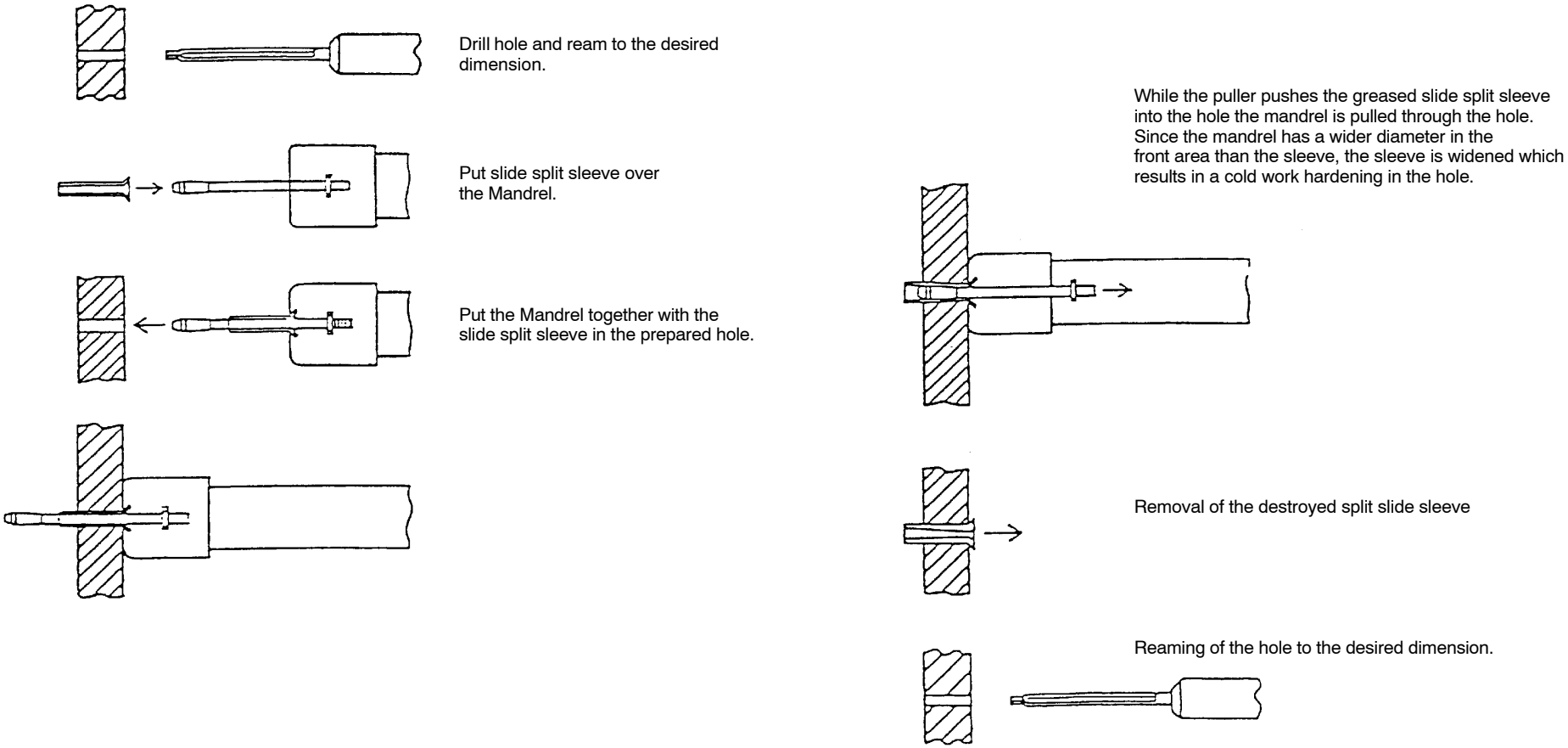


Figure 76 Cold Work Hardening of Holes

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IMPROVEMENT OF FATIGUE STRENGTH (CONT'D)

Shot Peening

A procedure for introducing compressive stress into surfaces to improve the fatigue limits.

Wolfram-carbide-shots are blasted with high velocity onto the surface of the part. So they deform the surface plastically and introduce compressive stress into the lower material layers. For this reason a tensile stress caused by operational loads is smaller in the shot peened areas, which decreases the risk of cracking.

This procedure is mainly applied for high stressed component sections made out of 2024, 7075 and 7178.

Shot peening is also adequate for non-cutting deformation of sheet material.

Flap Peening (Roto Peening)

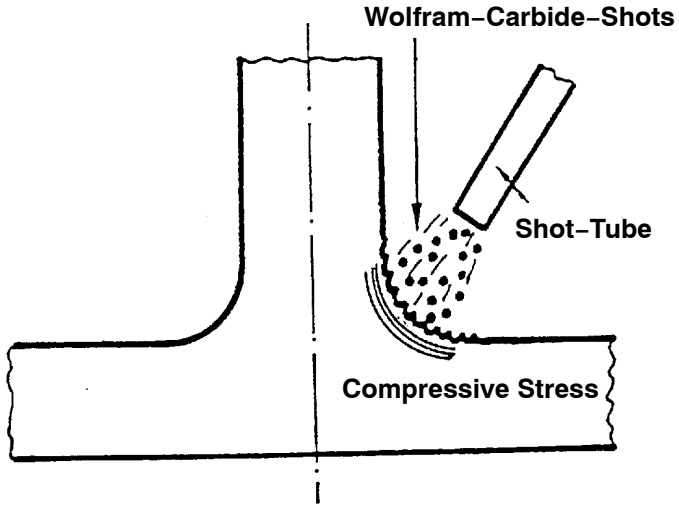
A procedure for introducing compressive stress into surfaces to improve the fatigue limits.

The effect is the same like during shot peening, but more concentrated on local areas and therefore especially suitable for already installed components:

- The shot carried out with a rotating flap.
- The advantage over shot peening is the mobile and clean application.
- Flap peening can also be applied to holes over ca. 25 mm.
- This procedure is nearly exclusively used for AL alloys.

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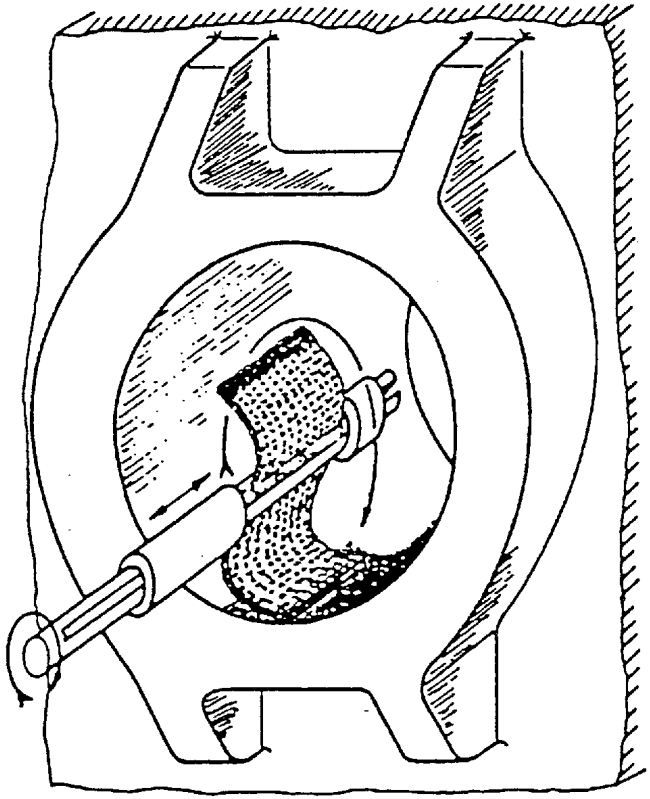


Figure 77 Peening Process

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Aircraft Corrosion Control

The Corrosion Prevention and Control Program

While problems with fatigue are predictable and largely controllable and can so be taken into account in the design phase by the manufacturer, the prevention of corrosion damages is mainly the in the responsibility of the aircraft owner and his corrosion prevention program.

Since the coaction of corrosion and fatigue impairs the lifetime prediction an important point for keeping up the continuous airworthiness during the ageing process appeared.

A nearly dramatically worldwide increase of corrosion damages has been discovered since the 1980. At this time many aircraft of the first ”Jet-Generation” changed their owner.

The aircraft were suddenly exposed to other operational and environmental conditions, whereas the maintenance procedures which were valid until that time were not adjusted to the new conditions.

Also the minset of some owner reached only so far to resign the **natural phenomenon** *”corrosion”*.

In order to detect corrosion caused ageing of aircraft it was necessary to develop a special control program (CPCP-Corrosion Prevention and Control Program).

For application of the CPCP on a particular aircraft type of the own fleet the operational and environmental conditions are particularly important.

This means especially:

- salty air
- industrial pollution, which can also rise up to higher altitudes
- transported cargo

To stop corrosion already at the beginning or to entirely prevent it the cleaning, inspection, conservation and greasing intervals have to be strictly met.

Immediate removal of corrosion after detection essentially increases the lifetime of an aircraft.

The following points should be a guideline for a successful implementation of the CPCP-mindset:

- the maintenance personnel should have fundamental knowledge about types of corrosion, origins of corrosion, cleaning and conserving (corrosion protection)
- the maintenance personnel should have basic knowledge about corrosion removal techniques
- periodical corrosion inspections on the basis of a exactly defined maintenance program
- periodical washing of aircraft (also in unpainted areas)
- keeping drain holes free
- check on the existence of anti-corrosion agents in the structure and if necessary the addition of these according to defined inspection plans
- immediate removal of corrosion after detection
- early detection of surface protection damages and restoration of the surface
- exact **documentation of all** CPCP works, like e.g. materials, tools, auxiliary menas and manuals or other technical instructions

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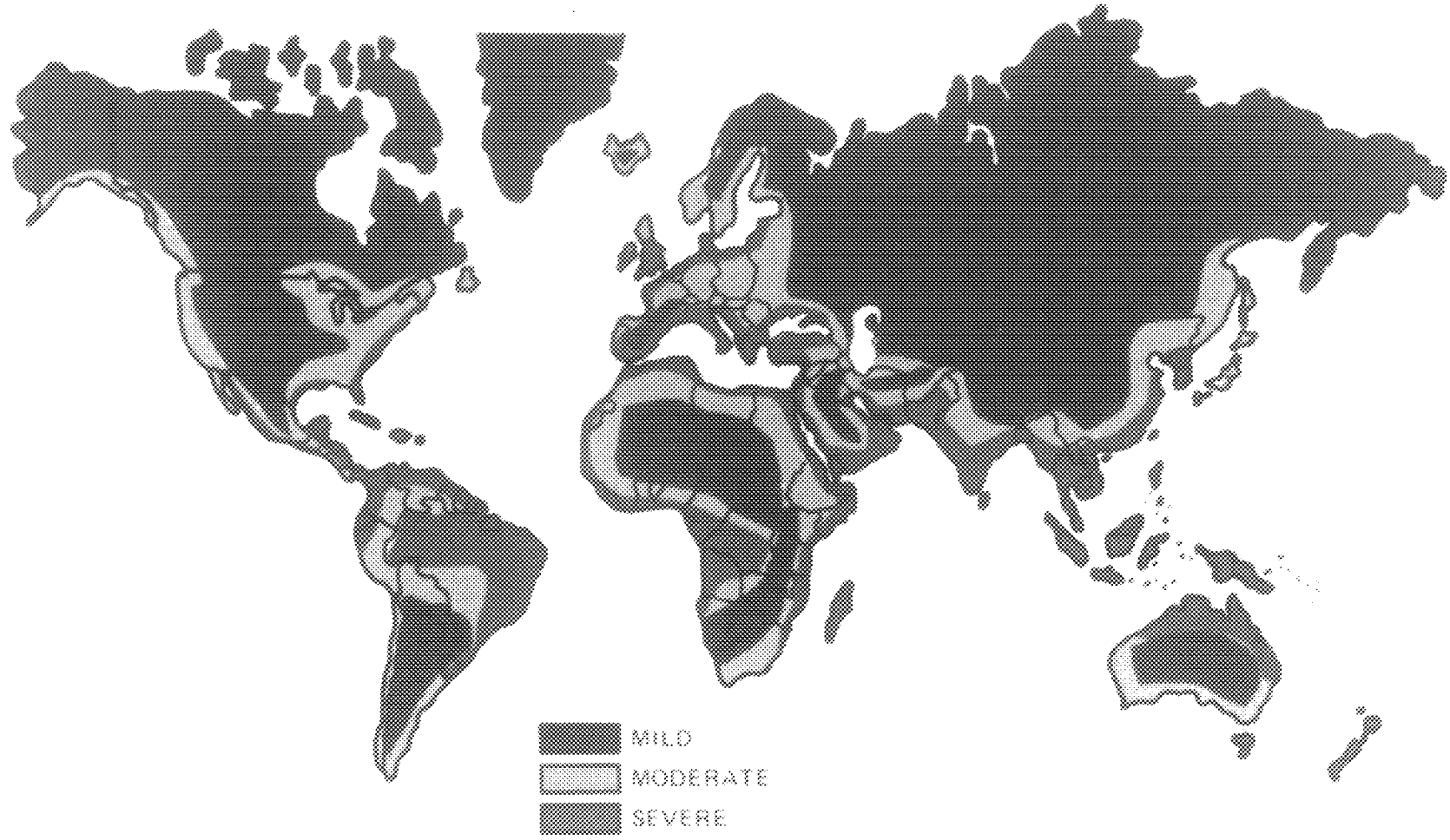


Figure 78 Corrosion Severity Zones

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CPCP History

The Aloha Accident

Already in the past some incidents put the focus of the aeronautical authorities on the topic of airworthiness of ageing aircraft.

One key event for the introduction of the CPCP was an accident at the 29. of April 1988 during which a Boeing 737 of Aloah Airlines lost a 5,5m large part of the upper fuselage structure due to corrosion in coaction with fatigue.

The aircraft was with a number of 89.680 flight cycles (FC) one of the longest-serving aircraft worldwide and had the second largest number of flight cycles in the worldwide B737 fleet. After this disaster a discussion was rising up if aircraft should be sorted out after a certain lifetime and so should be scrapped.

At last it was agreed to inspect older aircraft more penetrantly with an improved inspection program and introduced per airworthiness directive (AD–Note) the CPCP.

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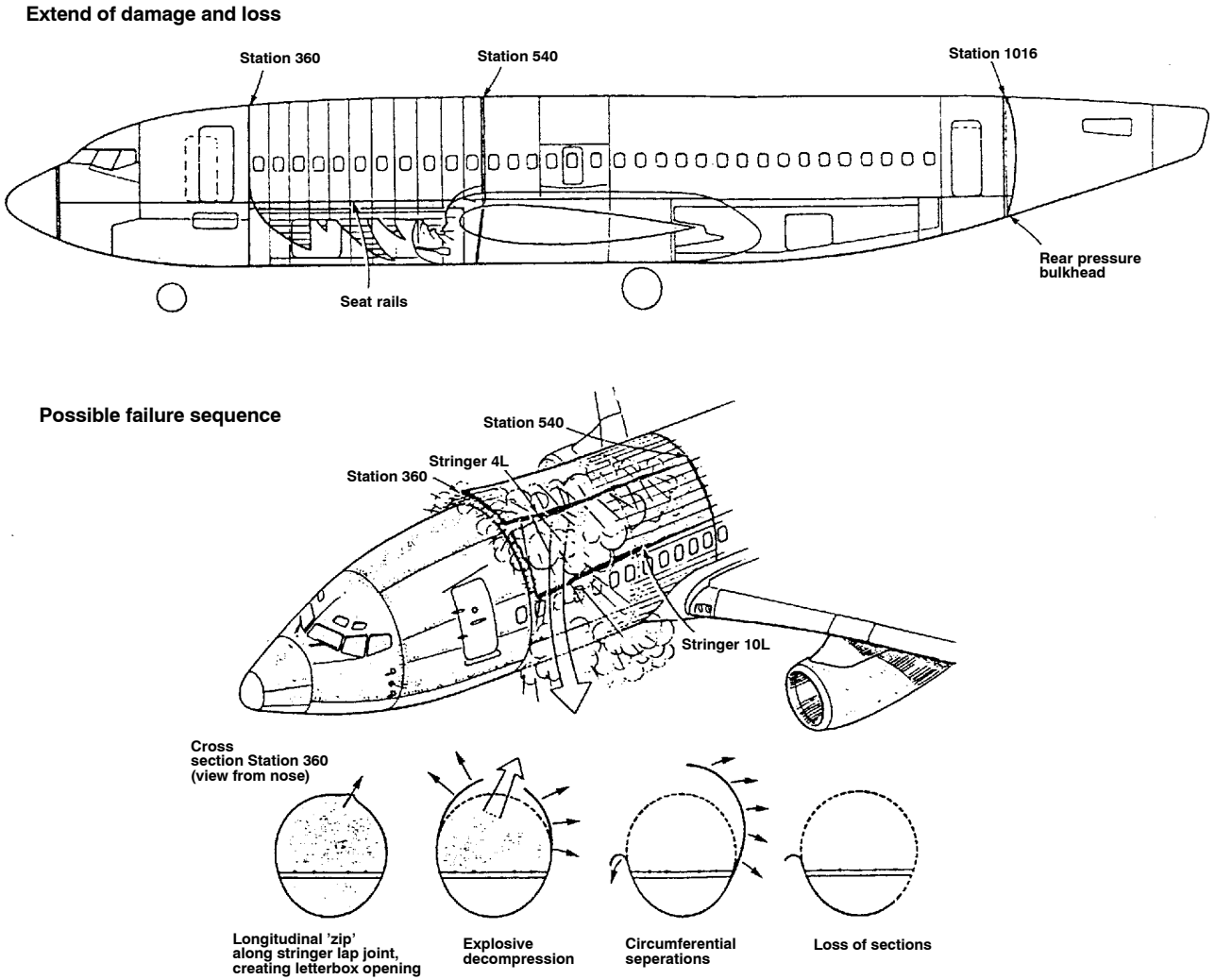


Figure 79 The Aloha Desaster

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Corrosion Prevention

General

A close contact between airlines, authorities and manufacturer is the most important thing for a successful implementation of the compulsory corrosion program.

The airworthiness of aircraft is in the hands of:

- Authorities (FAA, LBA)
- Manufacturer
- Aircraft owner/operator

The authorities provide the safety standards and supervise the fleet.

The manufacturers design durable, safe aircraft which can be maintained and overhauled without excessive complexity.

The Airlines should provide adequate maintenance, inspections and repairs of aircraft.

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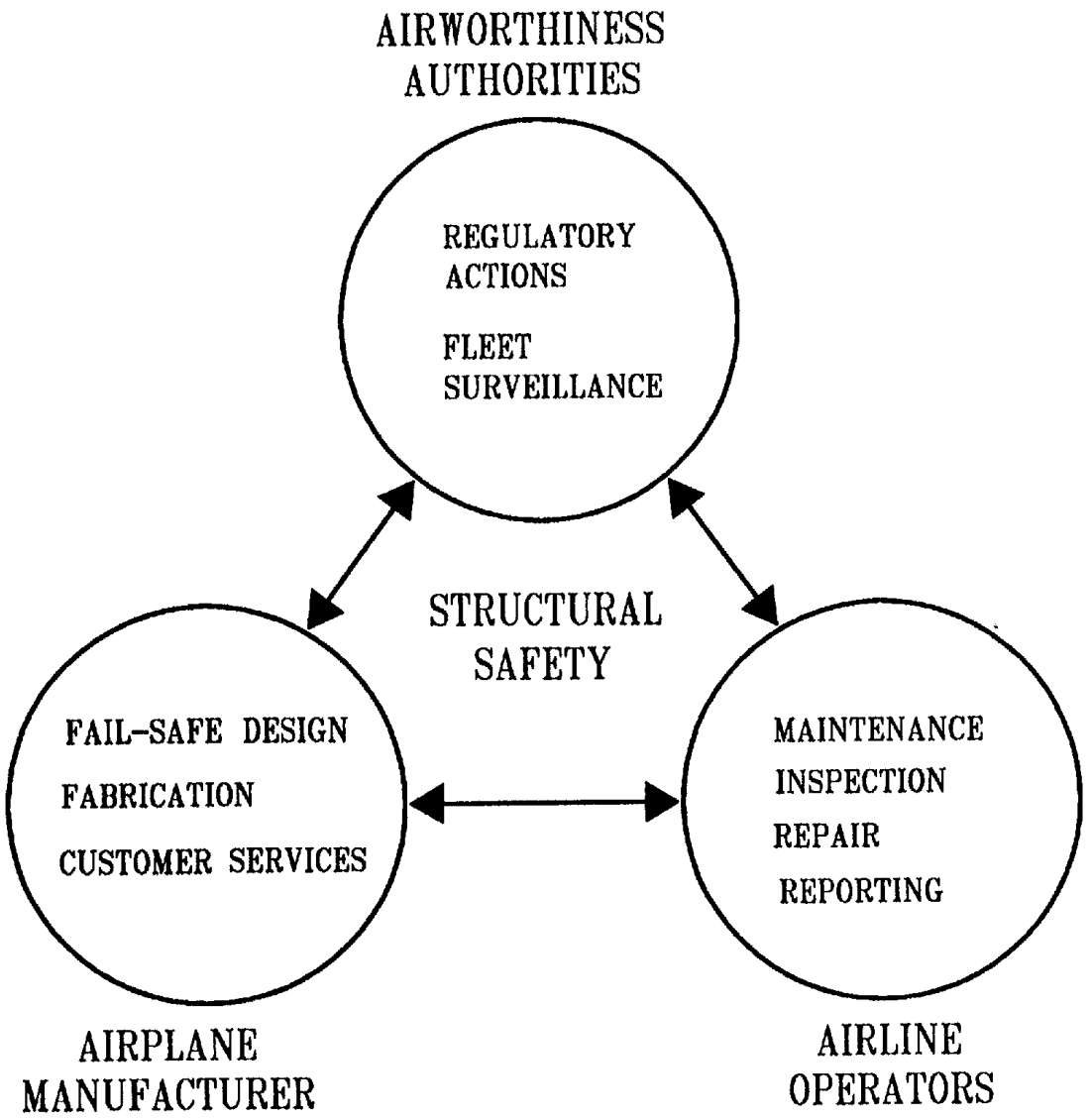


Figure 80 Corosion Prevention

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Accident Statistics

The success of this system is proofed by a look at the statistics which shows that only 3% of all aircraft accidents are caused by structural problems.

Despite that efforts have been made for further improvements of this system. Especially since accidents, which have technical and in particular structural reasons, shatter the trust in aircraft as a means of transportation.

The starting point for the introduction of the CPCP was the Aloha accident in April 1988. After rejecting the claim for a retirement of aircraft above a certain age, they agreed to put older aircraft under an improved control program and introduced the CPCP at the 01.01.1989 per airworthiness directive (AD-Note).

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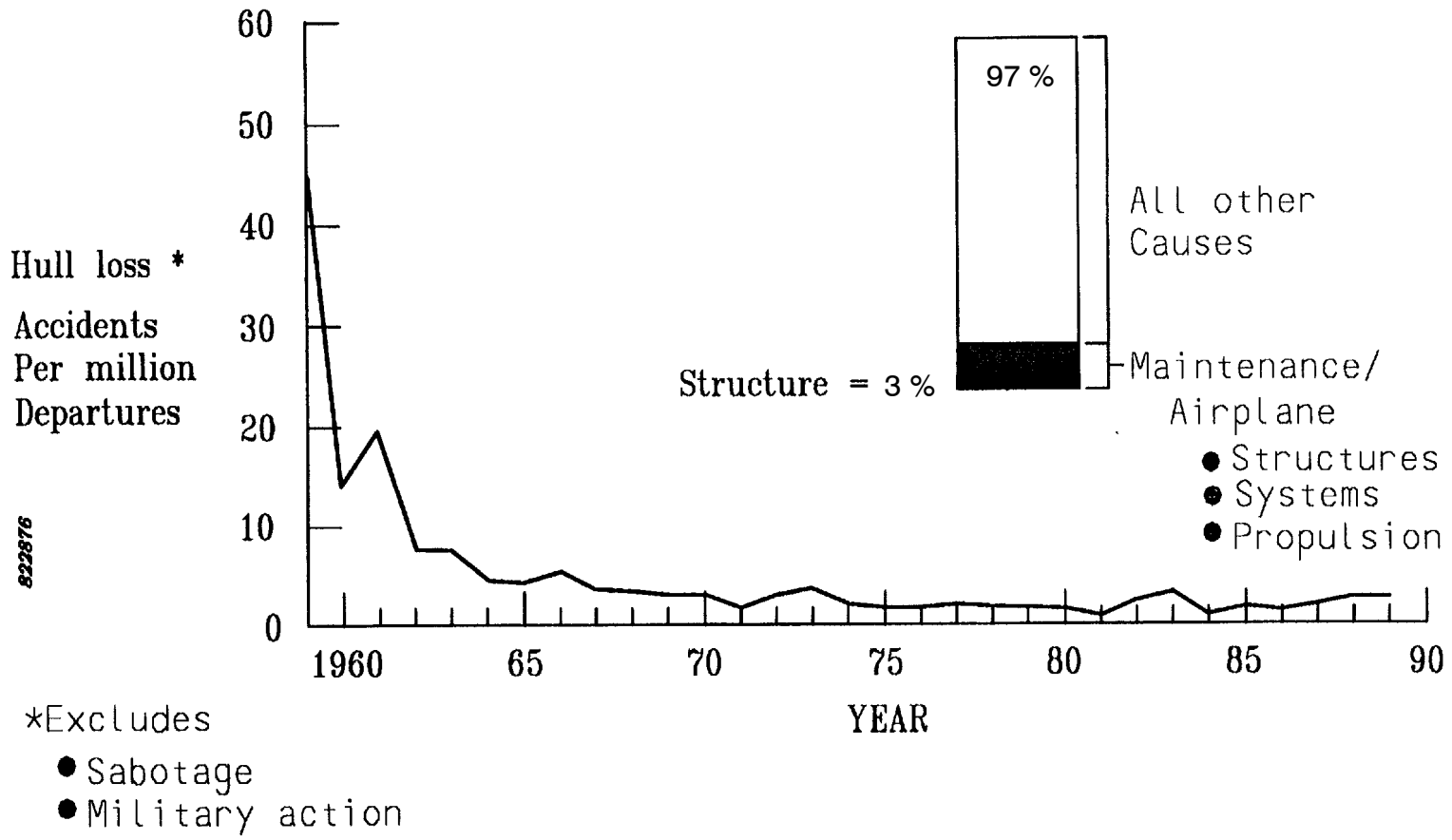


Figure 81 Structure Failure Statistics

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Which Factors have Influence on the Stability of an Aircraft?

Many factors affect the structural stability of an aircraft.

The older an aircraft gets, the more inefficient is the operation of it. These aircraft are then sold by big established airlines to small airlines which are probably unexperienced with the aircraft type. Furthermore they may not have qualified staff to operate their ”new” aircraft in a safe way.

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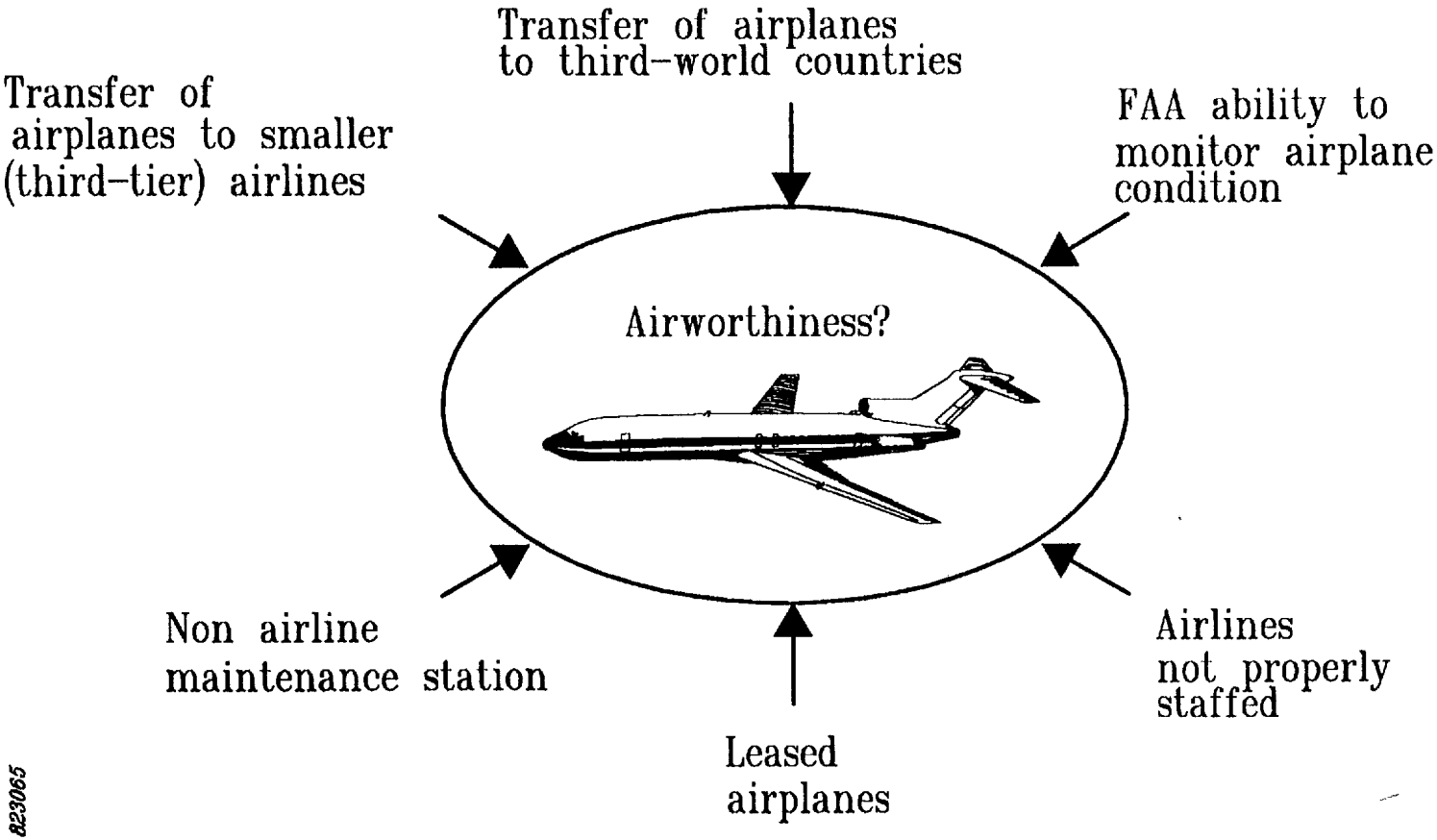


Figure 82 Influence on Airworthiness

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Present Corrosion Prevention Programs

Firstly the continuous development and improvement of existing aircraft types by the manufacturer must be named.

Like depicted in the figure opposite, the aircraft manufacturer have been working hard steadily on the corrosion protection by enhanced surface protection systems and improved aluminium alloys.

The permanent improvement is still present and is applied during overhaul, modification and repair.

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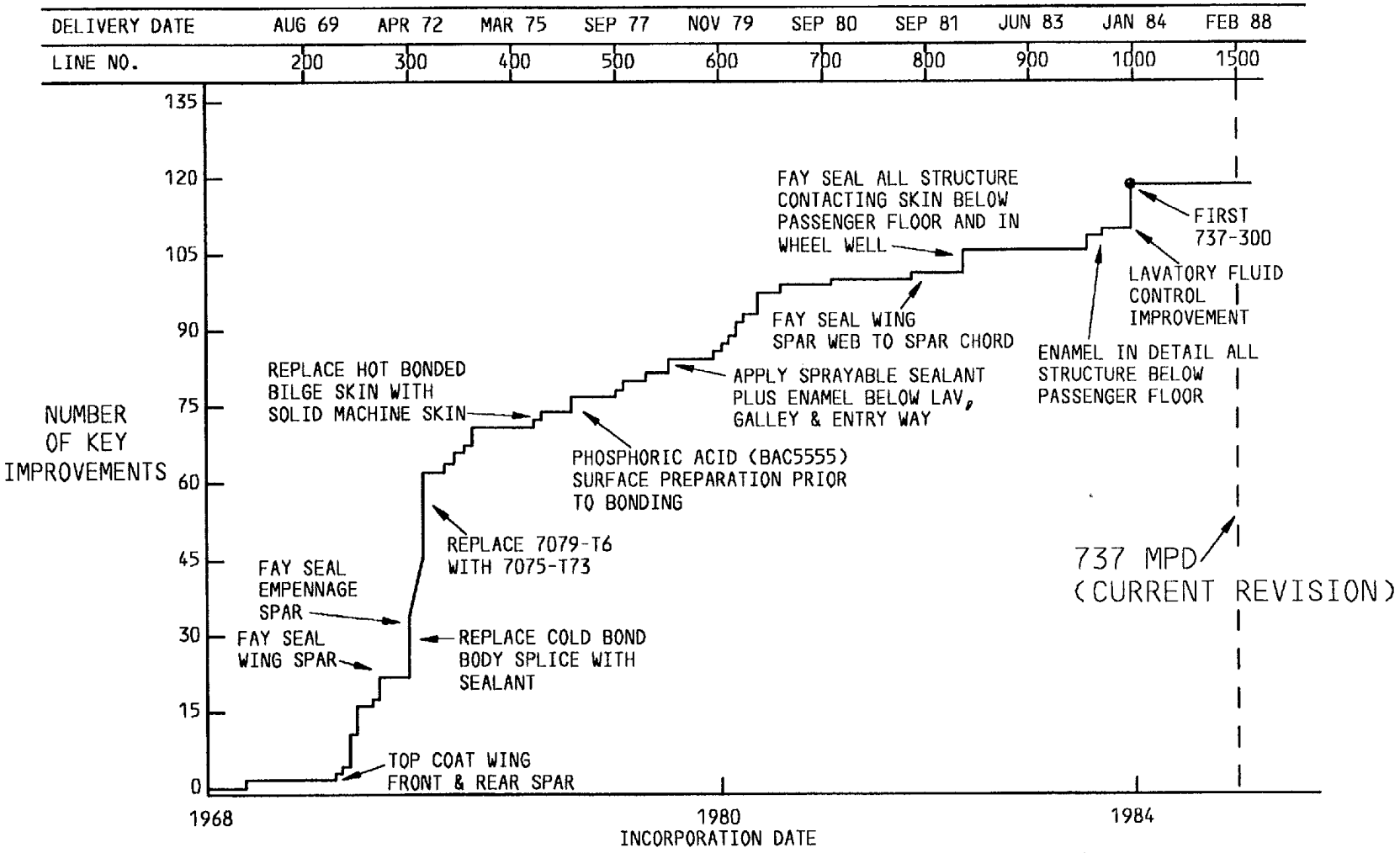


Figure 83 Life Improvement Methods

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Supplemental Structural Inspection Program

Das SSI-Programm

Das SSI-Programm gibt es seit 1979 für die verschiedenen Flugzeugmuster. Hierbei werden die Kontrollen aber nur an speziell ausgesuchten Flugzeugen durchgeführt (High Flight Cycle Airplanes). Wenn bei diesen Kontrollen Schäden gefunden werden, müssen diese dem Hersteller gemeldet (reported) werden. Der Hersteller wird dann Kontrollen vorschreiben, die in bestimmten Zeitabständen an allen Flugzeugen der Flotte durchgeführt werden müssen. Die Airlines bekommen diese Informationen vom Hersteller in Form von Service Bulletins.

Supplemental Structural Inspection Program

The SSI-Program

The SSI-Program exists since 1979 for different aircraft types. But the inspections are only done for especially chosen aircraft (High Flight Cycle Airplanes). If during these inspections damages are detected, they must be reported to the aircraft manufacturer. The manufacturer will then instruct inspections which must be carried out in certain intervals at all airplanes of the whole fleet. The airlines get this information from the manufacturer by Service Bulletins.

Fatigue Testing

Full Scale Fatigue Testing

The main goal of these tests is the finding of areas in new airplanes in which early fatigue emerges. During these test the aircraft lifetime is simulated in time-laps, so you know very early when fatigue cracks might be present in the fleet. These can than be prevented by suitable modifications. These test are carried out in special designed test cells. But the tests can not include events like corrosion or other damages caused by external effects, which accelerate the creation of fatigue cracks.

In the past such test were also carried out by Boeing with selected ”old” aircraft to get information about problems which are related to operational damages or old repairs. For this purpose Boeing bought back retired aircraft from some airlines. This information might be very significant but can not take the parameters, which are different from aircraft to aircraft, like corrosion or accidental damage, into account.

Fatigue Testing with High Cycle Airplanes

Boeing bought one B 747 with 25.000 flight cycles in short-haul operation and one 18 year old B737-200 with 59.000 flight cycles.

With the help of the B747 Boeing tries to proof the lifetime of the modification at the section 41.

The B737−200 was initially exposed to 20.000 additional pressure cycles (total 79.000FC). The following inspection showed many small cracks in the area of the upper rivet row of the lap joints. The decision was made to keep on testing in order to proof the fail safe characteristics of the structure in case of a failure (safe decompression). After 100.700 FC the lap joint collapsed by pushing the particular main field to the outside and purposefully blowing off the cabin pressure.

After repairing the test cell a 40 year lifetime should be proofed for the rear pressure bulkhead. So Boeing did about 130.000 pressure cycles with the test cell.

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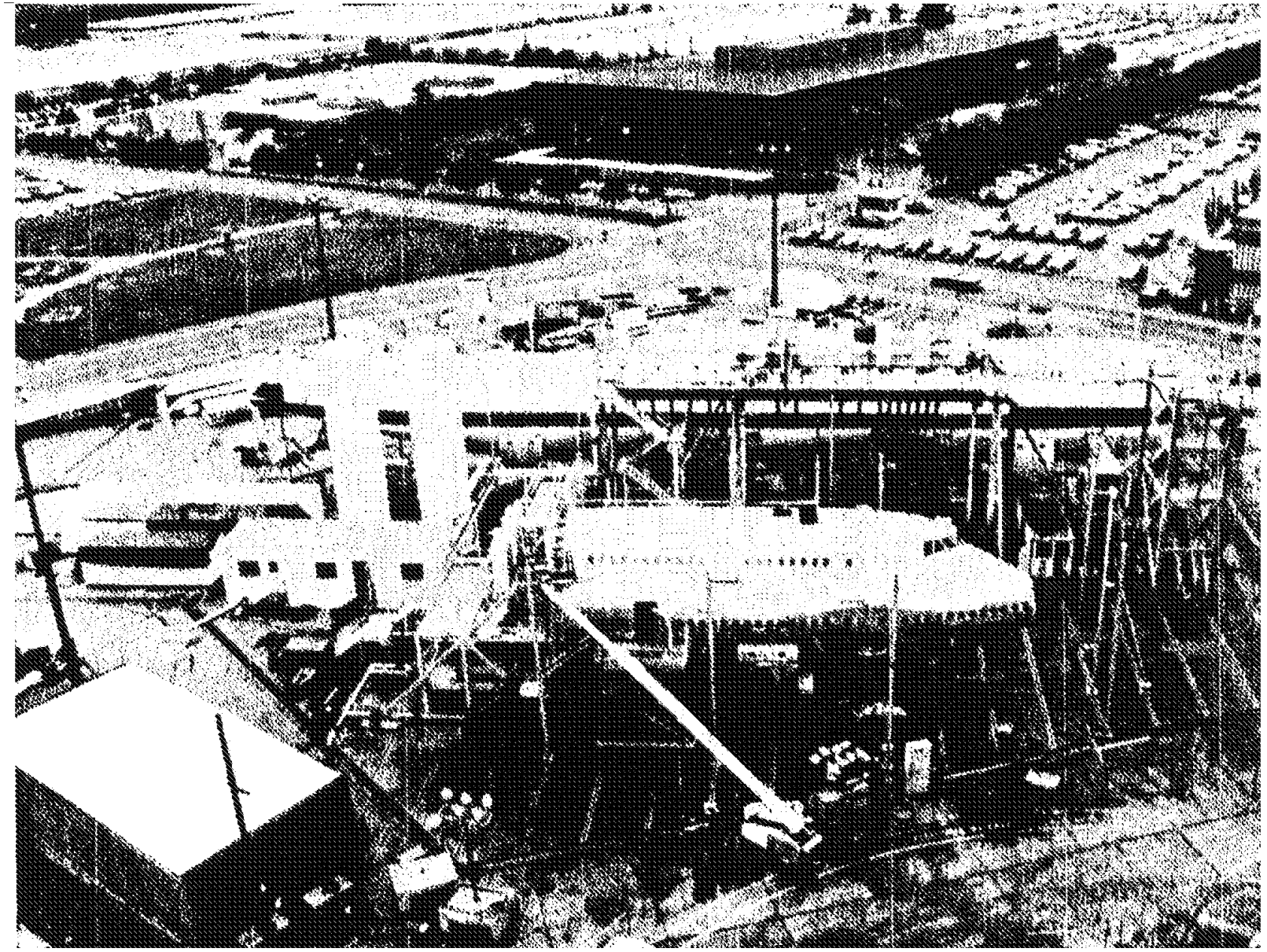


Figure 84 Full Scale Fatigue Testing

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Fleet Survey Program

Feet Monitoring

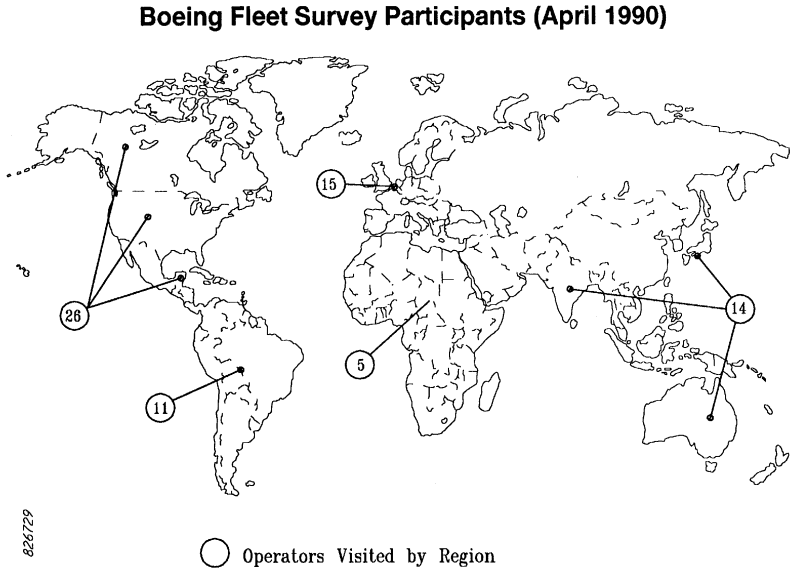
With the intention to gain more information about ageing aircraft, an at first limited to two years ”Aging Fleet Program” was introduced in 1986. Due to its great success it was applied to all Boeing aircraft and still continues up until now.

Between 1986 and 1991 aircraft of 71 airlines in 36 countries were inspected.

The selected aircraft were controlled by Boeing engineers during a overhaul. Additionally the operational conditions, the maintenance program and the operational reliability have been analysed.

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July 1991

- **128 airplanes surveyed**
- **71 operators visited in 36 countries**

Boeing Model

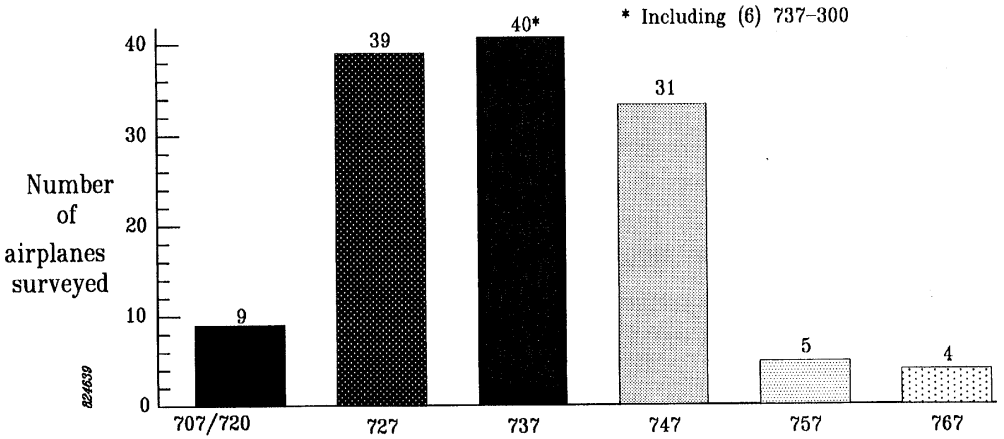


Figure 85 Fleet Survey Program

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Corrosion Prevention and Control Program (CPCP)

The CPCP

During the 1970's it has been become obvious, that the airlines will operate the aircraft far longer than the "Economic Design Life" of the manufacturer.

The aeronautical authorities were worried about the structural integrity of these "Ageing Airplanes" and saw the necessity of additional structural inspections in order to take, with the help of this data, certain actions for preservation of the airworthiness of these aircraft.

Thereupon Boeing was developing in collaboration with airlines and authoritys programs for the B707/720, B727, B737 and B747, to keep the airworthiness of these aircraft types beyond the "Economic Design Life".

The figure shows the damage rate that was assumed for the validation. Small fatigue cracks are assumed before the achievement of the "Economic Design Life" (20 years).

Corrosion does occur relatively early and stays according to the figure on such a low level, because Boeing acted on the assumption, that the airlines really carry out the by Boeing recommended actions for prevention and reduction of the problems.

This statement led to the introduction of the SSID program, in which it is assumed that the structure around a fatigue damage is only weakened by light corrosion. So the structure should have the ability to transmit the necessary loads until detection of the fatigue cracks.

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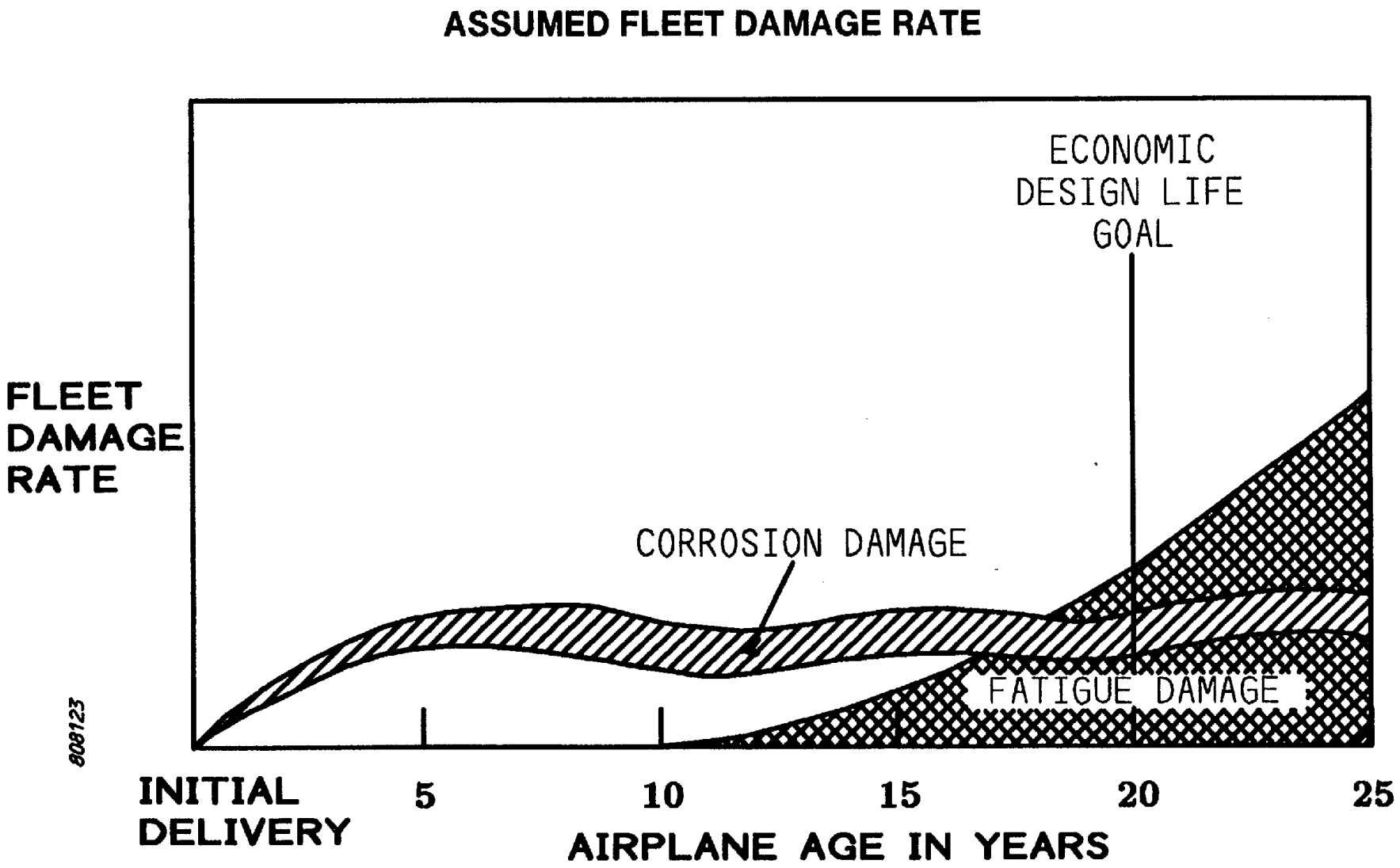


Figure 86 Assumed Fleet Damage Rate

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Ageing Aircrafts and Maintenance Practices

Since the introduction of the SID-program Boeing has inspected selected ”Ageing Airplanes” for the state of their structure and the corresponding maintenance practices. This research and some incidents have shown that the level of corrosion in the fleets of distinct airlines is very different.

Some airlines have carried out the necessary actions to keep corrosion on such a low level that only a few small repairs had to be carried out during maintenance events. This results in significant advantages, like e.g. a higher structural safety and a longer economical aircraft lifetime.

Other airlines accept permanent corrosion and react only after detection with, if necessary, a repair or a change of the structural component.

The figure opposite shows the actual trend of corrosion of the airline’s fleet. There are too many aircraft, which stay in service even with heavy corrosion. In this high age other damage types, like e.g. fatigue, do occur. If actions are not carried out on time, this can lead to an unacceptable degradation of the structural strength and in extreme cases to a loss of the aircraft.

The combination of heavy corrosion and fatigue cracks does decrease the damage tolerance of the structure significantly:

- considerable reduction of the remaining strength,
- larger starting damage,
- multiple site damage,
- higher crack propagation,
- reduction of damage-free periods,
- unpredictable distribution within the fleet.

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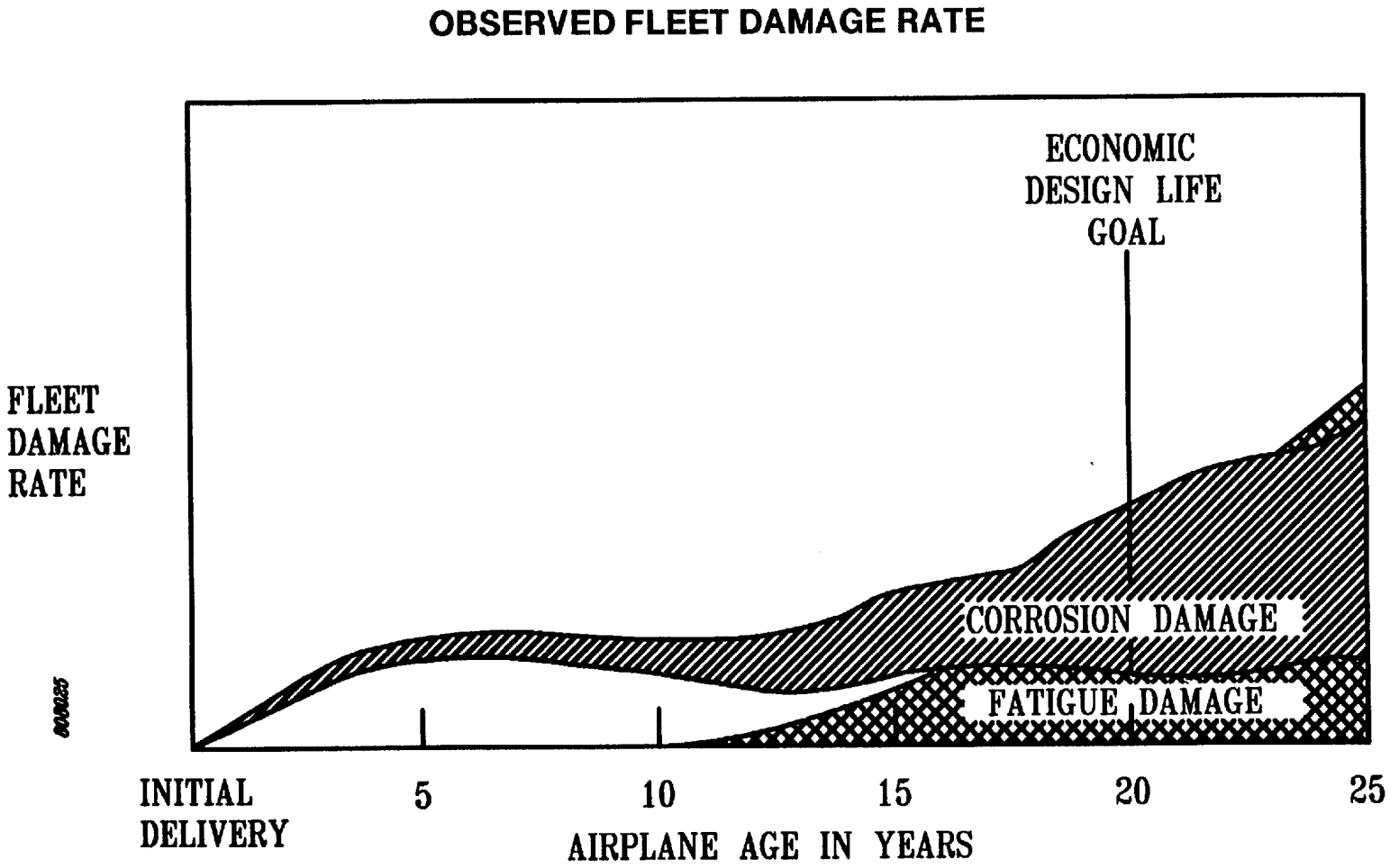


Figure 87 Observed Fleet Damage Rate

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Program Development

There are recommendations for corrosion prevention and reduction for every aircraft type from the particular aircraft manufacturer, like e.g. in form of a Corrosion Prevention Manual (CPM) or inside the Maintenance Planning Document (MPD). These recommendations have the goal to provide economical procedures for well known corrosion problem areas due to actual experience.

The main goal of the Corrosion Prevention and Control Progams (CPCP) is to ensure a **permanent airworthiness**.

There are great differences in type and amount of corrosive agents to which the different areas of an aircraft are exposed. The Bilge Area of the fuselage is for example exposed much more to corrosive agents than the Crown Area of the fuselage. So the known corrosion data is allocated to the different aircraft areas according to their corrosion endangering or their accessibility. The following figure shows the areas, in which the aircraft was departed.

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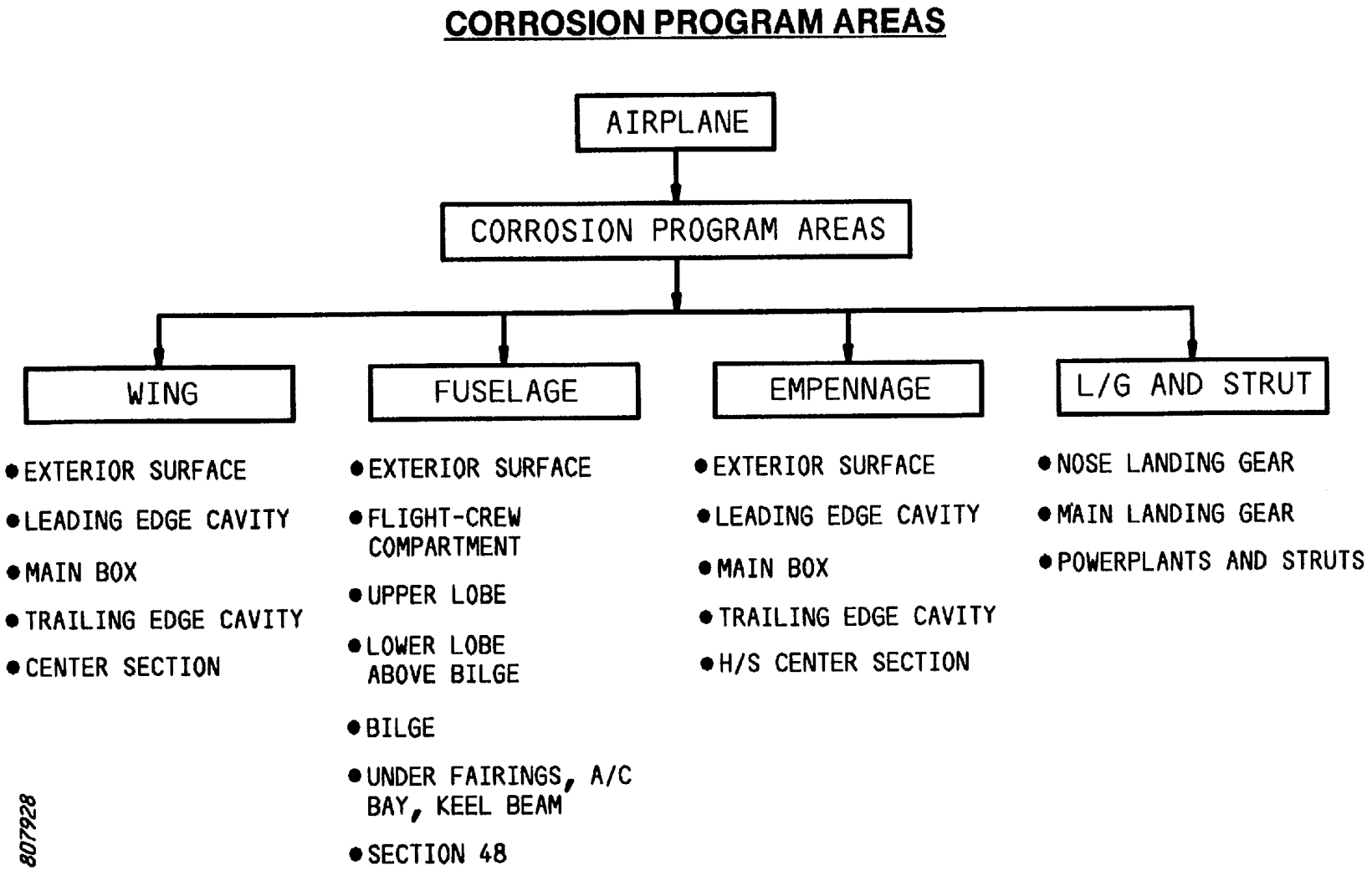


Figure 88 Corrosion Program Development

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Influences on Emerging and Extent of Corrosion

The large differences in the extent of corrosion between individual aircraft of one fleet are caused by the variation of the parameters depicted opposite.

These and other parameters interact with each other and have corrosion related effects which can hardly be estimated.

For this reason it was decided to develop a **"Baseline Program"** for every area of the airplane listed above and every aircraft type. This baseline program, which has firstly to be conducted for all affected aircraft of a fleet in the same way, sets the minimum standards for the Corrosion Prevention and Control Program (CPCP).

During the particular sequence checks, which are conducted in certain intervals, the airlines can adjust the program (up or down) due to their corrosion findings at their own aircraft. This adjustment is certainly done in cooperation with the manufacturer and the authority.

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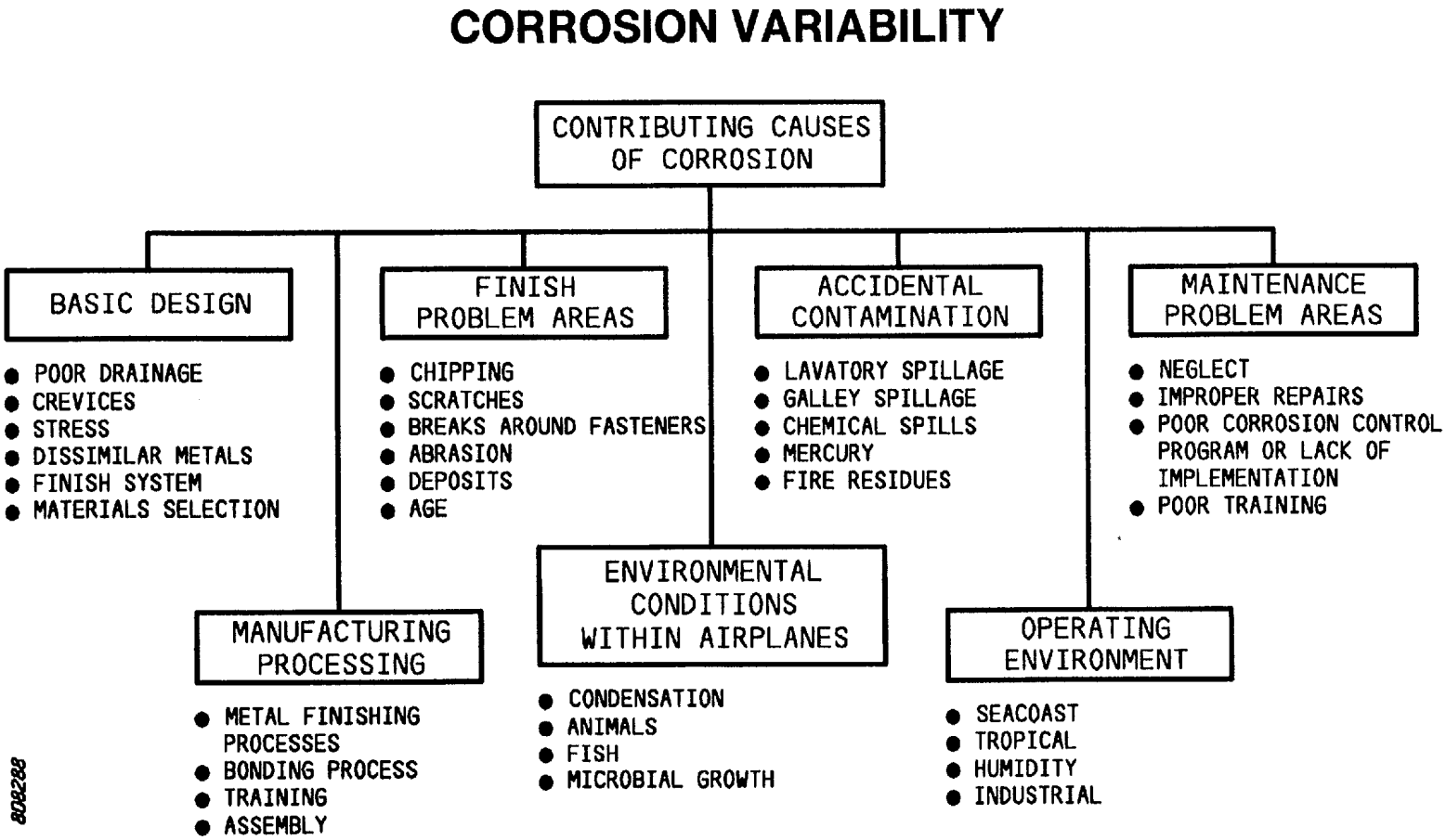


Figure 89 Baseline Program

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Program Introduction

For the implementation of the program the dates listed opposite are directed by the authorities.

As obvious, the authorities claimed a successive introduction of the program.

In the first year the airlines had to present a plan for the implementation of the program for every aircraft of the particular type to the authority.

In the second year the inspection at the first aircraft of the particular type had to be conducted.

In the third year the inspection at the second aircraft of the particular type had to be conducted.

However the authority allowed the airlines to split the inspections up to several airplanes of the particular aircraft. So the airlines had the chance to introduce the CPCP into the existing maintenance program as good as possible without creating excessive extra costs.

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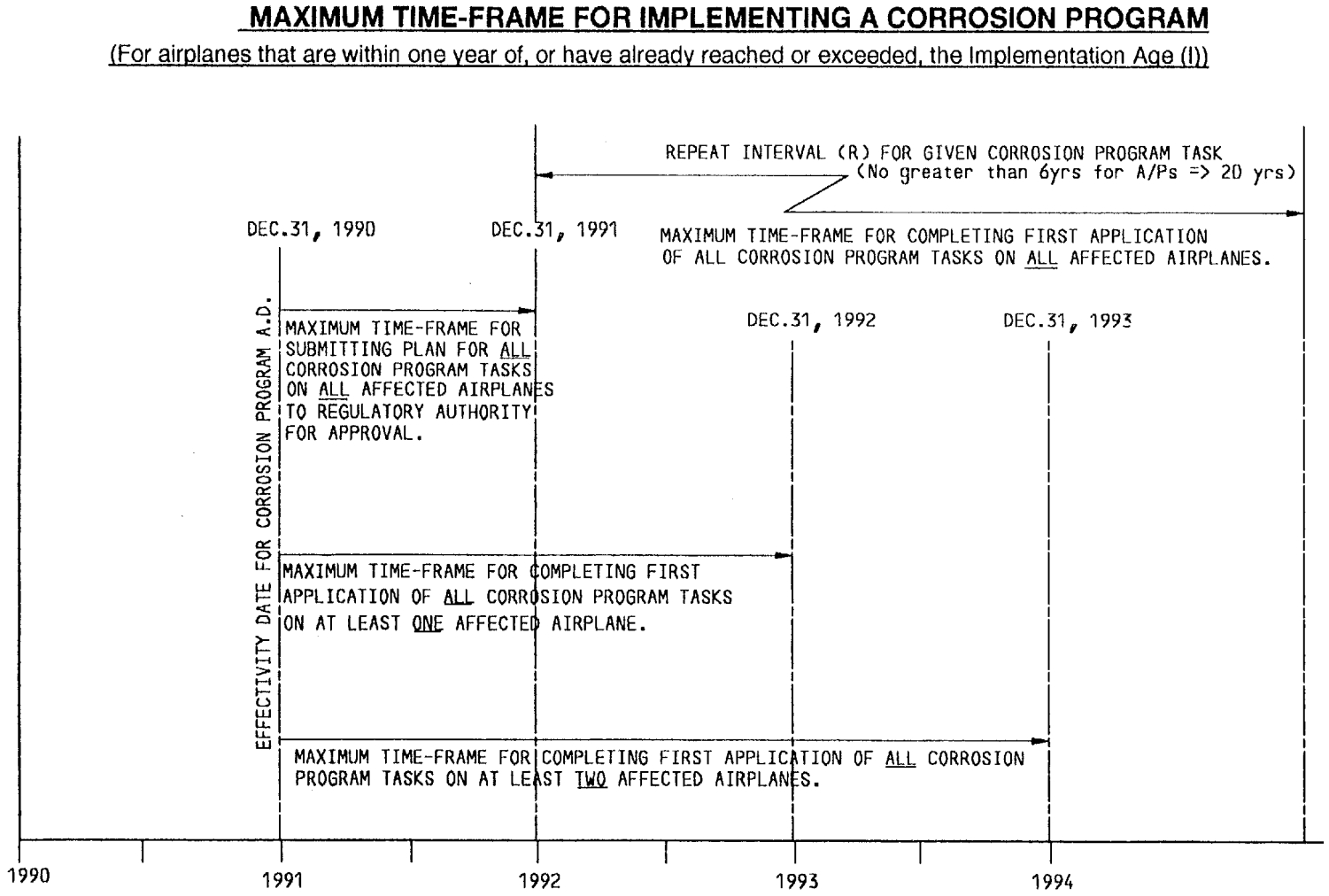


Figure 90 Implementation Age

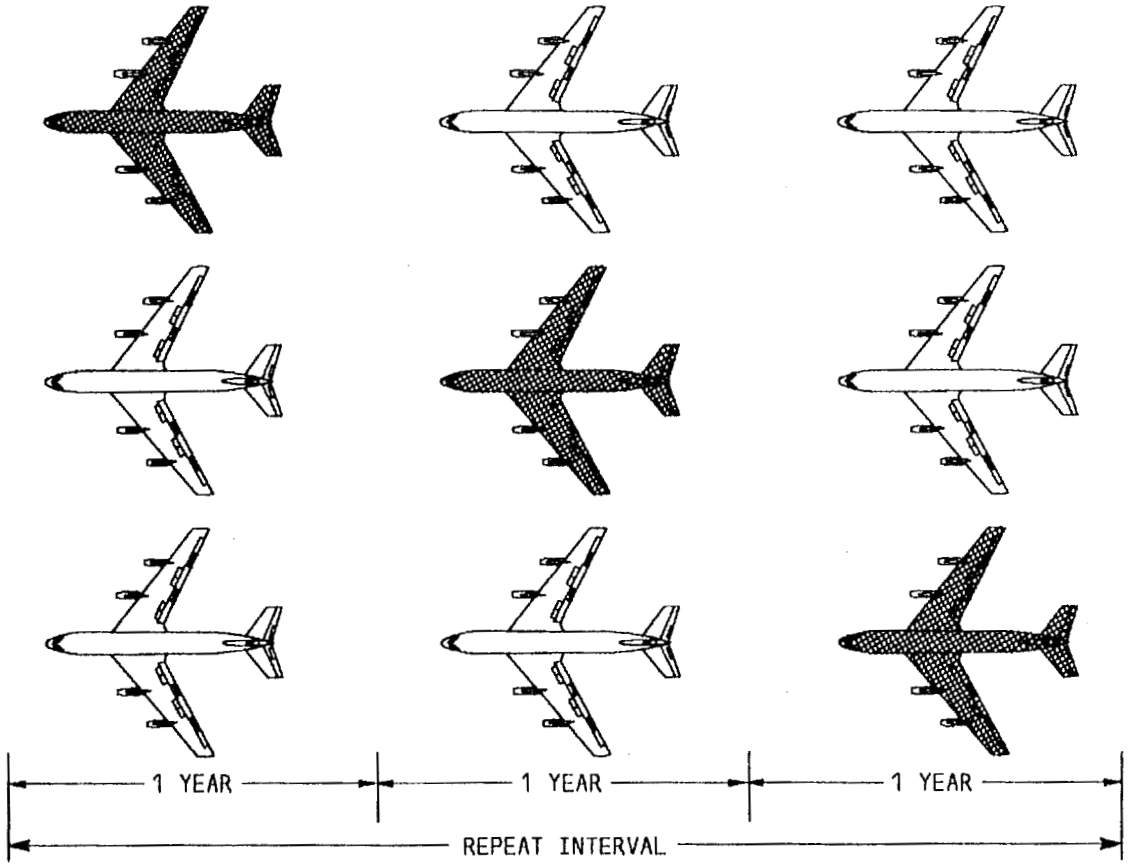
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Program Implementation Example

Operator has 3 airplanes and is implementing 3 tasks (one wing, one fuselage and one stabilizer) each having a Repeat Interval R = 3 years.

ALL TASKS ON A SINGLE AIRPLANE EACH YEAR



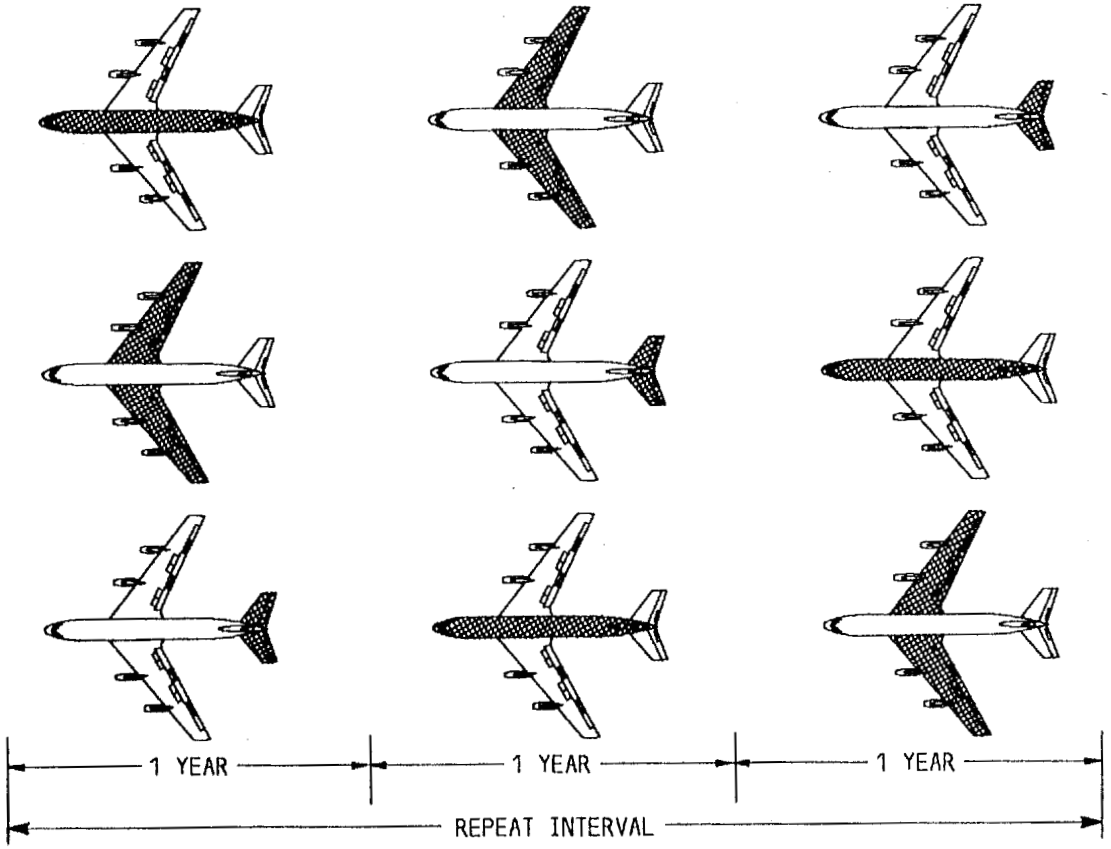
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Program Implementation Example

Operator has 3 airplanes and is implementing 3 tasks (one wing, one fuselage and one stabilizer) each having a Repeat Interval R = 3 years.

EACH TASK ON A SEPARATE AIRPLANE EACH YEAR



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BASELINE PROGRAM

This program sets the minimum Corrosion Prevention and Control requirements, which are necessary to provide a continuous airworthiness for every aircraft fleet. The efficiency of the program is based on the corrosion-level (described later), which has been detected in different aircraft areas between two sequenced checks.

This program does affect all aircraft, which have reached or exceeded the **Implementation Age (I)** for particular areas. To estimate the efficiency of the Corrosion Prevention and Control Progam, it is necessary to define an acceptable corrosion-level. The Baseline Program has the goal of keeping the corrosion at a level that does not impair the airworthiness through prevention or controlling. This includes the prevention of the dangerous combinations of fatigue cracks and corrosion. To achieve this it is necessary to restrict the corrosion at all structural parts that are important for the airworthiness of an aircraft in such a way, that **the ”Blend Out Limits”, defined by the manufacturer, are not exceeded between to sequenced inspections**.

Such primary structural components which have influence on the airworthiness of an aircraft are called **Principal Structural Elements (PSEs)**. They are defined in the ATA chapter 51 of the corresponding Structural Repair Manuals (SRM). The allowed ”Blend Out Limits” can also be found in the SRM.

Examples for structural components that are **PSEs**:

- Wing spars and skins
- Fuselage frames and skins
- Pressure bulkheads
- Landing gear beams

Examples for structural components that are **not PSEs**:

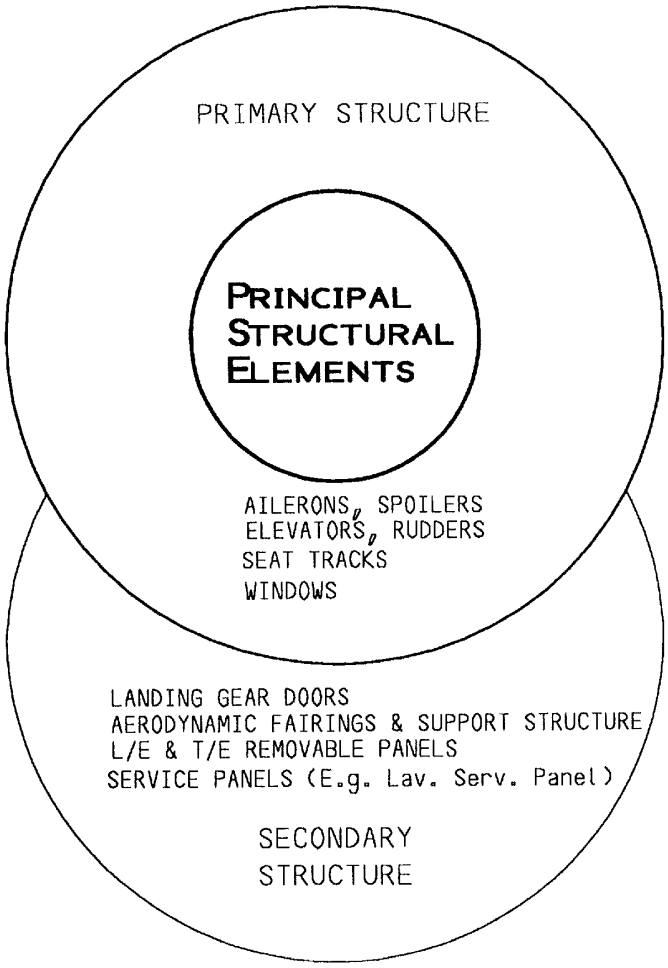
(Attention: At some aircraft types the following elements are defined as PSEs)
:

- Ailerons
- Elevators
- Rudders

In some cases structural elements that are not PSEs are also included in the Baseline Program.

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STRUCTURAL AREA	STRUCTURAL ELEMENT
FUSELAGE	FUSELAGE UPPER LOBE SKIN AND STRINGERS FUSELAGE LOWER LOBE SKIN AND STRINGERS FUSELAGE CIRCUMFERENTIAL SPLICES FUSELAGE LAP SPLICES FUSELAGE SKIN AT CORNERS OF CUTOUTS MAIN DECK AND UPPER DECK FRAMES BS 160 TO BS 2340 LOWER LOBE FRAMES BS 160 TO BS 980 OVERWING STUB FRAMES LOWER LOBE FRAMES BS 1500 TO BS 2340 FUSELAGE FRAMES BS 2377 TO BS 2346 UPPER LOBE FRAMES BS 2537.25 TO BS 2577.75 LOWER LOBE FRAMES BS 2506.8 TO BS 2575.2 FUSELAGE FRAMES BS 2618 AND BS 2638 ENTRY DOOR CUTOUT STRUCTURES SERVICE DOOR CUTOUT STRUCTURES CARGO DOOR CUTOUT STRUCTURES EMERGENCY EXIT HATCH CUTOUT STRUCTURES E/E ACCESS HATCH CUTOUT STRUCTURES NOSE LANDING GEAR WHEEL WELL CUTOUT STRUCTURE MISCELLANEOUS FUSELAGE CUTOUT STRUCTURES IN PRESSURIZED AREA FUSELAGE UPPER CROWN CREASE BEAM STRUCTURE FLOOR BEAM STRUCTURE FUSELAGE TENSION TIES STRINGER/FRAME ATTACHMENTS BULKHEAD BS 140 (FORWARD PRESSURE) FUSELAGE BS 247 BULKHEAD (NWW FORWARD BULKHEAD) FUSELAGE BS 340 BULKHEAD FUSELAGE BS 400 BULKHEAD FUSELAGE BS 1000 BULKHEAD (FRONT SPAR BULKHEAD) FUSELAGE BS 1140 BULKHEAD (MID SPAR BULKHEAD) FUSELAGE BS 1241 BULKHEAD (REAR SPAR BULKHEAD) FUSELAGE BS 1350 BULKHEAD FUSELAGE BS 1480 BULKHEAD FUSELAGE BS 2360 BULKHEAD (AFT PRESSURE BULKHEAD) FUSELAGE BS 2460 BULKHEAD FUSELAGE BS 2484 BULKHEAD FUSELAGE BS 2598 BULKHEAD FUSELAGE BS 2658 BULKHEAD UPPER LOBE BS 2502 BULKHEAD UPPER LOBE BS 2517 BULKHEAD

Figure 91 Baseline Program (Cont.)

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AGING AIRPLANE CORROSION PREVENTION AND CONTROL PROGRAM - MODEL 727

REV. A

AIRPLANE AREA: FUSELAGE - LOWER LOBE - INTERIOR, EXCEPT BILGE

CORROSION TASK NO.	DESCRIPTION OF AREA TO BE INSPECTED	ZONES	EFFEC-TIVITY	I YEARS	R YEARS	REFERENCE SB'S.	NOTES
C53-111-01	FUSELAGE LOWER LOBE INTERIOR STRUCTURE FORWARD OF THE BILGE, BS 178 TO BS 480 BELOW S-17, AND THE AREA ABOVE THE BILGE, BS 480 TO BS 740 AND BS 950 TO BS 1183 FROM S-17 TO S-26, INCLUDING SKIN PANELS, SKIN SPLICES AND JOINTS, FRAMES, STRINGERS, SHEAR TIES, SKIN CUTOUTS, BS 178, 740 FRONT SPAR AND 1183 BULKHEADS, N.L.G.W.W. STRUCTURE, MAIN DECK FLOOR STRUCTURE AND DOOR INTERIORS, WITH PARTICULAR ATTENTION TO THE FOLLOWING:	1-11, 1-12, 1-13, 1-14, 1-15, 1-16, 1-31	ALL	6	6		1
-01.01	LONGITUDINAL SKIN LAP SPLICES.						
-01.02	CIRCUMFERENTIAL SKIN BUTT JOINTS.						
-01.03	AREA UNDER GALLEYS AND LAVS., INCLUDING MAIN DECK FLOOR STRUCTURE.						
-01.04	SKIN AND DOUBLER AT S-27, 28 AND BL 0 BONDED STRAP FORWARD OF BS 480.						
-01.05	TOP PANEL OF THE NOSE GEAR WHEEL WELL, INCLUDING CHORDS, WEB AND STIFFENERS.						
-01.06	CARGO DOOR CUTOUT STRUCTURE.						
-01.07	SKIN AND DOUBLERS AT ANTENNA CUTOUTS.						
-01.08	SKIN AT FORWARD AND AFT TOILET SERVICE PANELS.						
-01.09	BS 360 AND 1183 PRODUCTION JOINT SPLICES AND BOLTS.						
C53-111-02	CARGO DOOR INTERIOR STRUCTURE.	1-13, 1-15	ALL	6	6	52-122	2,4
C53-111-03	FUSELAGE SKIN, HORIZONTAL WALKWAY BEAM AND CHORDS AT INTERSECTION WITH THE NOSE LANDING GEAR WHEEL WELL.	1-31	ALL	6	1.5 OR 3		3,4
C53-111-04	WING CENTER SECTION FRONT SPAR LOWER WEB.	1-14	L/N 001-1415	SEE	NOTE	57-146	5

NOTES:
1) A DUAL COAT OF CORROSION INHIBITOR PER BASIC TASK PART 6B) IS RECOMMENDED IN AREAS UNDER GALLEYS AND LAVS., INCLUDING SKIN AT TOILET SERVICE PANELS (OPTIONAL).
2) INCORPORATE S.B. 52-122 DRAIN MOD. AT THE IMPLEMENTATION AGE FOR DEACTIVATED NO. 3 CARGO DOORS.
3) RECOMMEND MODIFICATION PER S.B. 53-157 FOR AIRPLANES L/N 1 - 1544 (OPTIONAL). REPEAT INTERVAL OF 1.5 YEARS FOR AIRPLANES L/N 1 - 1544 WITHOUT MOD. PER S.B. 53-157. REPEAT INTERVAL OF 3 YEARS AFTER MOD. AND FOR AIRPLANES L/N 1545 AND ON.
4) A DUAL COAT OF CORROSION INHIBITOR PER BASIC TASK PART 6B) IS RECOMMENDED FOR THIS AREA (OPTIONAL)
5) VISUALLY INSPECT AND ACCOMPLISH TERMINATING ACTION PER S.B. 57-146 WITHIN 2 YEARS OF THE EFFECTIVE DATE OF THE A.D. FOR THIS DOCUMENT.

D6-54929

PAGE 4.3.11

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BOEING

Figure 92 Typical CPCP-Sheet

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Corrosion Levels

Three corrosion levels have been developed by work groups (SWGs) and have been approved by the aeronautical authorities.

ATTENTION:

Corrosion levels do **not** have an influence on the requirements on a repair.

Every corrosion which is found on a scheduled corrosion check has to be removed, if necessary the structure has to be enforced or replaced.

Blend-out or repair limits in a possible combination with airworthiness inspections are used to determine corrosion levels.

The corrosion levels are used to determine, which **additional** actions have to be conducted by the airline to keep the corrosion between two sequenced checks at an acceptable level.

Level 1 corrosion sets the standards for the acceptance of a corrosion program.

LEVEL 1 is the highest acceptable corrosion level at every PSE or also other structural element that is part of the baseline program.

The basis for a classification of a corrosion finding as level 1 or level 2 is the size of the needed blend out for a total corrosion removal. A second factor for the classification as level 1 or level 2 is the spread of the corrosion.

For a determination the denominations ”LOCAL” and ”WIDESPREAD” are used.

Findings have to be classified as level 3, if there is a risk that an equal or even larger finding can lead to an **Urgent Airworthiness Concern** at other aircraft of the owner’s fleet.

LOCAL and WIDESPREAD CORROSION

The following pictures show LOCAL and WIDESPREAD corrosion using the example of corrosion at fuselage, bulkhead, skin, stringer and stiffener.

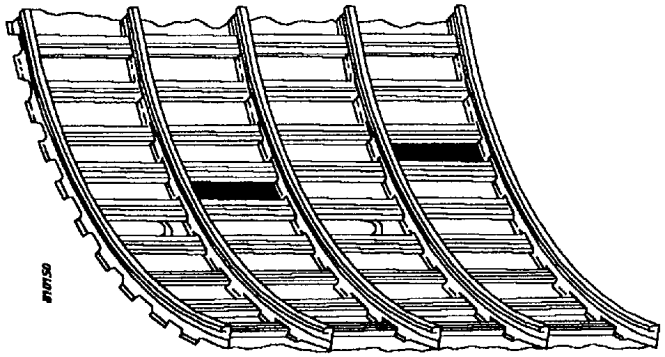
The main gaol of the CPCP is the prevention of an endangering of airworthiness by corrosion. Typically WIDESPREAD corrosion has major effects on the airworthiness of the airplane than LOCAL corrosion. This is especially valid for older aircraft, since here corrosion often occurs together with fatigue; additionally such combined damage is more likely together with WIDESPREAD corrosion.

To have a protection against such airworthiness problem, WIDESPREAD corrosion, which gets near to the allowed blend out limits in two sequenced checks, is classified as LEVEL 2.

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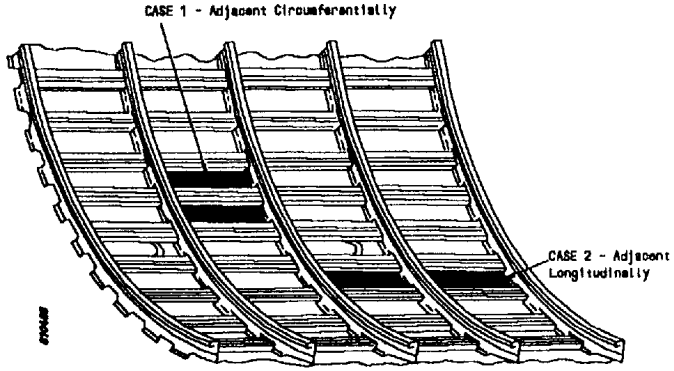
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EXAMPLES OF LOCAL AND WIDESPREAD CORROSION IN FUSELAGE SKIN PANELS



LOCAL CORROSION

(Corrosion occurring in non-adjacent skin panels)



WIDESPREAD CORROSION

(Corrosion occurring in adjacent skin panels)

Figure 93 Corrosion Examples

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Determination of the Corrosion Level

The goal of the CPCP is to keep corrosion damages at aircraft on a tolerable and not dangerous level, which does not exceed the limits given by the manufacturer or by a AD-note.

So the aircraft owner is in charge to manage his existing maintenance and overhaul program in such a way that the corrosion damages do not exceed a certain level **(LEVEL 1)**.

Furthermore the corrosion state of an aircraft is permanently monitored over the whole lifetime by the aircraft owner and the aircraft manufacturer. Also the notification requirement of findings beyond a certain level to the aeronautical authorities does exist.

In the majority of cases the aircraft owner has the ability to define the corrosion levels by itself and also to conduct certain actions like e.g. repairs and/or modifications of the existing corrosion program.

It is generally necessary to define a corrosion LEVEL for every PSE or other part that is listed in the baseline program.

During the second or following inspection either the accordance with the CPCP (LEVEL 1 or better) or the necessity for a program adjustment and/or other action is indicated.

An effective CPCP keeps the corrosion at LEVEL 1 or better.

- LEVEL 2 corrosion,

  which is detected during the second or following inspection, needs actions to keep the corrosion in this area inside the limit of LEVEL 1 or better in the future.
- LEVEL 3 corrosion
- needs the same actions as LEVEL 2, additionally a plan has to be developed to ensure the on time detection or the prevention of LEVEL 3 corrosion in the same area at all other airplanes of the same type in the fleet of the aircraft owner.

Every corrosion outside the combination ”Single/Widespread”, which is under the manufacturer’s limits after machining/grinding, is LEVEL 1 corrosion and proofs the functioning of the program.

Corrosion at a PSE, that has to be repaired or replaced after machining/grinding, is LEVEL 2 (Exception: Accidental Damage and Multiple Blend Out).

If there is the suspicion that a restriction of airworthiness within the fleet of the aircraft owner could emerge from a finding, further inspections have to be conducted and the corrosion has to be classified as LEVEL 3.

Normally there is no concern about the airworthiness if the corrosion has just exceeded the machining limits. That means that also no immediate, drastically action in the owner’s maintenance program is needed.

Commonly the situation allows a further inspection of the concerned area in order to see the possible extend and size of the problem. This will give a better basis of decision-making about certain actions for the reduction or removal of the problem at all aircraft of this type in the owner’s fleet.

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Effect of Corrosion Extent and Severity on Corrosion Level

Extent of Corrosion	Number of Successive Inspection Intervals to Reach Given Corrosion Severity	Corrosion Level for Given Severity and Extent				
		Well Below Allowable Limits	Approaching Allowable Limits	At Allowable Limits	Above Allowable Limits	
					Corrosion Is Not an Urgent Airworthiness Concern	Corrosion Is an Urgent Airworthiness Concern
Local	Single	Level 1	Level 1	Level 1	Level 2	Level 3
	Multiple	Level 1	Level 1	Level 1	Level 1*	Level 3 **
Widespread	Single	Level 1	Level 2	Level 2	Level 2	Level 3
	Multiple	Level 1	Level 1	Level 1	Level 1*	Level 3**

* Operator experience over several years has demonstrated only light corrosion between successive inspections but latest inspection and cumulative blend-out now exceed allowable limit.

** Unlikely event.

Figure 94 Corrosion Level-Classification

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ALLG. REPARATUR–, SRM–, ALTERUNGS–, ERMÜDUNGS– & KORROSIONS ERKENNUNGSMETHODEN

- Allowable Damage
- Repairable Damage
- Non Repairable Damage

Allowable Damage

ATTENTION: Der Begriff Allowable Damage bedeutet nicht, dass eine Reparatur unnötig ist. Wenn zum Beispiel ein Kratzer als Allowable eingestuft wird, so ist es notwendig, raue und scharfe Kanten auszupolieren und den Schaden insgesamt zu glätten. Zusätzlich muss das geforderte Oberflächenschutzsystem wieder aufgebracht werden.

Repairable Damage

Non Repairable Damage

GEN. REPAIR– & SRM METHODS, AGING–, FATIGUE–, CORROSION DETECTION

General Repair Techniques

Damage Classification

- Allowable Damage
- Repairable Damage
- Non Repairable Damage

Allowable Damage

ATTENTION: Allowable does not mean that repair is unnecessary. For example, scratches and burring are included in this category, and it is necessary to remove rough and sharp edges and smooth out the damage. Additionally, any damage to surface coatings and/or protective treatment must be repaired.

Repairable Damage

Non Repairable Damage

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Structural Repair Manual (Boeing)

MANUALS GENERAL

Manual Introduction

Der Aufbau der Handbücher folgt den Anweisungen der Air Transport Association of America (ATA) Spezifikation Nr.100:

„Specifications for Manufacturers Technical Data“.

Die Handbücher enthalten alle notwendigen Informationen, um die Fluggeräte warten und reparieren zu können.

Customized Manuals

Die Handbücher unterscheiden sich je nach Kundenausstattung, d.h. sie sind flugzeugtyp- und kundenbezogen (“Customized“), wie z.B.:

- Aircraft Maintenance Manual (AMM)
- Wiring Diagram Manual (WDM)
- Illustrated Parts Catalogue (IPC)

Non Customized Manuals

Andere Handbücher wiederum sind allgemeingültig, d.h. sie sind flugzeugtyp- aber nicht kundenbezogen (“Non-Customized“), wie z.B.:

- Structural Repair Manual (SRM)
- Fault Isolation Manual (FIM)

Manuals

Des Weiteren gibt es Handbücher, die weder kunden- noch flugzeugtypbezogen sind, wie z.B.:

- Component Maintenance Manual (CMM)

Structural Repair Manual (Boeing)

MANUALS GENERAL

Manual Introduction

The structuring of manuals is done according to Air Transport Association of America (ATA) Specification No.100:

„Specifications for Manufacturers Technical Data“.

The manuals contain all necessary information for maintaining and repairing aircraft and aircraft components.

Customized Manuals

The manuals differ depending on the customers configuration, that means they are aircraft type and customer related (“Customized“), like e.g.:

- Aircraft Maintenance Manual (AMM)
- Wiring Diagram Manual (WDM)
- Illustrated Parts Catalogue (IPC)

Non Customized Manuals

Other manuals are universal, that means they are aircraft type but not customer related (“Non-Customized“), like e.g.:

- Structural Repair Manual (SRM)
- Fault Isolation Manual (FIM)

Manuals

Furthermore there are manuals, which are nor customer nor aircraft type related, like e.g.:

- Component Maintenance Manual (CMM)

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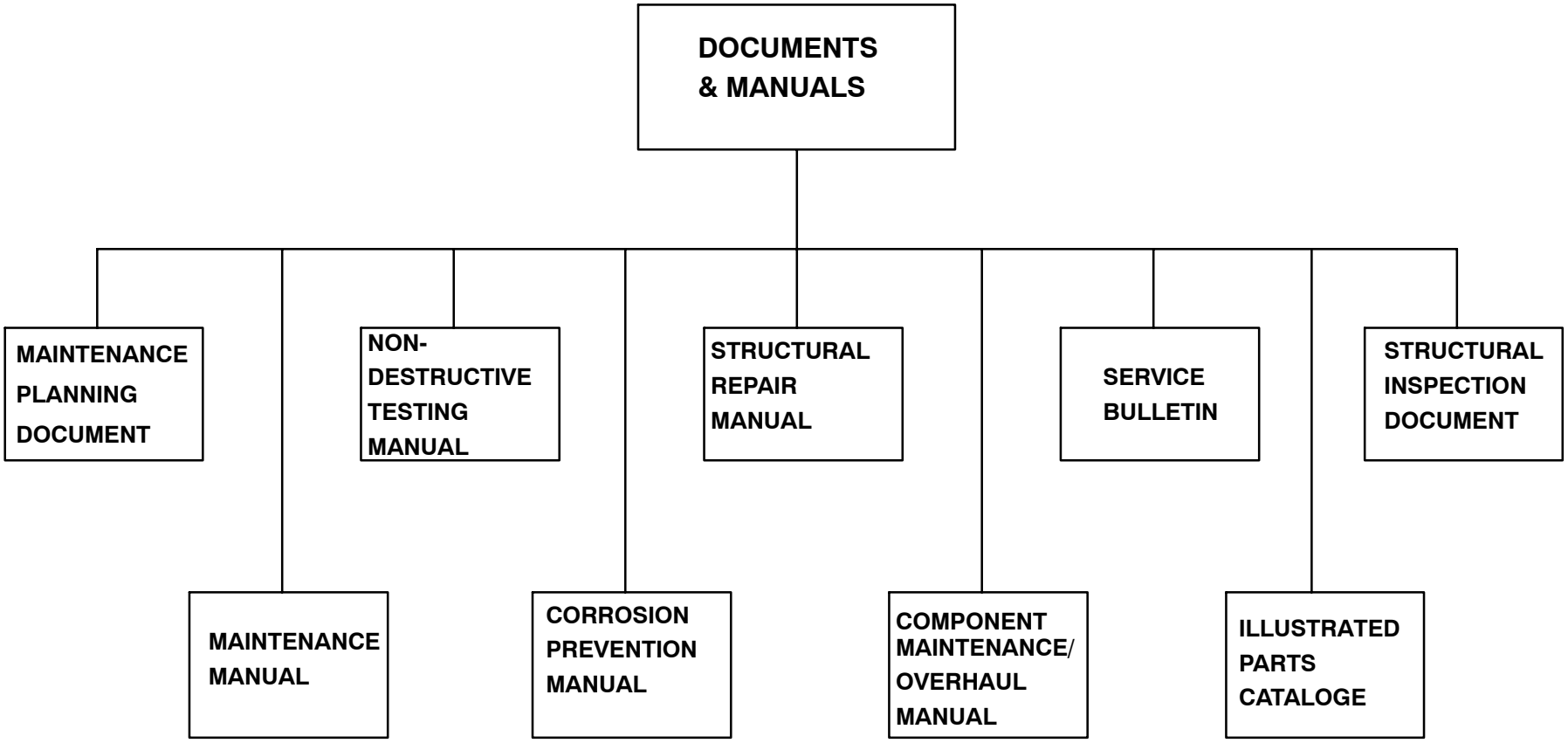


Figure 95 Manual Overview

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ATA Kapitel Gruppierung

General

Zur klareren Übersicht sind die Handbücher in *Kapitel* und *Gruppen von Kapiteln* aufgebaut, um ein leichteres Auffinden der gesuchten Informationen zu ermöglichen:

Gruppe	Kapitel-No
Allgemeines:	Kapitel 5 bis 12
Systeme:	Kapitel 20 bis 49
Struktur:	Kapitel 51 bis 57
Triebwerk:	Kapitel 71 bis 80

ATA Chapter Arrangement

General

For a clear overview the manuals are arranged in *chapters* and *groups of chapters*, to ensure an easy finding of the searched information:

Group	Chapter-No
General:	Chapter 5 to 12
Systems:	Chapter 20 to 49
Structure:	Chapter 51 to 57
Engine:	Chapter 71 to 80

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ATA 100 (Kapitel-Nr. und Titel)

AIRCRAFT

5 Time Limits
6 Dimensions and Areas
7 Lifting and Shoring
8 Leveling and Weighing
9 Towing and Taxing
10 Parking and Mooring
11 Required Placards
12 Servicing
13 Processes And Procedures

AIRFRAME SYSTEMS

20 Standard Practices Airframe
21 Air Conditioning
22 Autopilot
23 Communications
24 Electrical Power
25 Equipment and Furnishings
26 Fire Protection
27 Flight Controls
28 Fuel
29 Hydraulic Power
30 Ice And Rain Protection
31 Instruments
32 Landing Gear
33 Lights
34 Navigation
35 Oxygen
36 Pneumatic
37 Vacuum
40 Water and Waste
41 Electronic Panels And Multipurpose
49 Airborne Aux. Power

STRUCTURES

51 StructureGeneral
52 Doors
53 Fuselage
54 Nacelles and Pylons
55 Stabilizers
56 Windows
57 Wings

PROPELLERS/ROTOR

62 Propellers and Rotors Standard Practice
63 Propellers
65 Rotors

POWER PLANT

70 Engine Standard Practices
71 Power Plant General
72 Engines
73 Engine and Fuel Control
74 Ignition
75 Air
76 Engine Controls
77 Engine Indicating
82 Exhaust
83 Oil
84 Starting
85 Turbines

ATA 100 (Chapter-No. and Title)

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AIRCRAFT

5 Time Limits
6 Dimensions and Areas
7 Lifting and Shoring
8 Leveling and Weighing
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71 Power Plant General
72 Engines
73 Engine and Fuel Control
74 Ignition
75 Air
76 Engine Controls
77 Engine Indicating
86 Exhaust
87 Oil
88 Starting
89 Turbines

Manual Revisions

Überprüfung des Revisionsstatus

Vorschriften und Anweisungen bestehen in der Regel aus mehreren Seiten. Das Dokument kann vorliegen als:

- Lose Blattsammlung,

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- Mikrofilm
- digitaler Form (CD oder Intranet/Internet)

Diese Dokumente werden in bestimmten Zeitabständen revidiert - üblicherweise alle 3 oder 6 Monate.Die aktuelle Revisionsnummer ist bei der Blattsammlung/Mikrofilm-Form aus der „Übersichtsliste der gültigen Dokumentation“ (in der Regel in einem extra Ordner aufgeführt) zu entnehmen. Sollte ein Manual vor Erscheinen der Übersichtsliste herausgegeben werden, so ist immer die höchste Revisionsnummer gültig.

- Die Revisionsnummer innerhalb des verwendeten Manuals findet man vorangestellt, vor allen ATA-Kapiteln, in dem Abschnitt:

  „FRONT MATTER“ unter „TRANSMITTAL LETTER“.

Manual Revisions

Determination of Revision Status

Directives and Instructions normally consist out of several pages. The document can be present as:

- Loose page portfolio,
- Microfilm
- digital format (CD or intranet/internet)

These documents are revised in certain periods - generally all 3 or 6 months.

The actual revision number can in case of a portfolio or a microfilm be derived from the overview list of the record of revisions (generally in an extra folder). If a manual is released prior to the publishing of the overview list always the highest revision number is valid.

- The revision number inside the manual can be found in the front, prior to every ATA chapters in the section:
  - „FRONT MATTER“ under „TRANSMITTAL LETTER“.

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747-400
STRUCTURAL REPAIR MANUAL

Revision No. 60
Feb 20/2005

To: All holders of this Boeing Document D634U102

Attached is the current revision to the Boeing 747-400 Structural Repair Manual.

The Structural Repair Manual (SRM) is furnished either as a printed manual, on microfilm, or digital products, or any combination of the three. This revision replaces all previous microfilm cartridges or digital products. All microfilm and digital products are reissued with all obsolete data deleted and all updated pages added.

For printed manuals, changes are indicated on the List of Effective Pages (LEP). The pages which are revised will be identified on the LEP by an R (Revised), A (Added), O (Overflow, i.e. changes to the document structure and/or page layout), or D (Deleted). Each page in the LEP is identified by Chapter-Section-Subject number, page number and page date.

Pages replaced or made obsolete by this revision should be removed and destroyed.

ATTENTION

IF YOU RECEIVE PRINTED REVISIONS, PLEASE VERIFY THAT YOU HAVE RECEIVED AND FILED THE PREVIOUS REVISION. BOEING MUST BE NOTIFIED WITHIN 30 DAYS IF YOU HAVE NOT RECEIVED THE PREVIOUS REVISION. REQUESTS FOR REVISIONS OTHER THAN THE PREVIOUS REVISION WILL REQUIRE A COMPLETE MANUAL REPRINT SUBJECT TO REPRINT CHARGES SHOWN IN THE DATA AND SERVICES CATALOG.

TRANSMITTAL LETTER

Page 1
Feb 20/2005

D634U102

Figure 96 Transmittal Letter

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Temporary Revisions

Allgemein

Wichtige Revisionen, die innerhalb der normalen Austauschintervalle Gültigkeit erlangen sollen, werden als Temporary Revisions herausgegeben.Sie werden der Dokumentation beigeheftet bzw. bei Mikrofilmen in einem extra Ordner bereitgestellt (gelbe Seiten). In der Regel gibt es für ein bestimmtes Dokument Übersichtslisten über die Temporary Revisions.

- Liegt eine Temporary Revision für eine Arbeitsanweisung vor, so ist sie das gültige Dokument für die Arbeitsdurchführung.
- Liegt keine Temporary Revision vor, so ist die übliche Dokumentation zu verwenden.

Temporary Revisions

General

Important revisions which have to be in effect between the normal revision intervals, are published as Temporary Revisions.They are attached to the documentation or in case of a microfilm provided in an extra folder (yellow page). Generally there are overview lists concerning temporary revisions of a document.

- Is there one temporary revision for a work task, the revision is the effective document for the accomplishment of the work.
- Is there no temporary revision, the common documentation must be used.

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BOEING
747-400
STRUCTURAL REPAIR MANUAL
AFT CARGO DOOR CUTOUT - SKIN PANEL AND BEAR STRAP CRACK REPAIR
AT THE FORWARD UPPER CORNER

TEMPORARY REVISION 53-51

FILING INSTRUCTIONS

For the printed manual, file this temporary revision adjacent to the page(s) affected. Record the filing of this temporary revision in the Temporary Revision Record.

For the microfilm supplement, file this temporary revision in sequence by ATA number. Mark the microfilm cartridge to indicate that it has been changed by temporary revision(s).

This Temporary Revision will be incorporated in the revision dated Oct 20/03.

Revision reason: Added Alternative Method of Compliance data and added chamfer on repair doublers.

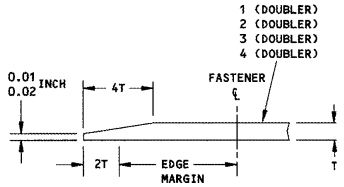
This temporary revision furnishes an advance copy of the following page(s) which supersede any previously issued page(s). The information thereon is to be used until this temporary revision is either incorporated or rescinded.

Chapter-Section-Subject	Page No.	Date	Code
53-60-01	209-213, 216-218	Oct 20/03	400.1

D634U102

W52488

BOEING
747-400
STRUCTURAL REPAIR MANUAL



DETAIL IV [G]

CATEGORY B INSPECTION REQUIREMENTS			
INSPECTION THRESHOLD	REPEAT INSPECTIONS		
	METHOD	INTERVAL	REFERENCE
15,000 FLIGHT CYCLES AFTER REPAIR INSTALLATION	DETAILED VISUAL	3,000 FLIGHT CYCLES	
NOTE: DETAILED VISUAL INSPECT THE SKIN PANEL, BEAR STRAP, STA 1810 EDGE FRAME OUTER CHORD AND UPPER SILL OUTER CHORD FROM THE INSIDE OF THE REPAIR AREA. DETAILED VISUAL INSPECT THE REPAIR PARTS AND THE SKIN AT THE EDGE OF THE REPAIR PARTS FROM THE OUTSIDE OF THE REPAIR AREA.			

TABLE III

Aft Cargo Door Cutout - Skin Panel and Bear Strap Crack
Repair at the Forward Upper Corner
Figure 204 (Sheet 10)

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Figure 97 Temporary Revisions

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NON DESTRUCTIVE INSPECTION TECHNIQUES

General

The need to inspect aircraft and aircraft parts without affecting the further serviceability and without changing their form is the reason for the NDT of materials.

These inspection techniques are under the most important methods for quality control and quality assurance in aircraft maintenance and manufacturing.

Comparable to the medical diagnostic, during NDT hidden failures in components and assemblies are identified prior to or in service so that unpredictable breakdown is prevented.

Furthermore this method gives a quick and reliable answer about the amount of damage of already detected failures which leads to the right choice of repair methods.

Due to the big competition between airlines nowadays, the economic operation of aircraft fleets is very important. This has an impact on the workload of the single aircrafts.

The more important is a accurate inspection of structural elements and single parts since fatigue damages are not always immediately visible.

The non-destructive testing is normally done with reference to the following points:

- Material
- Accessibility
- Possible failures
- Surface condition

The most common testing methods are:

- Visual examination
- Acoustic examination
- Penetrant testing
- Ultrasonic testing
- Magnetic particle testing
- Eddy current testing
- Radiographic testing
- Infrared / Thermography testing

Some further testing methods, which are not described in detail:

- Laser testing
- Mass spectroscopy
- Barkhausen procedure
- Pressure test

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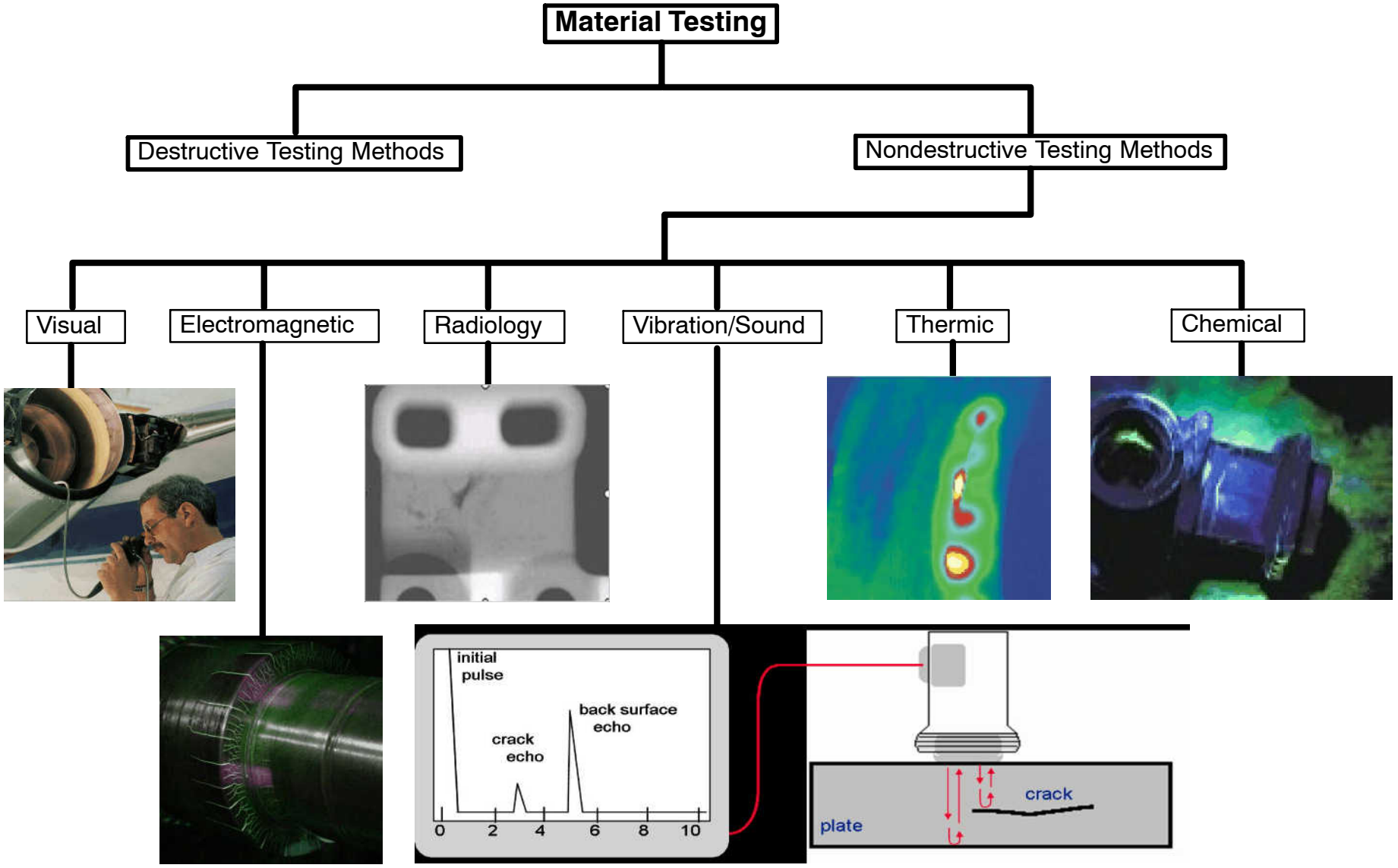


Figure 98 Nondestructive Testing Methods

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Visual Inspection

Visual Check (VC)

Nearly every NDT of an aircraft or part starts with a general visual check. Rough damages can often be seen on the first view (e.g. during Ramp-Check). These detections lead to a further inspection. No aids or limits are needed, the part is only “OK“ or “not OK“.

General Visual Inspection (GVI)

The general visual inspection includes a proper view under daylight, hangar light or with the help of a torch. As a general rule a distance of one arm length to the object should be kept. If there is a damage suspicion a more precise examination is needed. Maybe the particular area has to be made accessible or has to be cleaned. A ladder or a platform plus a mirror might be needed to inspect the area.

Detailed Visual Inspection (DVI)

An intensive inspection of a particular element in order to detect damages, failures or anomalies. Sometimes a cleaning of the area is needed and aids like mirrors and magnifying glasses and a good light source are instructed. Often the area has firstly to be made accessible, like e.g. by removing the floor panels or the opening of access covers.

Special Detailed Inspection (SDI)

During this particular inspection special techniques and also special instruments are used. the most common methods are borescope, holography and penetrant testing..

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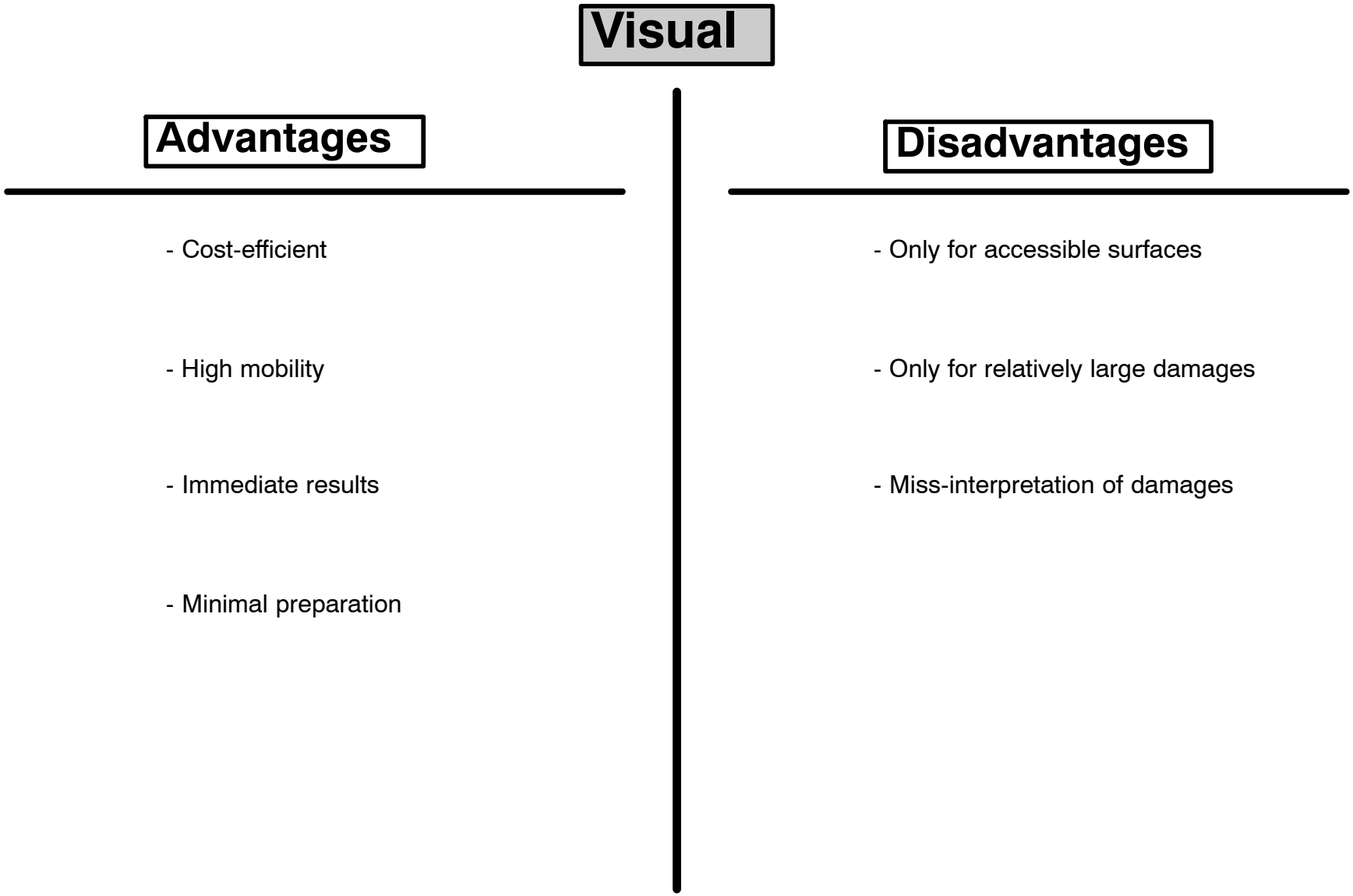


Figure 99 Advantages and Disadvantages of Visual Inspection

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VISUAL INSPECTION (CONT.)

Holography

This procedure is relatively new in the aircraft industry. Airbus uses this technology to inspect glass-fibre reinforced (GPR) components. Holography is normally known to everybody who has a credit card since there are a few holograms on this card. The advantages are the quick analysis and the quality of the testing (preferable in 3D). Mostly applied is the deformation method, during which two pictures of the component, one without load and one with load, are made. So even the smallest defects caused by stress can be depicted in an accurate quality.

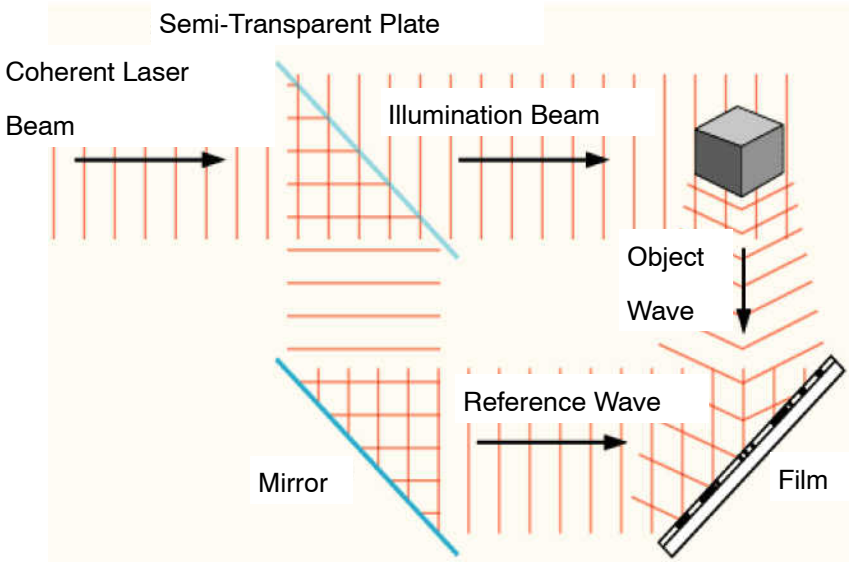


Figure 100 Holography

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Borescope Inspection

General

The denomination borescope is used in the technical area and is derived from the word bore. Borescopy was firstly used in the 19th century. A German doctor invented a rigid medical endoscope which has constantly improved until 1879 the first rigid endoscope, like it is known nowadays, was invented. Nearly 80 years later the flexoscope was invented.

Together with the jet engines the realization occurred that the borescope is an essential inspection tool since imminent fatal defects can be detected and so time and money can be saved with it.

Procedure

There are different borescopes for different inspections and requirements available.

From the simple hand borescope with magnifying glass and light source to the modern videoscope with a high-resolution screen, glass-fibre light guide and a flexible objective, every borescopy can be conducted optimally.

In former times the spark plug bores were used for viewing inside the engine. In the present engine technology every compressor / turbine section and the combustion chamber has its own borescope holes. So an inspection can be conducted fast and precisely.

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Manual Borescope



Rigid Borescope



Flexible Borescope



Videoscope

Figure 101 Systemes of Borescopes

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Assembly of Borescope

The assembly of a borescope is the same in every particular system.

A light source, an objective lens and a light transmitter is needed, which connects both ends. The light source normally consists out of a halogen or xenon bulb. These very sensitive light sources need a good cooling to produce the enormous intensity of light. So it has to be taken care that after borescoping not the whole unit, but only the bulb has to be switched off since so the ventilation can continue.

In order to transmit the light as well as possible to the objective lens, optical transmitters made out of glass fibres are used. This technology has proofed itself since it is flexible and therefore very mobile.

The borescope tube is available in two different types:

- **Rigid**

  A rigid tube can be used for compressor/turbine assemblies and also for combustion chambers since there are no obstacles in the way and therefore the borescope provides a stable image.

- **Flexible**

  Fibrescopes are used if there is no direct connection to the desired area. The end is often pivotable in every direction in order to see in and around edges.

Both systems can be equipped conventionally, that means with a eye-piece and a focusing ring, or with a video camera which shows the pictures on a monitor. Additionally fixed images can be made by connecting a camera.

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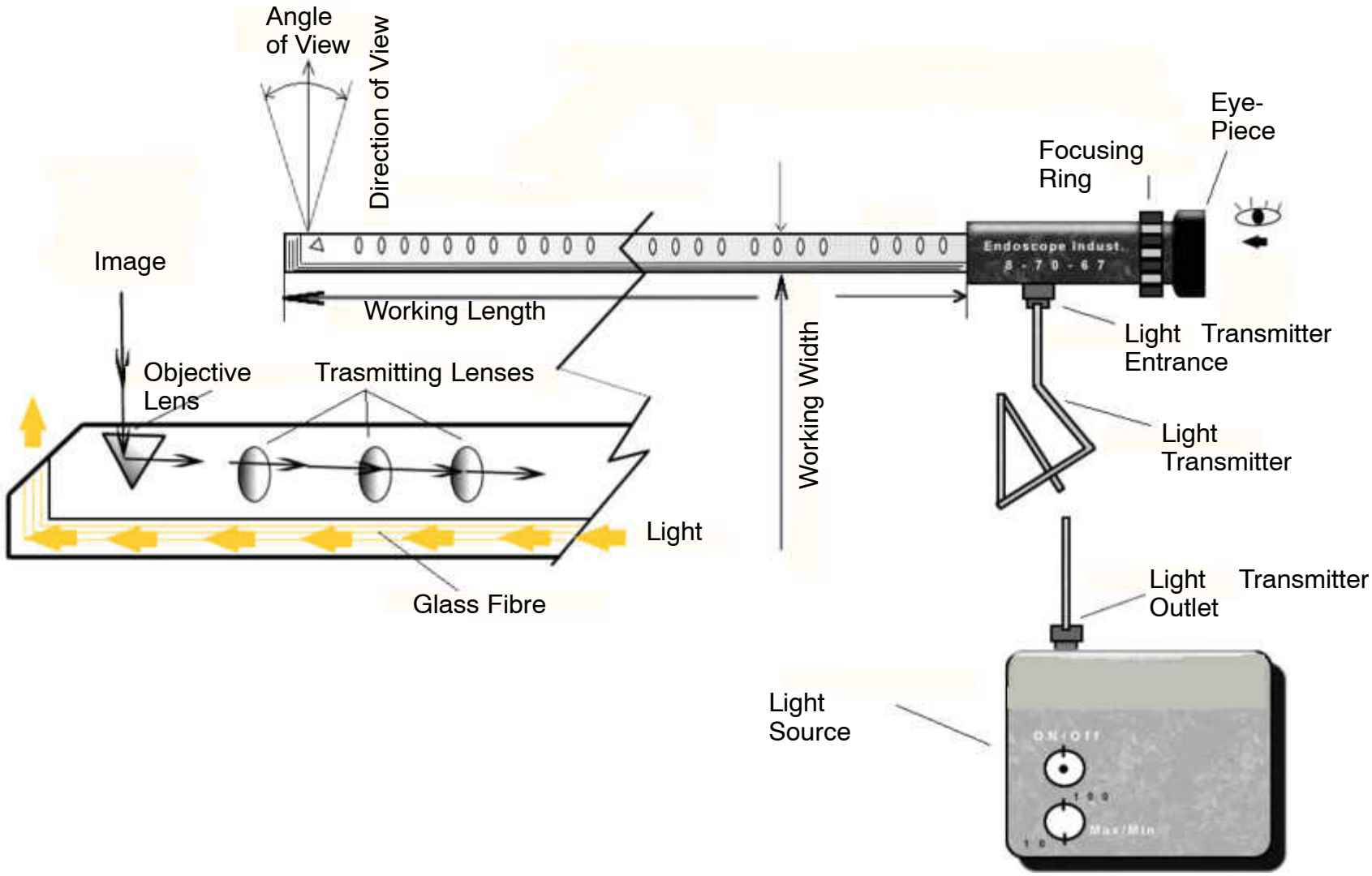


Figure 102 Assembly of Borescope

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Acoustic Examination

General

Cracks and defects in connection area of metal or plastic parts can be located by a tap test.

The railroad companies have been using this procedure for a long time. Cracked wheel rims are identified by a tap test. Cracked glass or porcelain elements can also be checked on large cracks and fissures by tapping them.

Procedure

This procedure is used at aircraft elements for the detection of a skin delamination of sandwich panels.

Manual Tap Test

The area that has to be checked is tapped with the help of a light hard device, whereas a clear and hard resonance sound does occur at the undamaged areas. In the areas that are damaged by delamination a dull and hollow sounding resonance noise can be heard.

The areas that sound dull are marked with a lead pen in order to make the damaged area recognizable. Dull sounds can indicate delaminations and entrapped water in the honeycomb structure. Tap testing needs experienced testing staff and do not always provide an one hundred percent diagnosis.

Computer Aided Tap Test

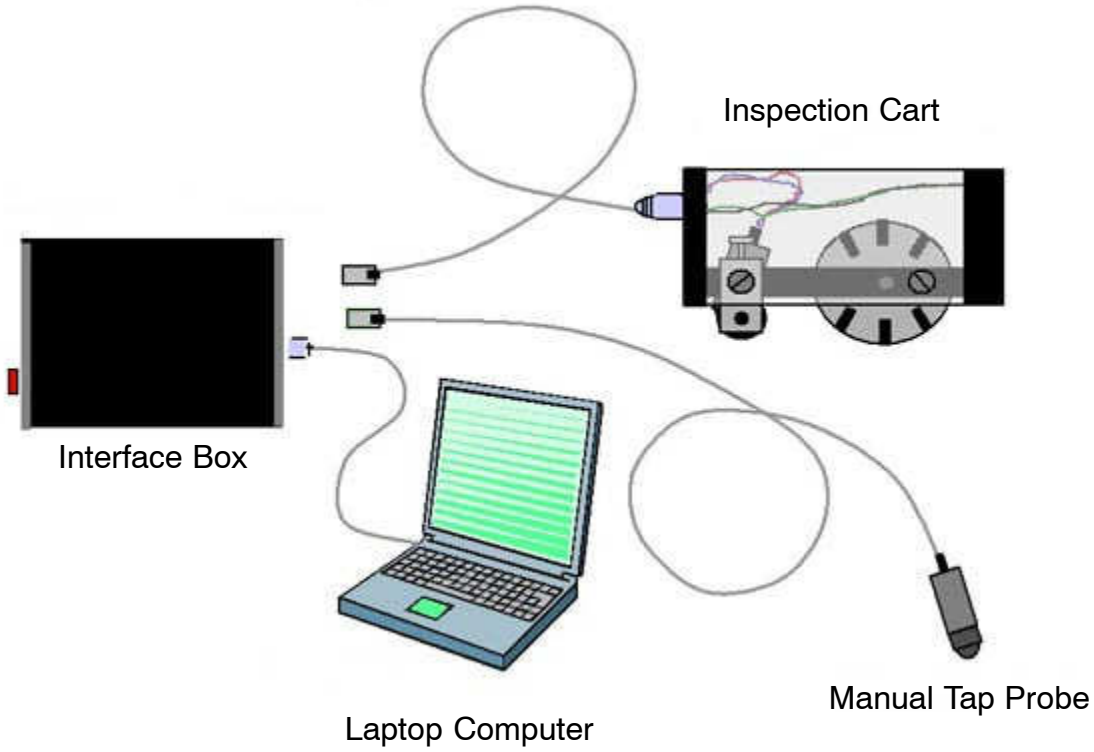
Newly procedures are used that are known as CATT procedure.

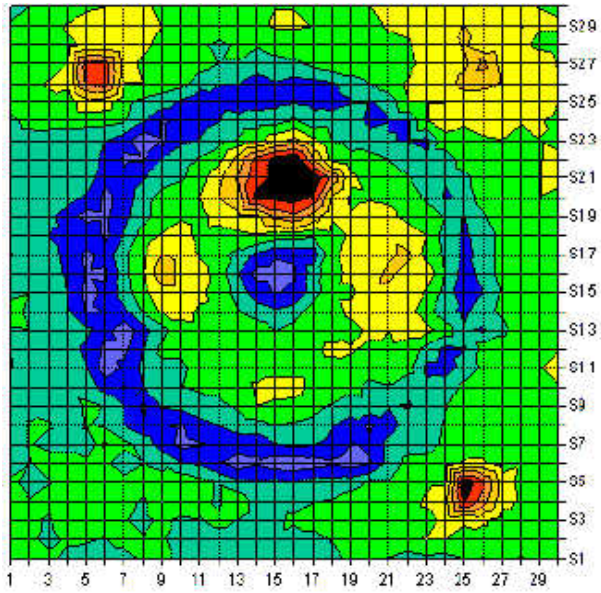
A small beater mounted on a test sled is moved up and down by a magnetic field. If the sled is moved along the element the beater taps the surface.

The sound is recorded at the sled and is illustrated in a grid. The duller the noise is the darker gets the picture in the particular area, like in a weather radar picture. So the user gets a accurate colored picture of the area concerning delamination or entrapped water.

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(CATT) Gitter

Figure 103 Acoustic Testing

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Penetrant Testing

General

The penetrant testing is probably one of the oldest and simplest procedures in NDT. The first mention goes back to the age of the crusader. Later in the 19th century the „Oil and Whiting“ procedure was applied by the railroad work in the United States, a precursor of the red-white procedure.

There are two different types of penetrant testing:

- Colored penetrant testing (red-white procedure)
- Fluorescent penetrant testing

Both procedures use the capillary force of liquids. So these procedures can only be used for surface defects since otherwise the liquid can not penetrate

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Penetrant Testing

Advantages

- Cost efficient
- High mobility
- Immediate results
- Very accurate results
- Quick testing of several parts
- Not so much experience needed
- Can be used for many materials

Disadvantages

- Only for penetrant-accessible surfaces
- Defect must be at the surface
- Surface must be free (paint, corrosion protection)
- No permanent image of damage
- Defects must be directly readable
- The area must be absolutely clean; high cleaning effort, also after analysis
- Only for smooth surfaces

Figure 104 Advantages and Disadvantages of Penetrant Testing

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PROCEDURE

Colored Penetrant Testing (Dye Check)

The procedure is the same for both types. First the surface has to be cleaned very accurately since even small residua can change the test results heavily. Also the surface has to be paint-stripped.

After that a penetrant with very good penetrating characteristics is applied. After a certain residence time the surface is freed from the penetrant, but the penetrant in small defects stays due to the capillary force. If the surface has dried the developer can be applied. This sucks the penetrant out of the defects and makes them visible.

In order to achieve a high contrast the penetrant is normally colored red and the developer white. A disadvantage of this procedure: you can only see that there is an defect and where it is located but you can not determine the depth.

Fluorescent Penetrant Testing (Zyglo Check)

An enhanced type of penetrant testing is the fluorescent penetrant testing. Even small defects can be identified due to the penetrant glowing greenly under ultraviolet light since the human eye is more light-sensitive than color-sensitive.

There are also differences considering the developer and the penetrant. Depending on the part there are developer/penetrants on oil basis, water-soluble penetrants and penetrants powder form. For example an oil based penetrant is applied and then a lipophilic developer is used, which absorbs the penetrant (comparable to blotter).

Because of high risk of oxidation the use of water−soluble agents on metal components should be avoided. Therefor solvent-based penetrants are used.

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Figure 105 Colored Penetrant Testing (red-white)

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Magnetic Particle Testing (Magnaflux)

General

This procedure is a part of the electro-magnetic procedures and can only be applied for ferromagnetic (not austenitic) materials. The material is differed in

- **Magnetically Soft**

  Magnetically soft material has a light remanence and after switching off the magnetic field there is barely remanent magnetism.

- **Magnetically Hard**

  Magnetically hard material has to be demagnetized after testing since high there is high remanent magnetism.

The advantage of this procedure in comparison to the penetrant testing is that also surface-near defects are made visible. The defect does not need implicitly a connection to the surface; the indicating agent does not need to penetrate.

Also the surface quality/geometry is not essential, even porous or complex-formed elements can be tested.

Procedure

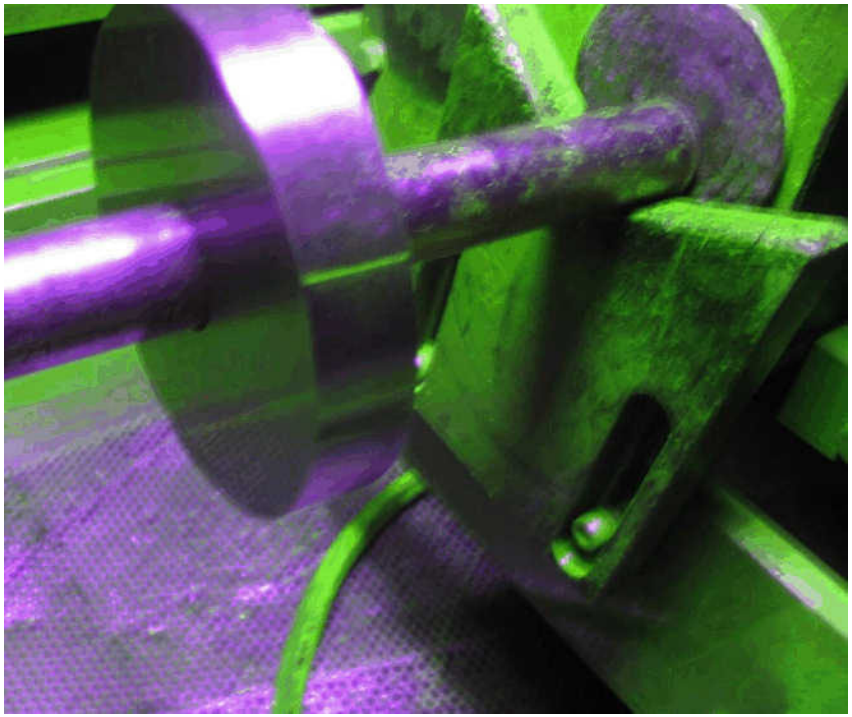
If a ferromagnetic part is magnetized (by DC- or AC-current) magnetic streamlines go straight-lined through the whole part. If magnetic streamlines meet a magnetically bad conducting area, like a surface crack, a change of field direction is generated by the magnetic resistance. This generates a magnetic leakage flux which makes surface damages visible due to the accumulation of ferromagnetic particles.

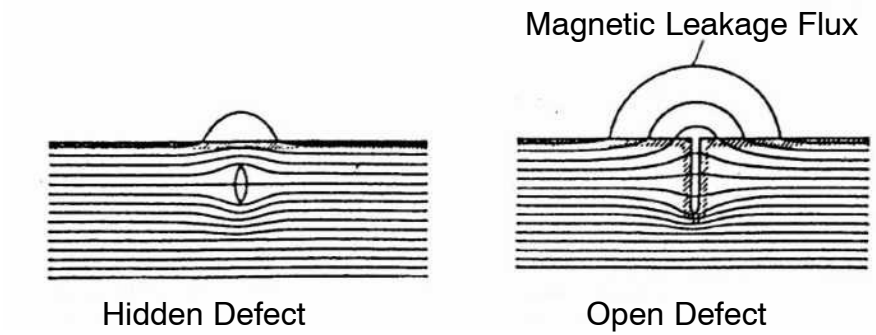
Ferromagnetic particle are normally applied in form of a fluorescent liquid and are clearly visible under ultraviolet light. Water with additives against oxidation is used as a vehicle due to environmental and work protection reasons. Only in exceptional cases oil is used, if the manufacturer instruction demands it.

Additionally a second testing (magnetic streamlines 90 degrees changed) has to be conducted since defects that lay parallel to the magnetic flux are not visible.

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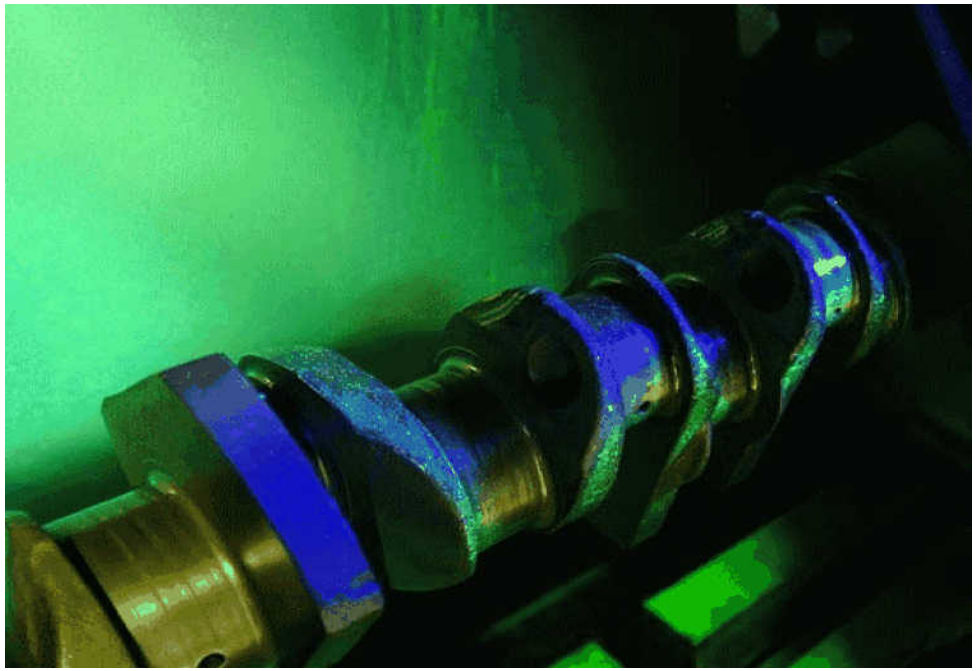


Figure 106 Magnaflux Procedure

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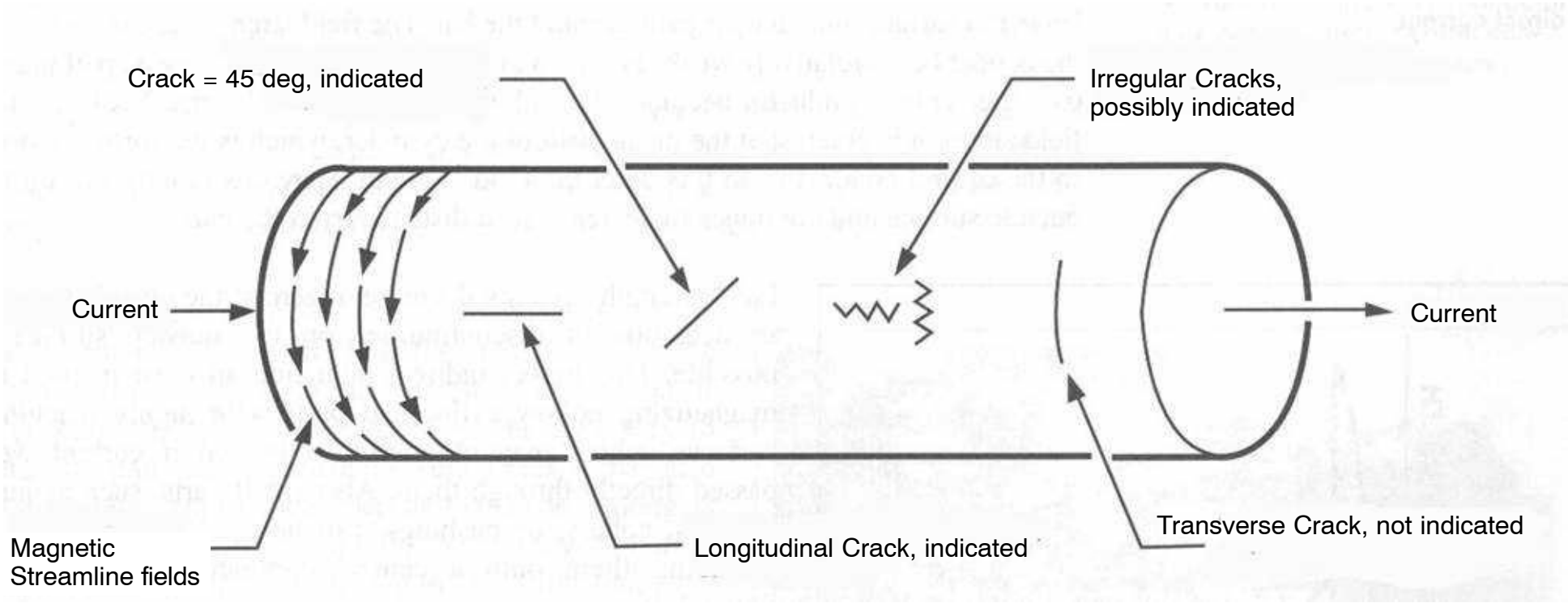


Figure 107 Crack Indication during Magnetic Particle Testing

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Magnetic Particle Testing

Advantages

- Mobile
- High sensivity also at small defects
- Also for surface-near defects
- Cracks and inclusions are identified
- Quick testing for individual parts
- Fair experience needed

Disadvantages

- Only for ferromagnetic materials
- Element must be physically and visually accessible
- Surface must be free (paint, corrosion protection)
- No permament image of damage
- Only directional Testing possible
- Strong magnetic fields disturb equipment located in the testing area
- Parts have to be demagnetized

Figure 108 Advantages and Disadvantages of Magnetic Particle Testing

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UltraSonic Testing

General

Ultrasonic is the sound which is not hearable for the human ear anymore (20kHz to 1GHz). The sound spreads in form of vibrations in gases, liquids and solid bodies.

Sonic obeys the physical laws and can be concentrated, focussed, reflected, refracted or, depending on the material, absorbed. If particular materials are loaded with tensile or compressive stresses, electric charges are created at the surfaces. This phenomenon is called piezoelectric effect. This is today nearly exclusively used for ultrasonic sound generation. The material of the probe's plate is barium titanate. The plate's upper and lower side are metallized, for example by vacuum vapor coating or by burning-in argentine water; on this wires for the application and the discharging of electric voltage can be soldered.

A German physicist worked after the tragic sinking of the Titanic with ultrasonic in order to find iceberg earlier. Later in the 2. world war this methods was used for finding u-boats and already in the 30's the ultrasonic method was used as a NDT in the United Sates ad Europe.

Procedure

With the help of an ultrasonic probe, which sends acoustic waves in the 500kHz to 25MHz area, and a coupling means made out of water gel or oil cracks or other defects are detected.

Thereby the impulse-echo principle is applied, that means the sound is emitted and the time is counted until the echo is back again (comparable to a radar). On the basis of this measurement an electronic image of the component can be depicted on a monitor and thus be saved easily. A coupling means is used since the probe and the part must have direct contact for transmitting sound waves.

The sound spreads in solid bodies with different velocities. Also a low frequency has a long wave-length and a high frequency a short wave-length.

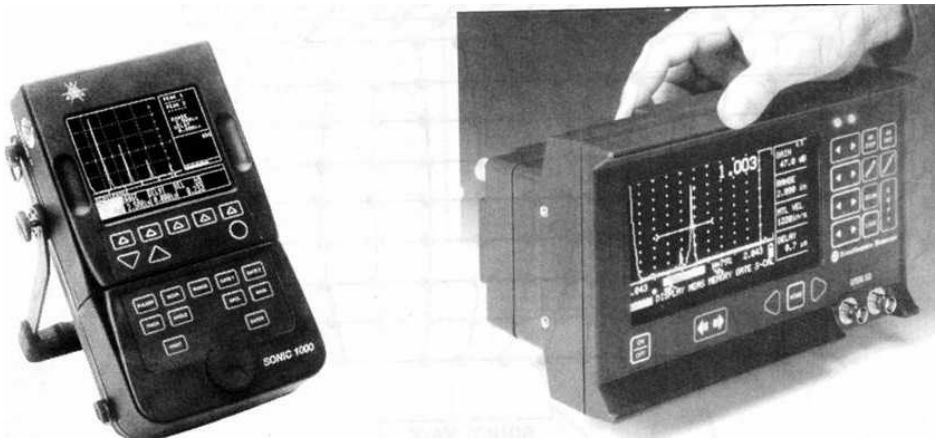


Figure 109 Ultrasonic Testing Monitor

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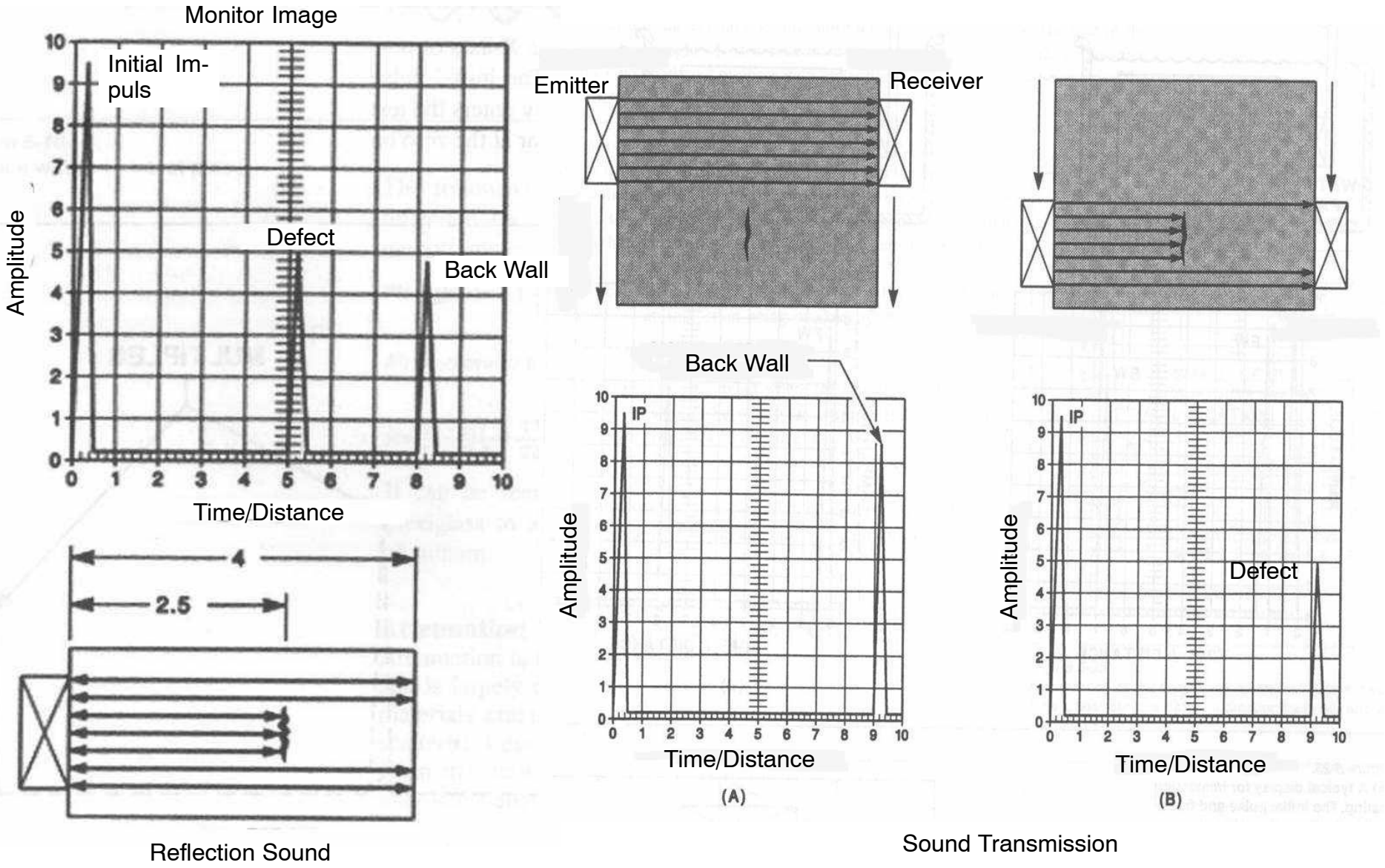


Figure 110 Reflection Sound and Sound Transmission

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Ultraschallverfahren

Advantages

- Mobile
- Fair sensibility even for small defects
- Also for surface-near defects
- Immediate test results, savable
- Nearly no preparation needed
- Many thickness can be tested
- Not only for metal
- Can be automated

Disadvantages

- Needs high experience and training
- Element muss be physically accessible
- Rough surfaces disturb the testing
- A coupling medium is needed
- Method is only directional (straight line)
- Very thin or complex parts are difficult to test

Figure 111 Advantages and Disadvantages of Ultrasonic Testing

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Procedure (Contd.)

The speed and frequency can be calculated with the help of this formula:

- $v = \lambda \times f$ (**Speed of Sound= Wave-Length times Frequency**)

In AL 2024−T4 sound spreads with a speed of 6320 m/s. If you take the formula you can calculate the wave-length:

at 1MHz: $\lambda = \frac{(6,32 \times 10^5 cm/s)}{1MHz} = \lambda = \frac{(0,632cm/\mu s)}{1MHz} = 0,632mm$

at 5MHz: $\lambda = \frac{(6,32 \times 10^5 cm/s)}{5MHz} = \lambda = \frac{(0.632cm/\mu s)}{5MHz} = 0,1624mm$

Herewith it can be recognized that the frequency is inversely proportional to the wave-length.

Here some examples of the speed of sound in solid bodies at 20 deg Celsius:

2024−T4:	6320m/s (longitudinal)	3130m/s (transversal)
Steel:	5950m/s	3230m/s
Plexiglass:	2700m/s	1400m/s
Beryllium:	12900m/s	8880m/s
Diamond:	18000m/s, the highest value of normal materials.	

In comparison:

Air:	343m/s (longitudinal)

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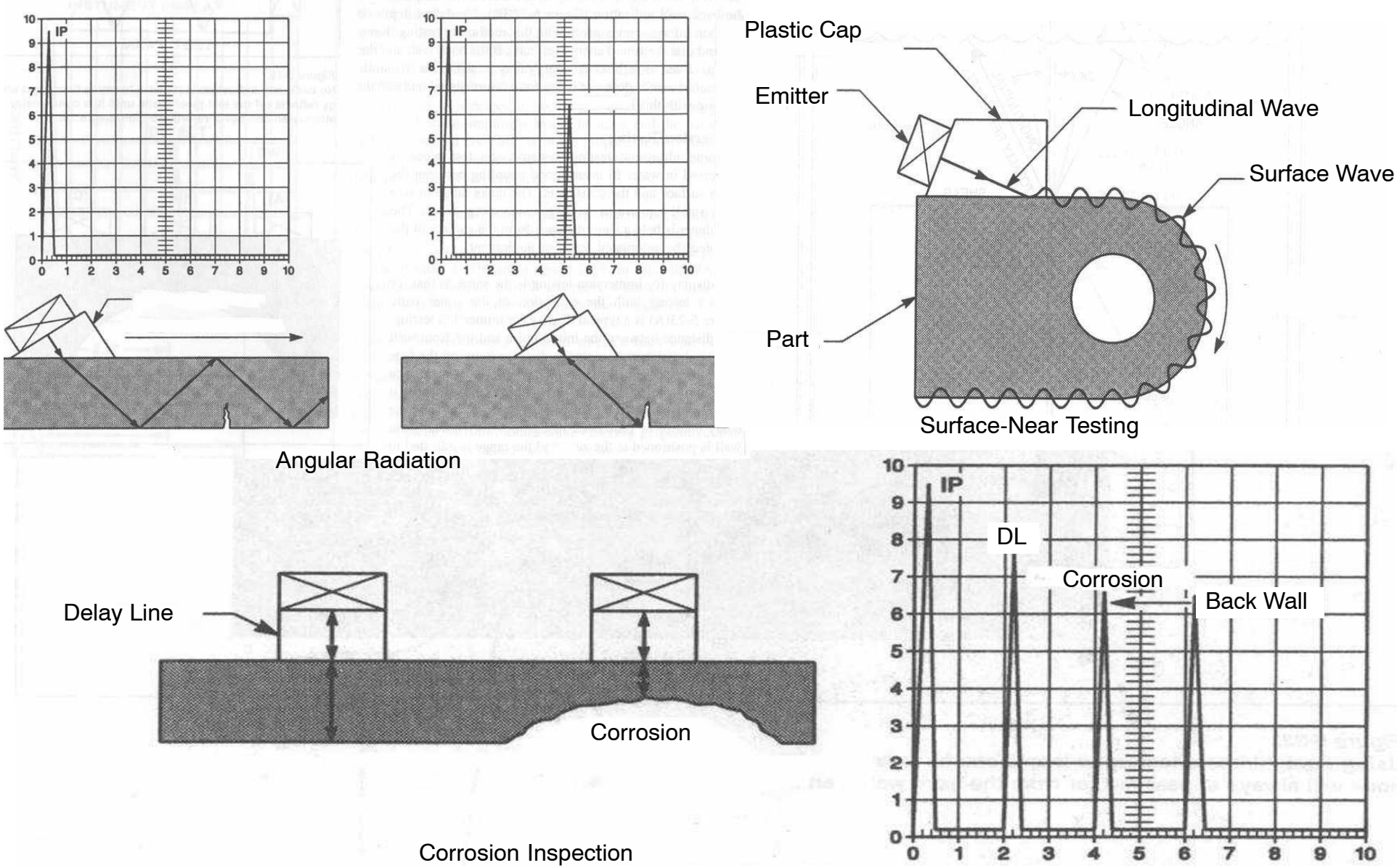


Figure 112 Ultrasonic Testing Methods

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Reflection Sound

In the reflection sound method the probe is emitter and receiver at the same time. First a short acoustic impulse is emitted and then it is waited for the echo. This initial pulse can be seen on the left side of the monitor. If the impulse is reflected from the back wall, it arrives after a certain time the probe. This is made visible on the monitor as a back wall signal. If you go over a defect, it is shown between these two signals since the time is shorter than the time from the back wall. With the help of the reflection sound method only defects that are larger than $\frac{\lambda}{2}$ can be detected.

The frequency can not be increased at will, since the material's grain boundaries can deflect or absorb the waves and so reduce the depth of penetration.

Also the material has influence. When working with rough crystalline structures, like e.g. steel castings, a low frequency must be used. The largest possible element thickness is ca. 5 m, which results in a way of sound of 10 m. The smallest is the wall thickness of a razor blade with a 50Mhz probe. With the help of this method the direction and depth of a defect can be determined.

Sound Transmission

In the transmission sound method an emitter and receiver is used, which face each other. The emitter constantly sends sound impulses which are recorded by the receiver. This can comparable to the reflection sound method be depicted on a monitor. But if the sound meets a defect on its way, a smaller sound energy arrives at the receiver. This leads to the fact that the back wall signal is decreased, there is no additional impulse depicted on the monitor.

Herewith no accurate statement can be made about the exact position of the defect, that is why the method is only used for certain testings or is used as a further developed method of finding blowholes in materials by tapping.

Also the spread of the waves is different:

- **Longitudinal Waves**

  Longitudinal waves are often pressure waves. That means that in a media zones of overpressure or compressive stress (under pressure tensile stress) spread along the propagation direction. The individual parts in the medium, atoms or molecules, resonate in the propagation direction with the magnitude of the amplitude. After accomplishment of an oscillation the parts move back to the idle or neutral position. During the propagation no energy, except for the energy loss due to the friction between the parts, is lost. These waves occur in all of the three aggregate states.

- **Transversal Waves**

  If the elements oscillate perpendicular to the propagation direction, they can transmit their energy only to the neighbor parts, if the particular material has a solid elasticity, that means it has the ability to transmit shear and torsion stress. Since the medium is stressed with shear, these waves are denominated as shear waves, but mostly called transversal waves. Compared to the longitudinal waves transversal waves can only spread in solid bodies.

Testing Methods

Surface-near damages can be detected with the help of the angular radiation, since otherwise the defect is in the dead area of the echo or initial impulse.

The surface wave moves only along the surface of the element, in the depth practically limited to half of the amplitude.

Another advantage is the automation. With the help of it even large parts, for example in a water bath, can be tested fully automatic and can be virtually depicted with a C- or D-Scan.

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Eddy Current

General

If a alternating current flows through a coil, magnetic alternating field are generated. If you take a metallic part into the area of the magnetic field, eddy currents are inducted into the part, which also produce a magnetic field.

In eddy current testing the effect, that most of the impurities and defects in a metallic material have another conductivity or permeability than the basic material, is used.

Eddy current testing is used for

- **Crack Detection**

  In this testing sensors are used, whose coils are arranged in such a way that small changes in material characteristics or distance of the sensor to the material surface are mostly compensated.

- **Thickness and Coat Thickness Testing**
  - Non-conducting coat on a conducting material:

    The distance between probe and conducting layer is measured by measuring the amplitude and so the thickness is determined. Application: Determination of coat thickness after painting.
  - Conducting layer on non-conducting material

    The amplitude rises with an increasing thickness since the conducting section is larger. The difference is the layer thickness.

- **Testing of Material Characteristics (Structure Testing)**

  Every material has a different conductivity or permeability, which can be used for the determination of state, hardness or for a definite identification of a part.

This procedure can only be applied to electrically conducting materials.

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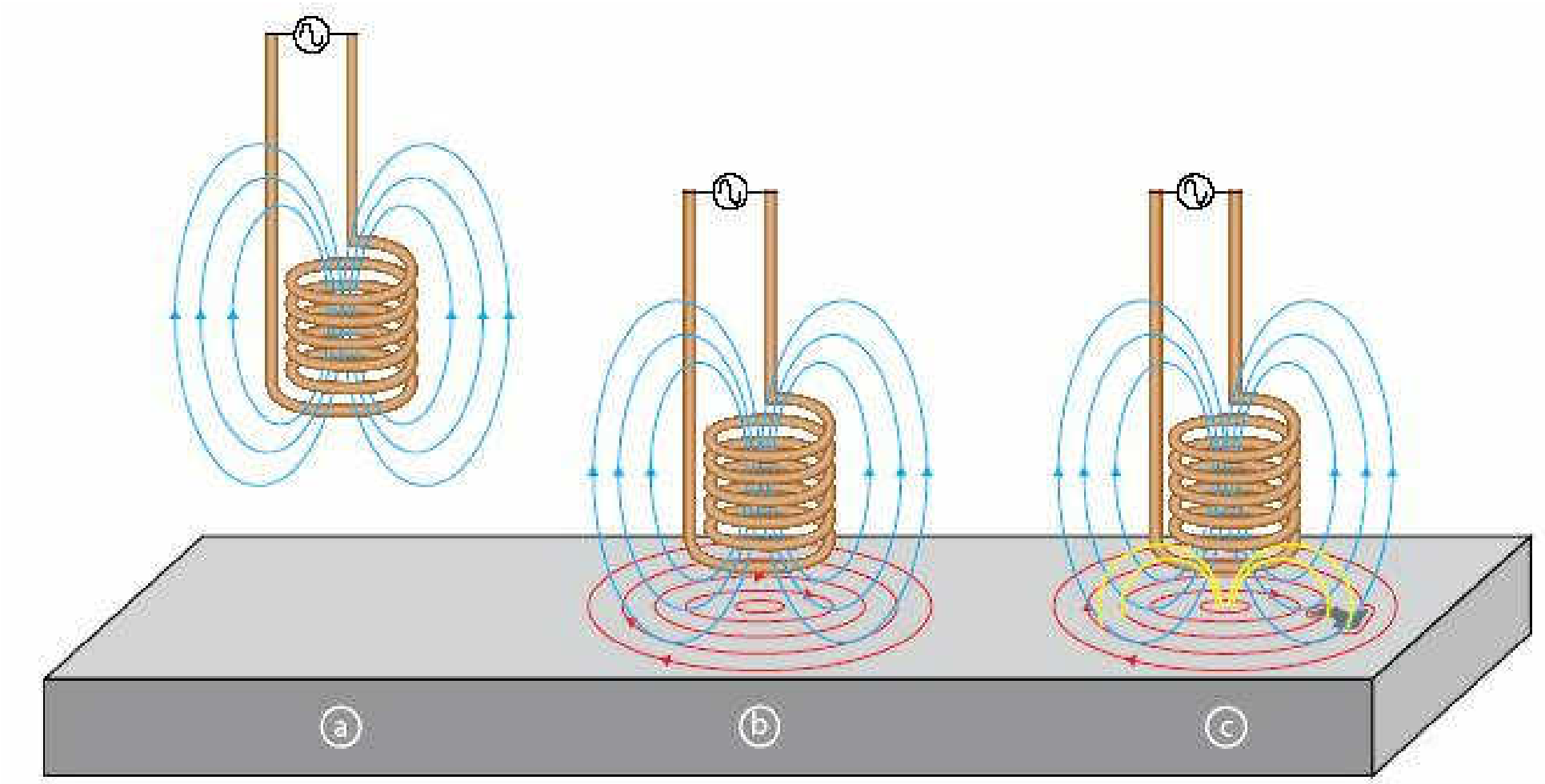


Figure 113 Principles of Eddy Current

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Tools for Eddy Current Testing

To generate an eddy current you need an eddy current probe and a testing device, which generates the required current in a particular frequency and, if required, amplifies the result and has a monitor for defect indication.

The probes are, depending on the type of test, available in different sizes, forms and types. For large surface a sliding probe, for rivet testing a ring probe and for hole testing a differential coil with pivoting method is used. On the monitor the eddy current is mostly depicted as a shining point (“flying point“) which moves back and forth if the magnetic field is changing.

To have accurate measurement results the probe must be calibrated firstly with a specified reference object. Depending on the method and type the device can be adjusted optimally and defects or thickness measurement can be clearly read.

Probes differ from each other in their number of coils. There are single- and double-coils, so called differential-coils. Single-coils indicate changes by a change of the magnetic field in the test part. Differential-coils work differently. Both coils are adjusted, so that their nominal value is zero. So even small changes in the test part can be detected, which makes this type more sensitive.

High Frequency Eddy Current (HFEC)

High frequency testing are mainly used for flaw detection in surface-near areas since the wave length is quite short

Low Frequency Eddy Current (LFEC)

Low frequency eddy current testing is used for corrosion or flaw detection, which can occur in multi-layer connection, like e.g. lap joint. Due to the large wave length it can be tested deep in the material, but the sensitivity is smaller and so only quite large defects can be detected.



Figure 114 Eddy Current Probe Types I

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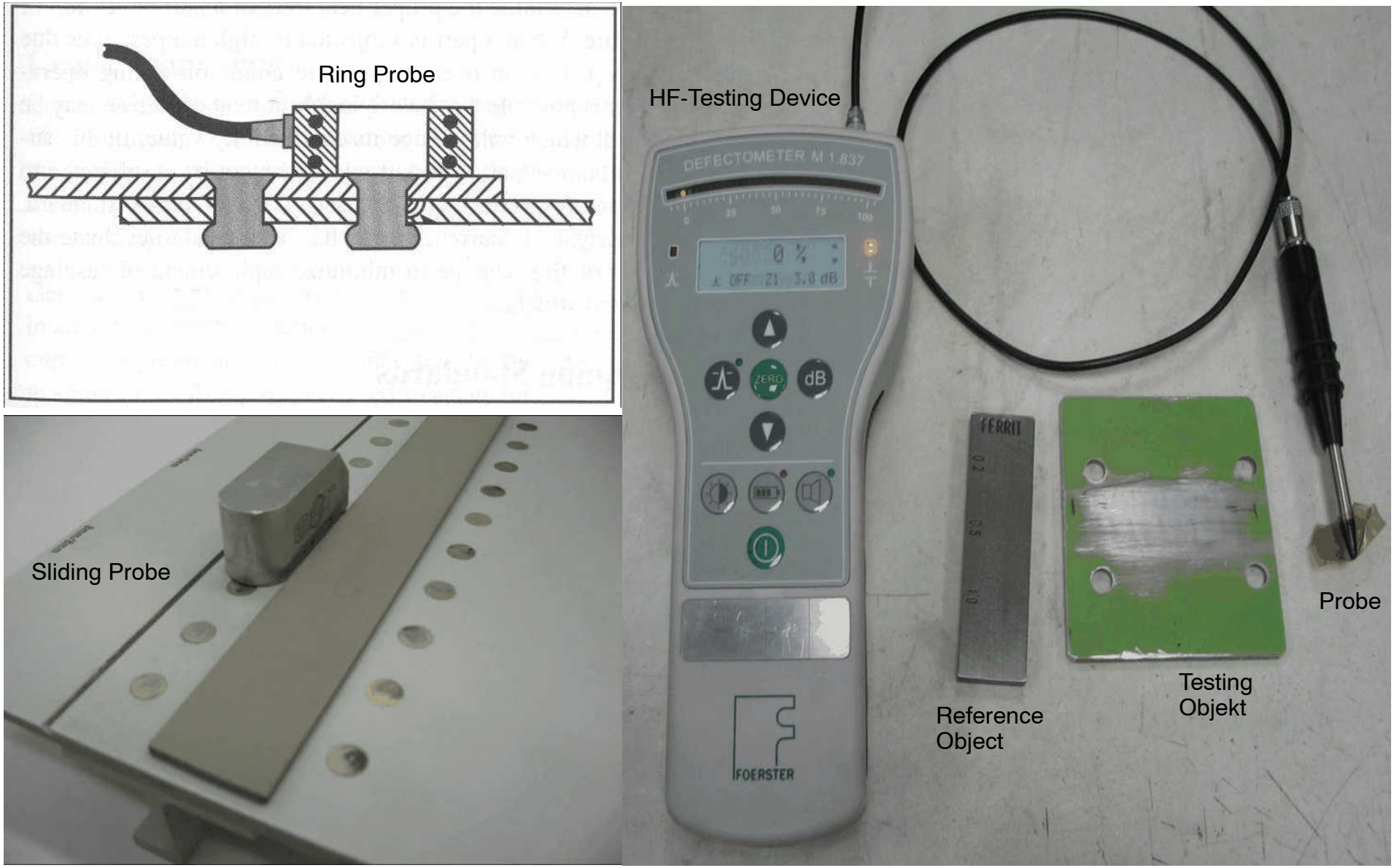


Figure 115 Eddy Current Probe Types II

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Figure 116 Application of Eddy Current Testing

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Eddy Current Testing

Advantages

- Medium costs
- Mobile
- Immediate results and directly savable
- Very accurate results also with small defects
- Little preparation work
- No coupling means
- Can be automated
- No damaging of surface protection

Disadvantages

- Surface must be accessible
- Rough surfaces disturb measurement
- Only for electrically conducting materials
- Needs high experience and training
- High time demand for large surfaces

Figure 117 Advantages and Disadvantages of Eddy Current Testing

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Radiographic testing (x-ray, Gamma-ray)

General

X-ray is the process of radiographing bodies with X-rays with the usage of a x-ray emitter and the display of the radiography of the body with suitable film material, phosphor plates or electronic sensors, like e.g. CCDs (digital radiography). X-rays and gamma-rays belong to the group of electro-magnetic waves, which spread with the speed of light.

X- and gamma-rays have the ability to move through all aeriform, liquid and solid materials. During irradiation of the material an energy loss occurs due to absorption and deflection with the result that the irradiated rays have a lower intensity than the emitted rays. The degree of energy loss depends on the thickness, the atomic number of the material and on the wave length of the radiation.

You differ relating to their ability to move through material between soft radiation with a long wave length with a poor ability and hard radiation with a short wave length with a good ability to move through material. In opposition to optical light, which can have a change of direction by reflection and refraction, x-rays move in a direct way through every material, if they are not absorbed due to their short wave length.

Procedure

A x-ray tube consists out of highly evacuated glass or ceramic tube, in which cathode and anode are melted in. By heating the cathode, which is made out of tungsten, electrons are emitted from the cathode due to thermoelectron emission. These are accelerated by a high voltage of 50 to 400 kV between cathode and anode. They hit the anode with a very high velocity and are decelerated, which generates the x-rays. Since only a small amount of the electron's energy is converted to x-rays and the remaining energy is converted in heat, the anode must be cooled and be made out of a material with a very high melting point (tungsten). During electron impact a radiation is produced, whose spectrum consists out of radiation of different wave lengths.

The oldest and also still most common method to show the intensity and distribution of intensity after the irradiation of a work piece is the recording with a x-ray film. This film is principally made like a normal film for black and white photography. That means an emulsion coat of 0,01–0,02 mm thickness, in which brom-silver grains are used as a light-sensitive substance, is applied on a fire-proofed layer.

Radiation Sources

X-ray radiation is the radiation that is produced if high velocity electrons are decelerated. In opposition to that gamma radiation is produced by the decay of radioactive nuclei, for example Ir 192 (Iridium) or Co 60 (Cobalt). Gamma rays are due to their high quantum energy, which can destroy chemical bondings in series, and their ability to move through material with a thickness of several centimeter to meters, relatively dangerous and the shielding is relatively complex since the radiation can not be turned off.

Safety Precautions

X- and gamma rays are very noxious. Therefore very strict arrangements must be made. The advices in instructions must be met. Due to ionization events in living cells of humans, animals and plants, the building and the working of irradiated cells can be changed and dangerous damages can be caused.

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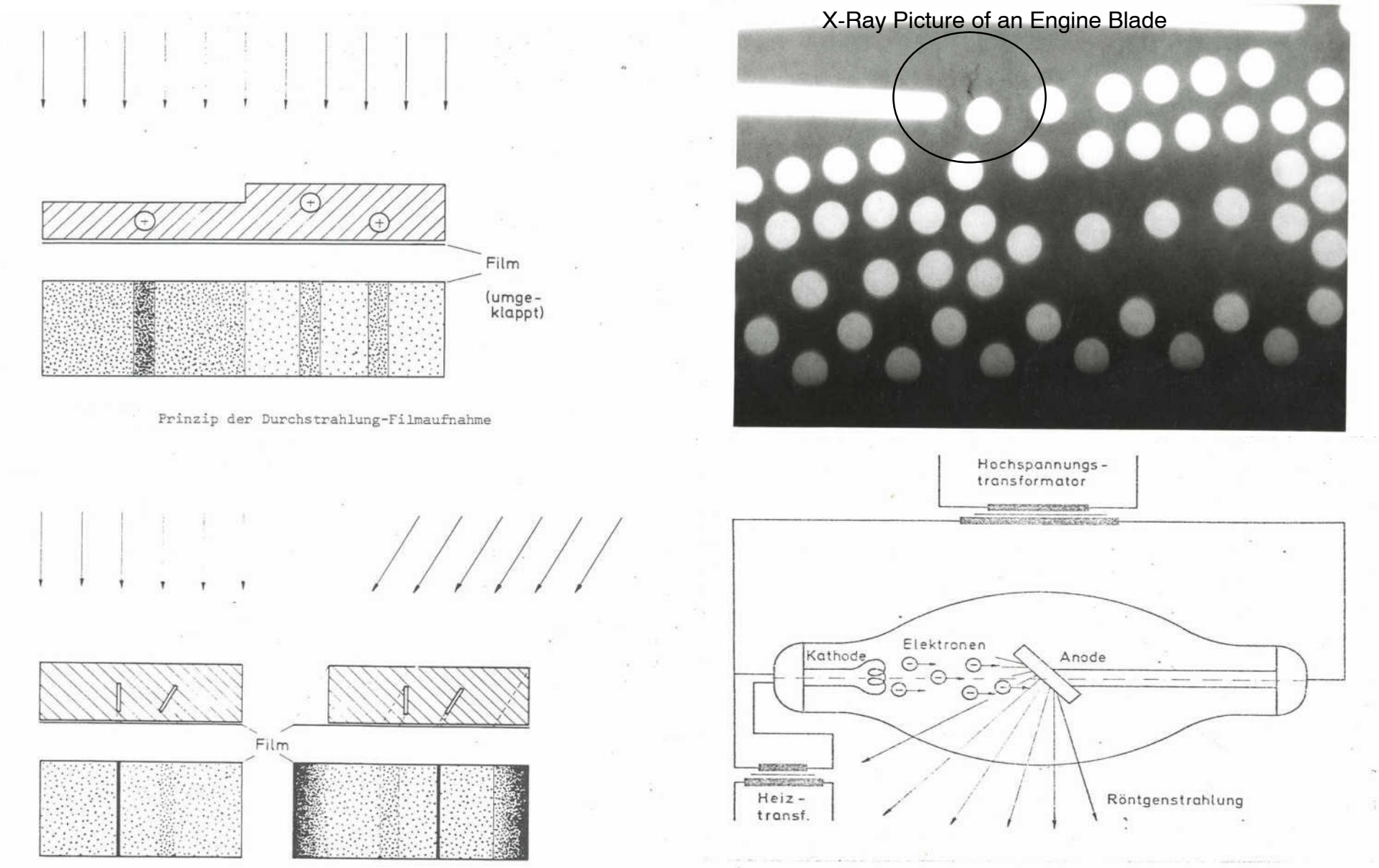


Figure 118 X-Ray Procedure

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X-Ray Testing

Advantages

- Many defects can be found
- Mobile
- Test result always available (film)
- Complex Assemblys must not be disassembled
- Minor preparation needed

Disadvantages

- Very expensive
- Long preparation time of the test equipment
- Radioactive, noxious
- needs a large amaount of experience and training
- Needs equipment for film development
- Very directional
- Underllays the strict laws of the Nuclear Regulatory Commission

Figure 119 Advantages and Disadvantages of X-Ray Testing

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Thermography

General

Thermography is a procedure that makes infrared radiation visible.

An infrared camera converts the infrared radiation, which is not visible for human eyes, into electric signals. Even small temperature difference can thus be made visible.

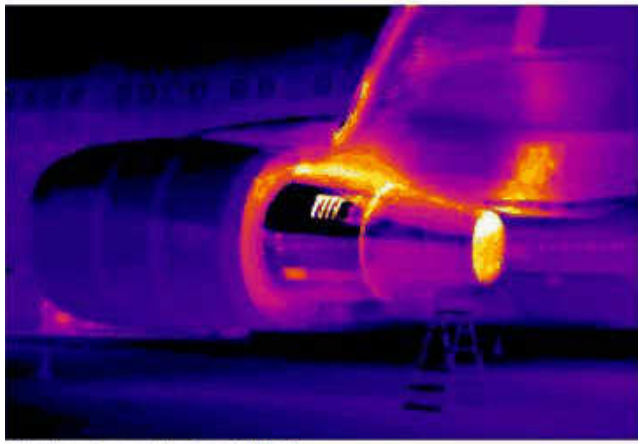
Procedure

The impulse thermography is a procedure in which the thermal balance of the test object is intentionally disturbed by a heat flow.

Failures, geometry irregularities or inhomogeneities change the heat flow and thus the temperature distribution on the part's surface. This can be recorded with the infrared camera.

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Motor einer Boeing B757

Bilder:LHT AG, WG915 (Breidenstein)



Wärmeaustritt an den **Cowlings** und an der **Fixed Nozzle**

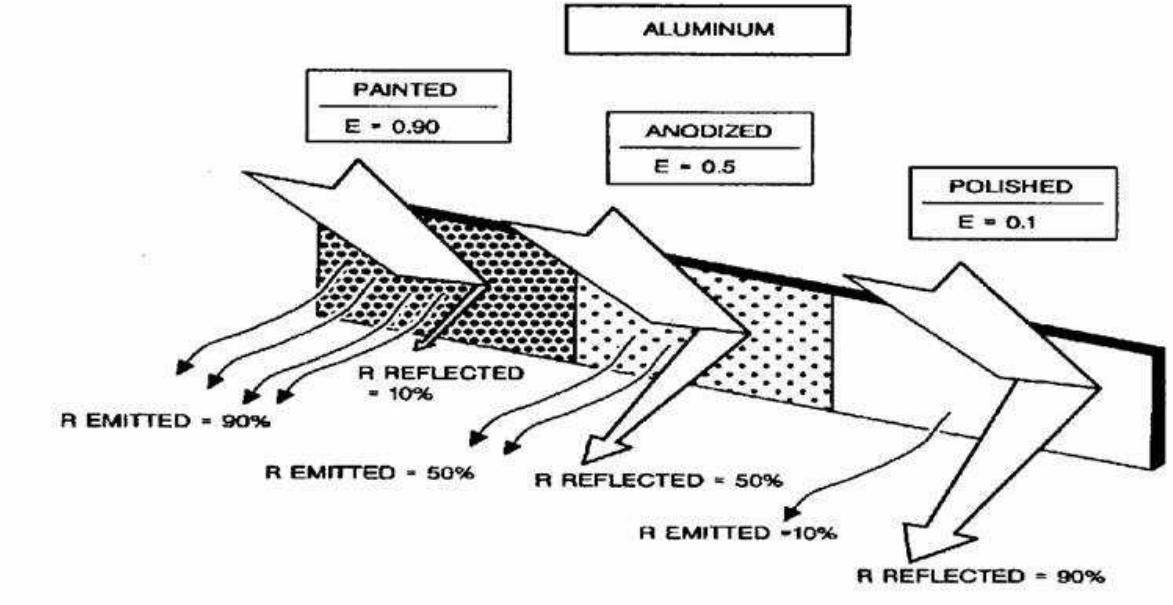


Figure 120 Thermography Procedure

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Procedure

By cooling parts to -5°C or by heating the part's surface with halogen bulbs or heating blankets, delaminations or entrapped water can be detected in composite structures.

Debonding of adhesives from different materials, like e.g. fibre-reinforced plastics or aluminium, can also be detected with this procedure.

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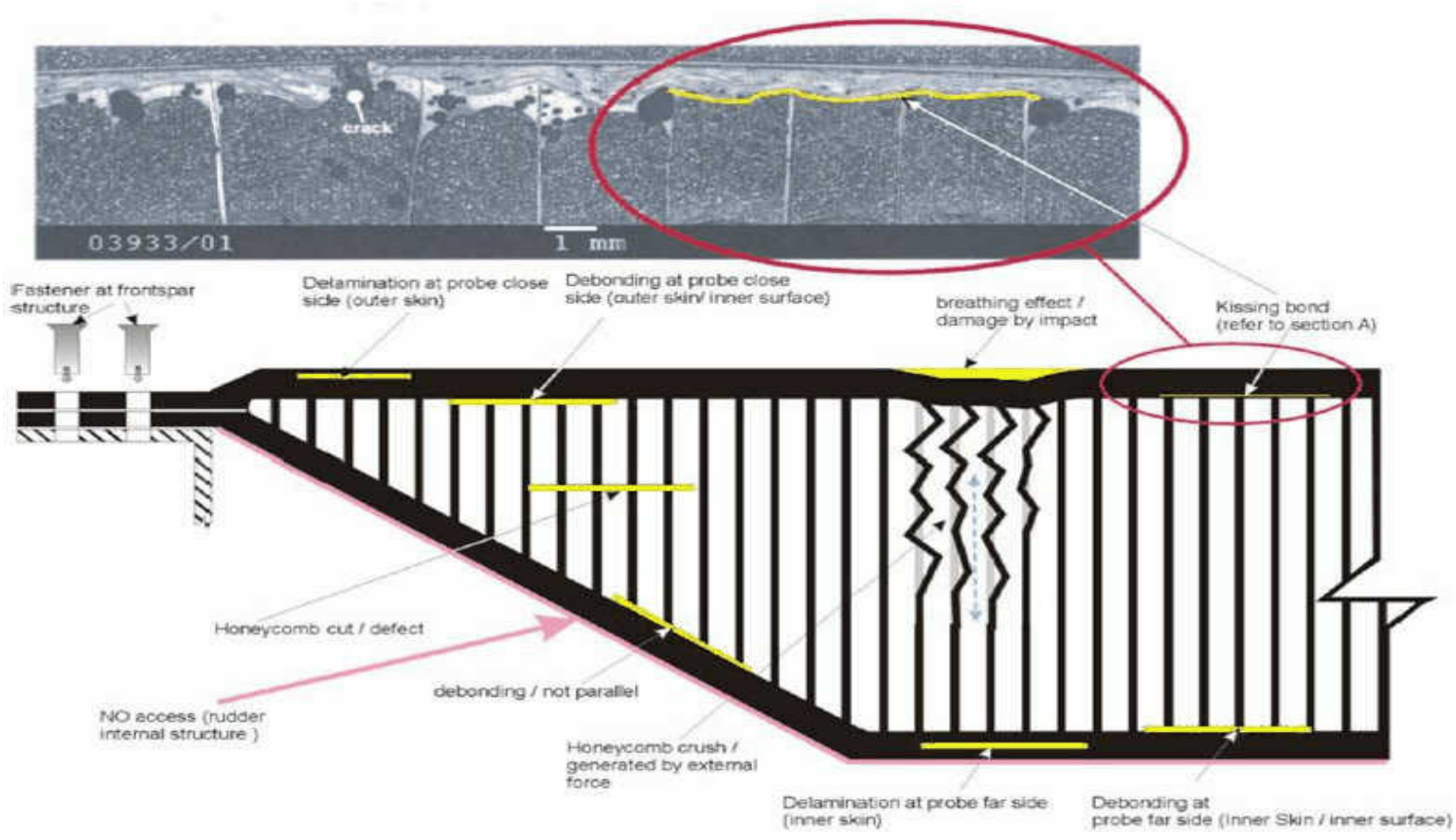
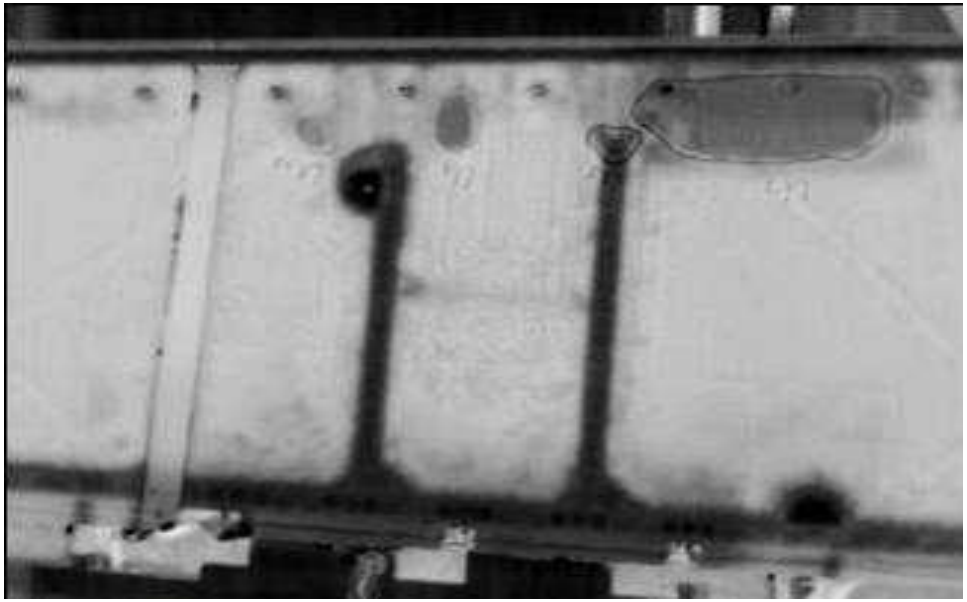


Figure 121 Detectable Defects

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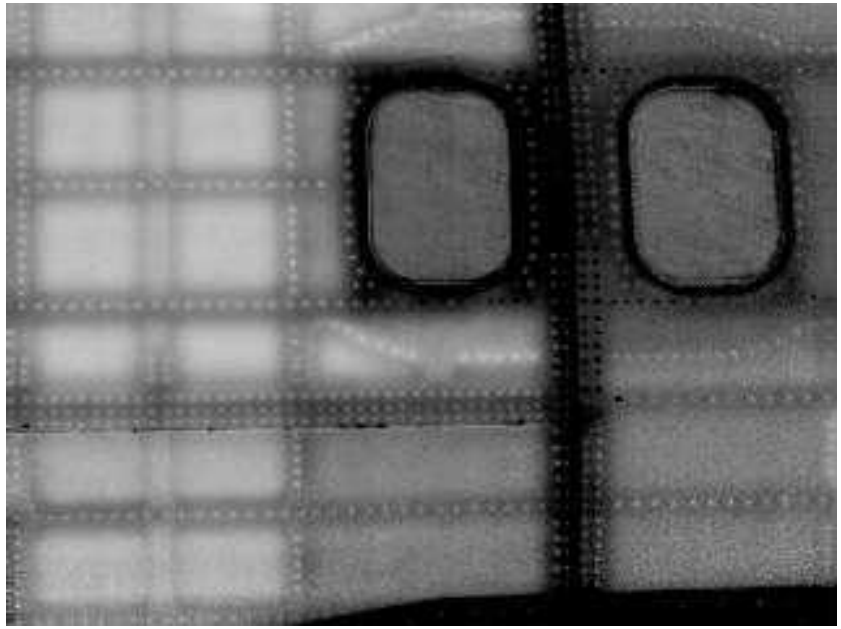


Figure 122 Thermography/Photos Finding Example

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Thermography

Advantages

- Quick
- Mobile
- Test result always available (Photo)
- Suitable for complex forms
- Minor preparation work of the part
- No damaging of the surface protection
- Distribution of failure visible

Disadvantages

- Very expensive
- Needs a large amount of experience
- Only for adhesive parts/ adhesive defects (adhesive debonding/Delamination/Water entrapment)
- No information about the depth of defect

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Figure 123 Advantages and Disadvantages of Thermography

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DISASSEMBLY AND RE-ASSEMBLY TECHNIQUES

Disassembly Techniques

Removal of Damage

In some instances it will be necessary to cut away the damaged material and dress back the surrounding structure. Although it should be ensured that no more material than is necessary is removed, it is necessary to make sure that the adjacent structure to which the repair is to be applied is in a sound condition.

Riveted Structure

When removing riveted structure, care must be taken not to damage during drilling out those rivet holes which are to be used again. Only with undamaged and clean holes can a transmission of forces and the airworthiness be ensured.

Bolt Holes

Bolt holes should be treated with equal care, it being particularly important that the holes in stressed parts should be free from scores or burrs.

Where necessary, bolts should be eased with penetrating oil before extraction but it is also necessary to ensure that the oil does not damage adjacent sealing media.

Cutting of damaged Structure

During cutting out damaged structure it has to be ensured that the remaining structure or material is not damaged by drills, rotary cutting tools, hack–saw blades, etc.

If damaged panels are to be removed by cutting (i.e. not by dismantling at a production joint), all edges must be free from burrs and notches and trimmed to a smooth finish.

It is important that the dimensions and locations of cuts are within the limits specified in the repair drawing.

Sealant

Repairs in pressure cabin and integral fuel tank areas may involve separation of members riveted and sealed together. Some sealants have considerable adhesion and may cause difficulty in separating the members.

Where such separation is necessary, the solvents specified and methods of separation detailed in the Repair or Maintenance Manual must be strictly followed.

ATTENTION: After repairs in a pressurized area or a fuel tank, either a leak test or a pressure test may be specified in the appropriate manual.

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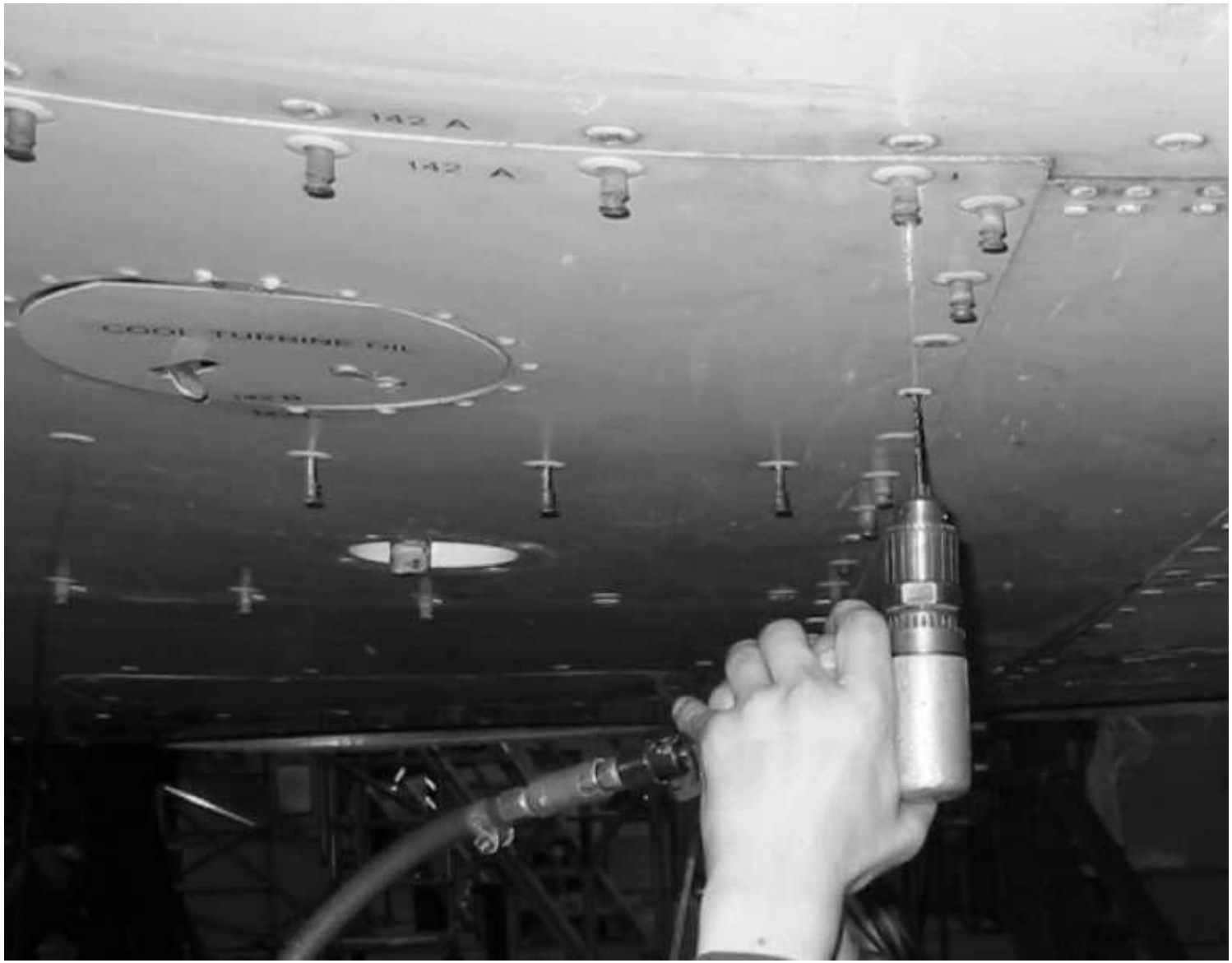


Figure 124 Drilling Out Seized Fasteners

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Re-assembly Techniques

Introduction

A repair to a stressed structure usually involves the removal of damaged panels, the complete or partial removal of structural members such as frames, ribs and stringers and the rebuilding of the structure in accordance with the repair scheme. The particular procedure involved will obviously vary with the design of the aircraft but the following paragraphs cover the general aspects of a repair.

Materials

Materials used for the repair should be checked for correct specification and gauge thickness and, where applicable, heat treated in accordance with specification requirements.

On completion of bending or forming operations the material must be free from defects.

Especially look for: Scratches, scribe marks, hairline fractures on the outside of bends, cracks at edges adjacent to bends, tool marks, twisting and warping.

Manufacturer-Supplied Parts

In some instances the aircraft manufacturer may provide preformed and partially built–up parts. Prior to installation it should be ensured that such parts are correctly identified and bear evidence of prior inspection.

Holes

Particular attention should be given to the drilling of holes, which should be circular and free from scores and sharp edges in order to satisfy design requirements.

In some cases it may be specified or recommended that holes in stressed parts should be drilled with a drill reamer, or drilled and then reamed to size.

It is also important that drills are sharpened correctly so as to produce the intended hole diameter; a drill running off–center will produce an oversize hole.

Replacement Fasteners

Where existing rivet holes are to be used again, repair schemes may often call for special repair rivets to be used. These rivets have a slightly larger shank diameter but the same size head.

However, if necessary (e.g. due to hole damage), the use of rivets the next size larger than the original may be permitted, in which case it should be ensured that the landing limits between the new rivets and the sheet edge or other rivets are maintained.

During de-/ and reassembly of fasteners and especially prior of choosing the right repair fastener as a replacement of the original fastener, the manufacturer instructions and work sheets have to be followed.

Sealant

Similar variations may also apply to the type of jointing compound used (e.g. in pressurized areas) and to the protective treatment required. The repair drawing should therefore be studied very carefully for any special instructions.

Debris

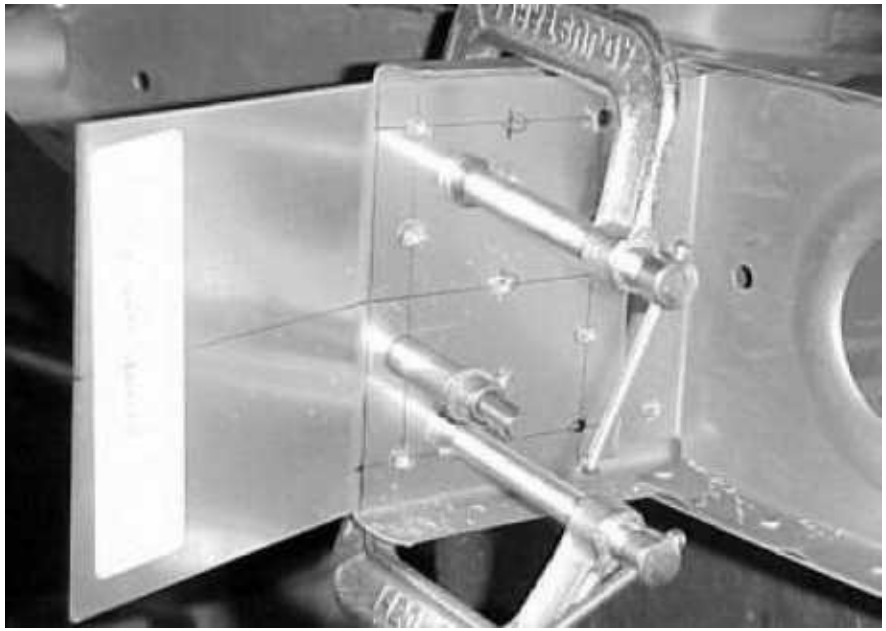
The produced swarf should be already sucked out during drilling operation, if possible. If this is not possible it has to be ensured that swarf does not get into areas, in which it may be a risk. Such areas should be protected before work.

When drilling through laminations or lap joints which cannot subsequently be separated for cleaning, it is essential to ensure that the parts comprising the joint are held firmly together during the drilling operation.

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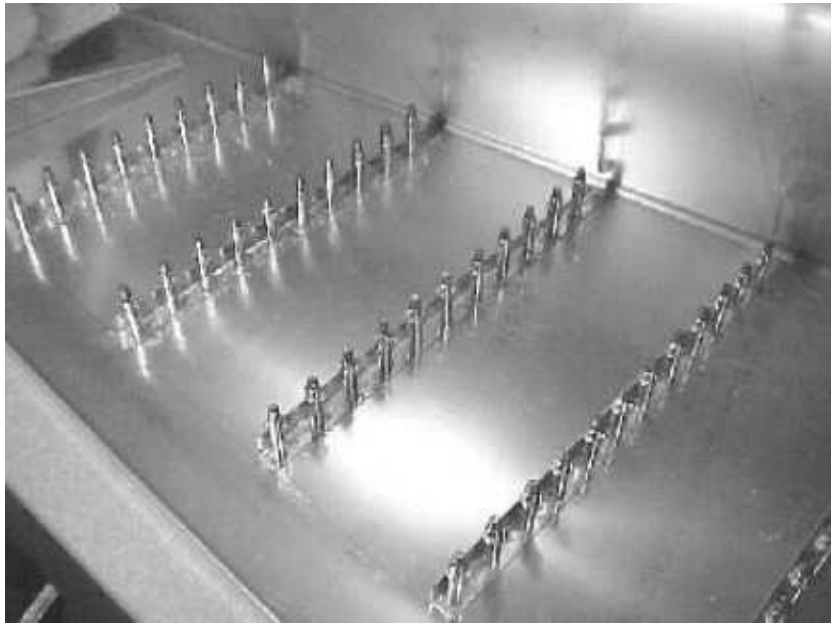


Figure 125 Clamping Prior to Assembly

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Pre-Assembly

Before assembling a joint it should be ensured that the contacting surfaces are clean and free from swarf and that all holes and edges are deburred. If specified, jointing compound should be applied evenly before final assembly and riveting and should form a fillet at the edges of the joint when assembly is complete. The manufacturer's instructions regarding the mixing, working and curing time of the jointing compound should be carefully followed.

Control Surfaces

When repairs have been made to control surfaces, the balance may have been upset by the additional weight of metal or paint.

Such surfaces should be checked for balance by the method given in the appropriate manual and the balance corrected as necessary. For reasons of balance the repairs permitted on control surfaces are often limited in area and position.

Metal-to-Metal Adhesive

Often metal adhesive requires a special heating and pressing equipment. Therefore metal adhesives can not always be applied for repairs. It can be necessary to cut out the damaged part and to rivet the new part in position.

When it is necessary to remove parts which are secured with adhesive, e.g. a stringer, this can be done as shown opposite. Care should be taken to avoid damaging any parts or material other than those to be removed.

ATTENTION: When paint is removed in the area of a metal–to–metal adhesive joint, only the paint stripper stipulated should be used. Some strippers may have a deleterious effect on metal–to–metal adhesives.

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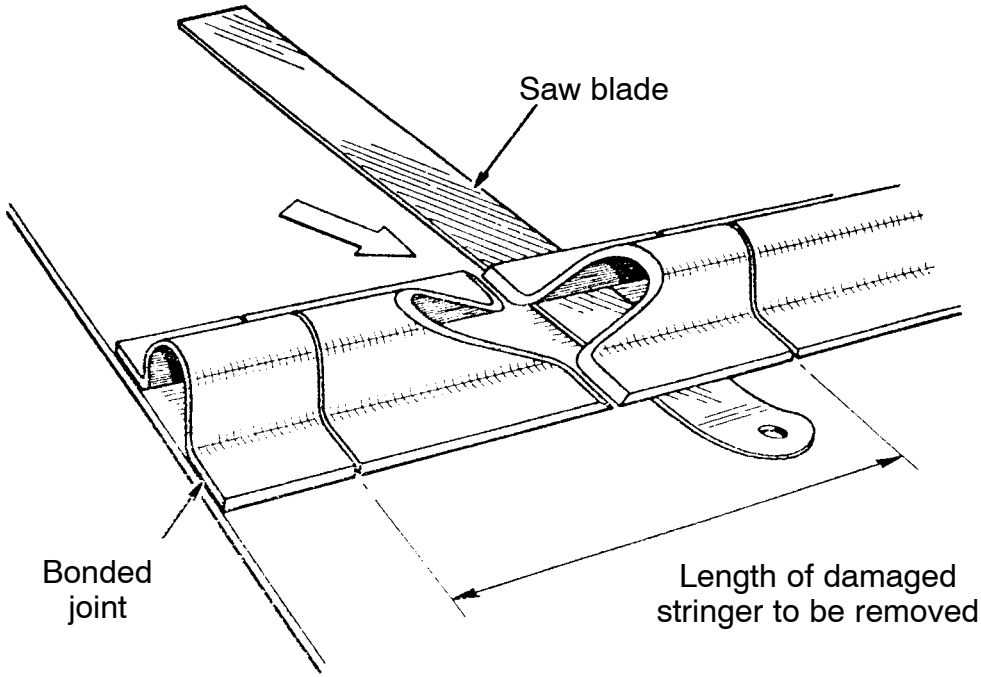


Figure 126 Removal of Bonded Component

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