AEROSPACE RECOMMENDED PRACTICE

ARP4915™ **REV. C**

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Superseding ARP4915B

Disposition of Landing Gear Components Involved in Accidents/Incidents

RATIONALE

Section 6 had an error in the final decision option paragraph reference. Flowchart referenced §6.2, and it should be §5.3.

1. SCOPE

This document establishes a procedure for disposition of landing gear components that have been involved in accidents/incidents. The recommendations in this document apply to components made of ferrous and non-ferrous alloys. The recommendations in this document do not apply to components made of nonmetallic composite materials.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of the other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +724-776-4970 (outside USA), www.sae.org.

AMS2643 Structural Examination of Titanium Alloys, Chemical Etch Inspection Procedure

AMS2649 Etch Inspection of High Strength Steel Parts

AMS2759 Heat Treatment of Steel Parts General Requirements

AMS2759/9 Hydrogen Embrittlement Relief (Baking) of Steel Parts

AMS2770 Heat Treatment of Wrought Aluminum Alloy Parts

AMS2801 Heat Treatment of Titanium Alloy Parts

AMS2658 Hardness and Conductivity Inspection of Wrought Aluminum Alloy Parts

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E1417 Standard Practice for Liquid Penetrant Testing

ASTM E1444 Standard Practice for Magnetic Particle Testing

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +724-776-4970 (outside USA), www.sae.org.

ARP5600 Disposition of Damaged Wheels Involved in Accidents/Incidents

2.2.2 Other Publications

UK Civil Aviation Authority, Civil Aircraft Airworthiness Information and Procedures CAP 562, Leaflet 11-28 Return to Service of Aircraft Items Recovered From Aircraft Involved in Accidents/Incidents.

2.3 Definitions

2.3.1 RESIDUAL STRESS

Stress present in a component that is free of external forces or thermal gradients.

2.3.2 RESIDUAL STRAIN

Plastic deformation that remains permanently after removal of the load that caused it.

2.3.3 FERROUS ALLOY

High strength alloys such as medium-carbon low alloy steel (examples: 300M, 4340, 4330V, Hy-Tuf, D-6AC, ...); medium-alloy air hardening steels (examples: H11 Mod., 9Ni-4Co, AerMet 100, ...); precipitation-hardening stainless steels (examples: 15-5PH, PH13-8Mo, 17-4PH, ...).

2.3.4 NON-FERROUS ALLOYS

High strength aluminum alloy in the artificially aged and overaged condition (examples: 7075-T6, -T73, 7049-T73, 7050-T74, ...) and titanium alloys (examples: Ti-6Al-4V, Ti-10V-2Fe-3Al, ...).

2.3.5 INORGANIC COATING

Metallic and non-metallic coating such as: electroplating (chrome, nickel, cadmium); anodizing (chromic, sulfuric, hard); non-metallic (chemical conversion, phosphating); ceramic (carbide, HVOF); metallic (thermal spraying, ion vapor deposition).

2.3.6 ORGANIC COATING

Coating having an organic base. General term for paint (primer and topcoat).

2.3.7 ACCIDENT/INCIDENT

An accident/incident either on-aircraft (e.g., hard landing, off runway excursion, towing or push back incident, pothole encounter) or off-aircraft (e.g., a component dropped during original manufacture or during repair and overhaul).

3. IDENTIFICATION OF DAMAGE

See Section 6 for a flowchart overview of the ARP4915C identification of damage and disposition process.

3.1 Landing gear components involved in accidents/incidents can be classified under one or more of the following four different damage types:

Type I: Components with visible severe mechanical damage (gouged, pierced, fractured, etc.).

Type II: Components suspected of having been exposed to temperature above the design limits (e.g., fire, brake heat, frictional heat, bearing induced heat, etc.).

Type III: Components with visible or measurable dimensional deformation/distortion.

Type IV: Components with no visible or measurable deformation/distortion or defect but known to have been involved in an accident/incident (no heat damage) that could have detrimentally overloaded them.

These types of damage are not normally identified in repair and overhaul manuals; therefore, separate dispositions are required. A damage assessment is essential to determine the applicable category.

3.2 Identification of Materials

Class 1: Ferrous Alloys

Class 2: Aluminum Alloys

Class 3: Titanium Alloys

4. DISPOSITION

See Section 6 for a flowchart overview of the ARP4915C identification of damage and disposition process.

NOTE: The disposition processes detailed in the following subparagraphs only include process steps required to address risks associated with accidents/incidents and do not include all necessary normal repair and overhaul process steps.

4.1 Type I Damage Disposition

These components are to be considered scrap unless subjected to detail evaluation by cognizant engineers and approved by the airworthiness authorities. However, if the components are to be returned to service, it is strongly recommended to follow disposition steps shown for Type III.

4.2 Type II Damage Disposition

Type II damage will likely cause a reduction in strength, ductility, fatigue properties, and/or stress corrosion cracking, due to changes in material properties. Changes in material properties can occur when components are exposed to temperatures above the tempering temperature, e.g., softening and/or re-hardening. Also, liquid metal embrittlement can occur, e.g., due to overheat of cadmium plating and subsequent diffusion into the base metal. Heat can also relax the surface layer of compressive stress induced by shot peening, with consequential reduction of fatigue life. The severity of damage caused by intense heat cannot be accurately evaluated with normal shop procedures. Investigation by approved engineering personnel is essential. A cognizant engineer should carry out an assessment of the accident/incident to try to determine the possible suspected areas of heat damage for particular detailed inspection.

NOTE: Do not remove any paint, primer, or plating, and do not apply any chemicals prior to the investigator viewing the component. Essential evidence may be lost.

4.2.1 For Class 1 Material Components

Examination of corrosion protection (such as cadmium) coated surfaces for evidence of blistering and any color change to primer and topcoat paint, together with accurate testing methods involving hardness and nondestructive methods, are required for the proper assessment of heat damage. Examination of other coatings (such as chrome/HVOF) for evidence of abnormal discoloration is also essential. Unless a thorough investigation is performed, these components are not to be returned to service. For components exposed to local heating effects, a nital or ammonium persulphate local etch inspection is required (refer to AMS2649). Plated or HVOF coated components should be stripped prior to etch inspection.

The following are the recommended steps when investigating Type II damage:

a. The component should be thoroughly cleaned using approved solvent or approved detergent and water. Abrasives or chemicals which may bleach or discolor the component must be avoided.

b. Prior to stripping the component:

   1. Examine primer or painted surfaces for color changes or blistering.

   2. Examine corrosion protection (such as cadmium) coated surfaces for blistering.

   3. Examine other coatings (such as chrome) for evidence of discoloration.

c. Based on the evidence found during the initial examination, the following other steps may need to be undertaken:

   1. Remove all bushings and finishes.

   2. Partially or completely strip all organic and inorganic coatings from the component.

   3. Perform a nital or ammonium persulphate etch inspection for overheat. Components that have been nital etched should be subjected to a hydrogen embrittlement relief bake (refer to AMS2759/9).

   4. Perform hardness and other nondestructive tests for overheat.

d. Components that required hardness testing should, following test, have the hardness test indentation removed by blending and then the blended area re-shot peened to original drawing requirements.

WARNING: Unless a thorough investigation by properly qualified personnel is performed, Type II damage Class 1 material components are not to be returned to service.

4.2.2 For Class 2 and Class 3 Material Components

Examination of organic coated surfaces for evidence of blistering and any color change to organic finishes, together with accurate testing methods involving hardness and nondestructive methods, are required for the proper assessment of damage.

The following are the recommended steps when investigating Type II damage:

a. The component should be thoroughly cleaned using approved solvent or approved detergent and water. Abrasives or chemicals which may bleach or discolor the component must be avoided.

b. Prior to stripping the component:

    1. Examine primer or painted surfaces for color changes or blistering.

    2. Examine inorganic coated surfaces for discoloration.

c. Based on the evidence found during the initial examination, the following additional steps may need to be undertaken:

    1. Remove all bushings.

    2. Partially or completely strip all organic and inorganic coatings.

    3. For Class 3 material, immerse in acid etch solution for discoloration detection of overheat (refer to AMS2643).

    4. For Class 2 material, perform a conductivity test on suspected areas of heat damage in conjunction with hardness test using HRB scale (refer to AMS2658). Components that have been hardness tested should, following test, have the hardness test indentation removed by blending and then the blended area re-shot peened to original drawing requirements.

WARNING: Unless a thorough investigation by properly qualified personnel is performed, Type II damage Class 2 and 3 material components are not to be returned to service.

4.3 Type III Damage Disposition

Any visible or measurable dimensional deformation/distortion (e.g., bending, ovalization, impact indentation) indicates that the component has been subjected to overload in excess of its material yield limit. Overload compressive stresses above material yield stress can result in residual tensile stresses. Overload tensile stresses above material yield stress can result in residual compressive stresses.

Residual tensile stress can have detrimental effects:

- Stress corrosion cracking
- Reduced fatigue life

Residual compressive stresses can also reduce fatigue life.

Tensile or compressive overloads can relax the surface layer of compressive stresses induced by shot peening, with a consequential reduction of fatigue life.

Straightening a deformed/distorted component will contribute to an increase of the residual stress level and will reduce the component's resistance to fatigue cracking due to the two cycles of reversed bending overload.

The following sequential disposition steps, 4.3.1 b. to j. for Class 1 material components and 4.3.2 b. to f. for Class 2 and 3 material components, try to determine whether or not a component has detrimental residual stresses and/or cracking due to overload. However, even after performing these steps without findings, undetected detrimental residual stresses may still exist, e.g., residual stresses below the threshold level for stress corrosion cracking but high enough to reduce fatigue life, and should be considered in the decision on whether to return the component to service. It is therefore recommended that, prior to performing these disposition steps, a cognizant engineer should, if appropriate and practicable, perform disposition step a. analysis to try to determine the risk of detrimental overload to individual components.

4.3.1 For Class 1 Material Components

The recommended minimum requirements for Type III damage disposition are:

a. Analysis for Detrimental Overload

A cognizant engineer should, if appropriate and practicable, perform an analysis for detrimental overload.

Using accident/incident recorded data (e.g., acceleration, mass, etc.), and/or data produced by simulation of the accident/incident, components identified as at risk of having been overloaded should be analyzed to determine predicted levels and locations of detrimental residual stresses. These residual stresses should be assessed for acceptability by comparison with an applicable stress corrosion cracking threshold stress and by fatigue analysis.

Components shown by analysis to have detrimental residual stresses above the stress corrosion cracking threshold stress and/or above a level that would result in a reduction in fatigue life should be considered scrap.

Components shown by analysis to not have detrimental residual stresses should be subjected to disposition steps b. to j.

Components that cannot be analyzed, e.g., due to lack of quantitative data from the accident/incident, should be subjected to disposition steps b. to j.

b. Visual and Dimensional Inspections for Overload

Perform visual and dimensional inspections looking for any signs of overload damage, such as cracked paint or plating and deformation or distortion.

The availability of the engineering drawings is essential, since repair and overhaul manuals will not provide all dimensions and geometrical tolerances. If available, a comparison against original manufacturing dimensions is preferred, as detrimental deformation/distortion can occur within drawing tolerances.

A cognizant engineer should carry out an assessment of the accident/incident to try to determine possible areas of overload for particular detailed visual and dimensional inspections.

From the visual and dimensional inspection report on the subject component, determine if the component is functionally acceptable.

1. If the component is not functionally acceptable, it should be considered scrap. Cold working a deformed/distorted component is structurally not acceptable.

2. If the component is functionally acceptable, further assess the component and rework per steps c. through j.

c. Strip

Remove all bushings and organic and inorganic coatings. The component should be completely stripped.

d. Stress Relieve Bake

Bake at 50 °F (27.7 °C) below material tempering temperature for 24 hours. AMS2759 can be used as a guide to locate material tempering temperature.

The objective of the bake is to try to reduce any residual stresses in the component.

NOTE: The bake may not reduce residual stresses to levels below which they are not detrimental to stress corrosion and fatigue life.

e. Magnetic Particle Inspection

Perform magnetic particle inspection (refer to ASTM E1444).

The objective of the inspection is to check, prior to performing the extended storage period, that there has been no cracking due to deformation/distortion and/or residual stresses from the accident/incident.

f. Store for an Extended Period

The objective of the storage period is to develop stress corrosion cracking in components that have residual stresses above the threshold stress level for stress corrosion cracking.

Store the component indoors for an extended period, a minimum 6 months from start to end of storage period, is recommended. During the storage period, the component should be unprotected (i.e., no permanent or temporary corrosion protections). The start of the storage period should begin after removal of organic and inorganic coatings. After completion of the storage period, inspect for and repair any corrosion.

NOTE: After the storage period, if the component is found not to be cracked, residual stresses could still exist in the component at levels that could be detrimental to fatigue life or could result in stress corrosion cracking.

g. Magnetic Particle Inspection

Perform magnetic particle inspection (refer to ASTM E1444).

The objective of the inspection is to check that stress corrosion cracking due to residual stresses has not occurred during the storage period.

h. Shot Peen

The objective of the shot peen is to restore the original manufacturing shot peen induced beneficial residual compressive stresses that may have been relaxed by the overload incident and/or by the stress relieve bake.

Shot peen the entire component to the original manufacturing specifications. It is essential that the shot peening technique (shot peen media type, peen intensity, peen coverage) and areas to be peened are in accordance with the original manufacturing drawing requirements, because the component is to be brought to original drawing requirements.

i. Re-Apply Inorganic Coatings

Re-apply inorganic coatings to original drawing or maintenance manual requirements.

j. Nondestructive Test Inspection

Due to the embrittling effect of cadmium, chrome, and nickel plating, if excessive tensile residual stresses are still present after the stress relief bake, the component may crack during the plating procedures. Therefore, a magnetic particle inspection (refer to ASTM E1444) should be performed after plating, but prior to bush assembly and application of organic coatings.

4.3.2 For Class 2 and Class 3 Material Components

The recommended minimum requirements for Type III damage disposition are:

a. Analysis for Detrimental Overload

A cognizant engineer should, if appropriate and practicable, perform an analysis for detrimental overload.

Using accident/incident recorded data (e.g., acceleration, mass, etc.), and/or data produced by simulation of the accident/incident, components identified as at risk of having been overloaded should be analyzed to determine predicted levels and locations of detrimental residual stresses. These residual stresses should be assessed for acceptability by comparison with the stress corrosion threshold stress (not applicable to Class 3 material components) and by fatigue analysis.

Components shown by analysis to have detrimental residual stresses above the stress corrosion cracking threshold stress and/or above a level that would result in a reduction in fatigue life should be considered scrap.

Components shown by analysis to not have detrimental residual stresses should be subjected to disposition steps b. to f.

Components that cannot be analyzed, e.g., due to lack of quantitative data from the accident/incident, should be subjected to disposition steps b. to f.

b. Visual and Dimensional Inspections for Overload

Perform visual and dimensional inspections looking for any signs of overload damage such as cracked coatings and deformation/distortion.

The availability of the engineering drawings is essential, since repair and overhaul manuals will not provide all dimensions and geometrical tolerances. If available, a comparison against original manufacturing dimensions is preferred, as detrimental deformation/distortion can occur within drawing tolerances.

A cognizant engineer should carry out an assessment of the incident to try to determine possible areas of overload for particular detailed visual and dimensional inspections.

From the visual and dimensional inspection report on the subject component, determine if the component is functionally acceptable.

1. If the component is not functionally acceptable, it should be considered scrap. Cold working a deformed/distorted component is structurally not acceptable.

2. If the component is functionally acceptable, further assess the component and rework per steps c. to e.

c. Strip

Remove all bushings and protective treatments/coatings (organic and inorganic). The component should be completely stripped.

d. Stress Relieve Bake

For Class 2 material components, a stress relief bake at 50 °F (27.7 °C) below the minimum aging temperature for 1 to 2 hours is recommended. AMS2770 can be used to locate the material aging temperature.

For Class 3 material components, a stress relief bake at 50 °F (27.7 °C) below the aging temperature may be performed if dimensional and surface integrity can be maintained. AMS2801 can be used to locate the material aging temperature.

The objective of the bake is to try to reduce any detrimental residual stresses in the component.

NOTE: The bake may not reduce residual stresses to levels below which they are not detrimental to fatigue life and stress corrosion.

e. Fluorescent Penetrant Inspection

Perform fluorescent penetrant inspection (refer to ASTM E1417).

The objective of the inspection is to check that there has been no cracking due to the deformation/distortion and residual stresses.

f. Shot Peen

The objective of the shot peen is to restore the original manufacturing shot peen induced beneficial residual compressive stresses that may have been relaxed by the overload incident and/or by the stress relieve bake.

Shot peen the entire component to the original manufacturing specifications. It is essential that the shot peening technique (shot peen media type, peen intensity, peen coverage) and areas to be peened are in accordance with the original manufacturing drawing requirements, because the component is to be brought to original drawing requirements.

4.4 Type IV Damage Disposition

Although these components will appear to be sound, detrimental residual stresses may be present due to local yielding/plasticity of the material as a result of overload. It is, therefore, important to confirm that there is no deformation/distortion due to overload and that assessment/analysis of the accident/incident does not conclude that there is a risk of detrimental overload.

The following disposition steps b. and c., try to determine whether or not a component has deformation/distortion and/or cracking due to overload. However, even after performing these steps without findings, undetected detrimental residual stresses may still exist. It is therefore recommended that, prior to performing these disposition steps, a cognizant engineer should, if appropriate and practicable, perform disposition step a. analysis to try to determine the risk of detrimental overload to individual components.