AEROSPACE INFORMATION REPORT

AIR5885™ REV. A

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Superseding AIR5885

(R) Landing Gear Common Repair

RATIONALE

This report provides information regarding the most common repairs performed on landing gear structural components made of metallic alloys during overhaul or new manufacture. This document will require periodic review in order to stay up to date with latest repair technologies and processes.

AIR5885A has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

This document outlines the most common repairs used on landing gear components. It is not the intention of this AIR to replace overhaul/component maintenance or technical order manuals, but it can serve as a guide into their preparation. Refer to the applicable component drawings and specifications for surface finish, thickness, and repair processing requirements. This document may also be used as a guide to develop an MRB (Material Review Board) plan.

The repairs in this document apply to components made of metallic alloys. These repairs are intended for new manufactured components and overhauled components, including original equipment manufacturer (OEM)/depot and in-service repairs. The extent of repair allowed for new components as opposed to in-service components is left to the cognizant engineering authorities.

Reference could be made to this document when justifying repairs on landing gears. For repairs outside the scope of this document, a detailed justification is necessary. Landing gear repair is often a combination of several repair types defined herein.

It must be understood that all the repairs listed in this document are not to be applied without the involvement of the cognizant engineer.

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 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.

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https://www.sae.org/standards/content/AIR5885A/

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 +1 724-776-4970 (outside USA), www.sae.org.

AMS2404	Plating, Electroless Nickel
AMS2406	Plating, Chromium, Hard Deposit
AMS2438	Plating, Chromium, Thin, Hard, Dense Deposit
AMS2460	Plating, Chromium
AMS2759/9	Hydrogen Embrittlement Relief (Baking) of Steel Parts
AMS2759/11	Stress Relief of Steel Parts
AMS-QQ-N-290	Nickel Plating (Electrodeposited)
AIR5913	Landing Gear Component Heat Damage
ARP4462	Barkhausen Noise Inspection for Detecting Grinding Burns in High Strength Steel Parts
ARP4915	Disposition of Landing Gear Components Involved in Accidents/Incidents
ARP5935	Use of HVOF Thermal Spray Coatings for Hard Chrome Replacement in Landing Gear Applications

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

2.1.3 U.S. Government Publications

Copies of these documents are available online at https://quicksearch.dla.mil.

MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys
MIL-STD-865	Selective, Brush Plating, Electro-Deposition
MIL-STD-867	Temper Etch Inspection
MIL-STD-868	Nickel Plating, Low Embrittlement, Electrodeposition (sulfamate)
MIL-STD-870	Cadmium Plating, Low Embrittlement, Electrodeposition
MIL-STD-1501	Chrome Plating, Low Embrittlement, Electrodeposition
MIL-STD-1504	Abrasive Blasting of Aircraft Components
MIL-STD-8625	Anodic Coatings for Aluminum and Aluminum Alloys

USAF drawings available from Hill AFB, Landing Gear Engineering Office.

20157831	Restoration of Dimensional Surfaces of ID Aluminum Cylinders Using Magnetron Sputtering Deposition
200310641	High Velocity Oxygen Fuel (HVOF) Coating Application
201027456	Low Hydrogen Embrittlement Plating Process Specification Zinc-Nickel

2.2 Definitions

ACCEPTABLE AS IS: An engineering disposition given to a part with a departure from its drawing requirements when it is judged that such deviation will have no effect on its functional and structural integrity, as well as on its reliability, interchangeability, and maintainability.

DEPOT REPAIR: Material maintenance or repair requiring the overhaul, upgrading, or rebuilding of parts, assemblies, or subassemblies, and the testing and reclamation of equipment as necessary. Typically performed in a dedicated repair facility.

IN-SERVICE REPAIR: A repair performed on a component that can be accomplished by the aircraft operator, or authorized source, without full disassembly or removal of all coatings.

ORIGINAL EQUIPMENT MANUFACTURER (OEM): Company that designed the component or subsystem.

OVERHAUL MANUAL (OHM)/COMPONENT MAINTENANCE MANUAL (CMM): Repair instructions for a component or subsystem.

REPAIR: An engineering disposition to restore a component to within acceptable limits of its design requirements without adversely affecting its interchangeability, reliability, and maintainability while maintaining its functional and structural integrity.

REWORK: An engineering disposition to restore a component to within its drawing requirements.

3. CLASSIFICATION

Type I: Depot repair with functional plating, coating, surface modification

Type II: Repair with bushing

Type III: Repair of damage marks

Type IV: Repair of localized heat damaged surface

Type V: Localized repair of damaged plating

Type VI: Repair of damaged threads

Type VII: Repair of lubrication hole

Type VIII: Repair of lugs with spherical bearing

Type IX: Repair of plastically deformed surface

Type X: Repair of mis-located features

Class 1: Ferrous alloys

Class 2: Aluminum alloys

Class 3: Titanium alloys

4. REPAIRS

4.1 Type I (Depot Repair with Functional Plating, Coating, Surface Modification)

4.1.1 Plating

The cognizant engineering authority should evaluate each application to determine the appropriate repair. There are different types and classes of surface coatings which can affect the reliability and maintainibility of the components being repaired. Reference to reliable data on the fatigue impact due to the application of the coating is recommended for any plating repair.

Shot peening (or other residual compressive surface stress process) of reworked areas prior to plating is required. Stripping and re-plating is recommended rather than attempting to plate over breakthroughs or damaged areas. Caution should be given to minimize amount of repeated electro-plated operations for high-strength Class 1 materials to mitigate risk for hydrogen embrittlement. Peening layer integrity after multiple strip/replate operations should also be considered, depending on shot peen intensity.

Electro or electroless plating on Class 3 materials is not often done because of difficulty achieving proper adhesion, but it can be successfully accomplished by some repair facilities.

Be sure to account for masking allowance and plating/coating runout (plating/coating taper from full thickness to zero thickness) at the boundaries of the plated area in your repair definition. Masking tolerance and plating/coating runout may consume as much as 0.080 inch of surface length at each end of the plating.

4.1.1.1 Repaired surfaces of cylinders and rods that have dynamic seals and bearings running against them should be repaired in such a way that they meet the original requirements for surface finish chrome plating.

Chrome plate repairs are typically limited to a deposited thickness of 0.012 inch (0.3048 mm), since a heavier plating thickness could severely affect the fatigue life of the part, due to the residual tensile stresses induced at the base metal surface. It may also be necessary to limit chrome plating thickness to avoid delamination and excessive mud cracking for items under high stress/strain/reverse-high-loading conditions. In general, increased-thickness chrome plate repair should be used only in locations where plating already exists or where the Overhaul Manual (OHM)/Component Maintenance Manual (CMM) allows it.

This repair is used when a hard, wear-resistant, and low-friction surface is required. It can be used over other softer plating, like sulfamate nickel, when a hard wear surface is required. Thick chrome repairs, requiring post-plating grinding operations, in reworked areas for high-pressure nitrogen seal applications, are not typically recommended.

Chrome plating is widely used on all Class 1 materials, including low alloy high strength up to 300 ksi (2068 MPa). Precautions are often taken when applying on stainless steel components due to adhesion difficulties. For Class 2 materials, because of their metallurgical surface characteristics, multiple undercoatings are normally required, such as zinc, copper, and nickel.

Components using the chrome plate process on Class 1 materials are hydrogen embrittlement relief baked per the applicable specification.

4.1.1.2 Sulfamate Nickel Plating

The allowable thickness for sulfamate nickel plating is limited by the amount a particular plating shop can apply. Achievement of thick coating will normally require multiple plate-machine-plate operations. Machining rather than grinding is advised because the relatively soft coating can smear. Shot peening (or other residual compressive surface stress process) prior to plating is required.

Plating thickness should be evaluated for strength impacts and potential hydrogen embattlement effects for thicker plating applications greater than 0.012 inch thick. Typically, the strength of the plating becomes less as thickness increases.

This repair can be used to restore large out-of-tolerance dimensions. Bearing/shear loads on the buildup coating should be evaluated, especially if the area is not a fully captured “fill” area. It can be used under hard plating, such as chrome or HVOF, when the limits in 4.1.1 are exceeded and it is essential to obtain the chrome plating surface hardness. If used under chrome, the sulfamate nickel should be glass bead peened or grit blasted, and processed with witness specimens to validate proper adhesion prior to chrome or HVOF application. Machining of sulfamate nickel is also a good way to verify proper adhesion to the base metal.

Nickel plating is widely used on all Class 1 materials, including high strength up to 300 ksi (2068 MPa). Precautions should be taken when applying on stainless steel components due adhesion difficulties. For Class 2 materials, because of its metallurgical surface characteristics, multiple undercoatings are sometimes required, such as zinc, tin, and copper.

Components using the sulfamate nickel plate process on Class 1 materials are hydrogen embrittlement relief baked per the applicable specification. Plating area may be limited, or an extended hydrogen relief bake may be a required, due to the difficulty for hydrogen to escape through the dense and crack-free nature of the coating.

4.1.1.3 Electroless Nickel Plating

This type of repair is widely used because of its few post-plating operations required after repair of discrepancies. Although it is normally limited to thickness of about 0.002 inch (0.0508 mm), build-ups of 0.006 inch (0.1524 mm) are possible. Thicknesses in excess of 0.006 inch are typically porous and have poor adhesion. Caution is taken when applying heavier plating thickness since the fatigue life of the part could be affected, because of the residual tensile stresses induced at the base metal surface. Shot peening (or other residual compressive surface stress process) prior to plating is completed per the applicable specification. Post-plate thermal treatment to increase hardness may require a high-temperature bake, which can relieve the shot peen effect. Electroless nickel is applied per approved specifications noted on the engineering drawing or OHM/CMM.

When using electroless nickel plating, it is essential to specify the hardness required, since different solutions and different thermal treatment will result in different surface hardness. This repair could be used when a harder surface is required, and chrome plating cannot be used (example: it is not recommended that two chrome plated surfaces be in contact because of the danger of galling). Softer formulations of electroless nickel with better corrosion resistance are used in axle locations where cadmium is not allowed due to temperature limitations.

Electroless nickel is widely used on all Class 1 materials, including high strength up to 300 ksi (2068 MPa). Precautions should be taken when applying on stainless steel components due to adhesion difficulties. For Class 2 materials, because of their metallurgical surface characteristics, multiple undercoatings are sometimes required, such as zinc, copper, and tin.

4.1.2 Thermal Spray

4.1.2.1 Plasma (Flame) Spray

Care should be taken when selecting the thickness, type of process, and alloy used. Plasma spray is very flexible because of the wide variety of materials that it can deposit. Particular attention should be made for contact stresses, since under point loading, on low cohesive strength thermal sprayed alloy, serious damage can result (peeling). Plasma-sprayed coatings tend to be fairly porous, therefore unsuitable for many sealing surfaces. Plasma spray is applied per approved specifications noted on the engineering drawing or OHM/CMM.

Plasma spray process is widely used on most Class 1 and Class 2 materials, but is normally limited to secondary structural member with lower ultimate tensile strength. Meanwhile, some precautions should be taken when applying on stainless steel components, because adhesion can be more difficult. In all cases, an undercoated alloy (bond coat, 95Ni/5Al) is required on those materials to ensure minimum bond strength. Thermal spray coating is rarely used on Class 3 material because of its poor adhesion. Care must be exercised to ensure that the item being coated is not overheated during application. Plasma spray is typically not used in areas required to seal hydraulic fluid or dry nitrogen.

4.1.2.2 HVOF

High velocity oxygen fuel (HVOF), a thermal spray process, is being widely used to replace hard chrome plating with tungsten carbide (WC) based materials. Preliminary qualification results show an equal or better performance to chrome plating. HVOF is applied per approved specifications noted on the engineering drawing or OHM/CMM. Study needs to be completed for the impact of thicker HVOF coating to resist spalling in high stress/high load reversal fatigue applications when coated on substrates operating in flexural bending of piston rods near the yield strength of the material. Different powder alloy combinations can be used depending on the application.

HVOF can be applied over all Class 1, 2, and 3 materials with very good cohesive strength. In addition, it can be applied over sulfamate nickel repairs as referenced in 4.1.1.2. Refer to ARP5935 for considerations when switching from chrome to HVOF applications.

Because of the process variables involved, HVOF is applied by a qualified applicator, particularly for fatigue-sensitive components. HVOF is a line of sight process, therefore not suitable for some internal diameter applications. Also, thickness should normally be limited to 0.010 inch (0.2540 mm), but in areas of high flexural bending stresses (such as pistons) it should be limited to 0.005 inch (0.1270 mm) to preclude spalling for tungsten carbide-based HVOF coatings. HVOF coating systems using duplex or triplex layers of different materials, and capped with WC-based material, have been qualified for applications requiring a thicker build. The cognizant engineering authority should be consulted on the appropriate repair criteria.

CAUTION: Due to spalling issues under high stress/strain/reverse-high-loading conditions, typically seen on carrier-based aircraft, not all applications are appropriate for HVOF repairs. Therefore, HVOF must be a pre-approved repair process for each specific location prior to repair application.

HVOF is not locally repaired (touched up) when locally damaged and requires a complete strip and recoating if not acceptable as is.

4.1.3 Surface Modification of Aluminum Alloys

4.1.3.1 Hard Anodize

Hard anodizing is usually limited to a buildup of about 0.002 inch (0.0508 mm). A better hard anodizing success rate is usually achieved on 7XXX series aluminum as compared to 2XXX aluminum series. Some processors can build up hard anodize to 0.006 inch (0.1524 mm) for 7XXX series Al alloys. Caution should be taken not to affect the fatigue properties of the repaired section, since the high interface bond strength and pitting nature of anodize will downgrade fatigue life due to crack initiation at the surface, resulting in propagation through the substrate. This is due to cracks initiating in the brittle anodized layer.

Anodize has no impact on crack growth since the anodize layer is very thin. Hard anodize is applied per approved specifications noted on the engineering drawing or OHM/CMM.

It is important to note that a build-up of 0.001 inch (0.0254 mm) represents a total hard anodize thickness of 0.002 (0.0508 mm) due to out-growth and in-growth during plating (see Figure 1). Shot peening (or other residual compressive surface stress process) is required before plating.

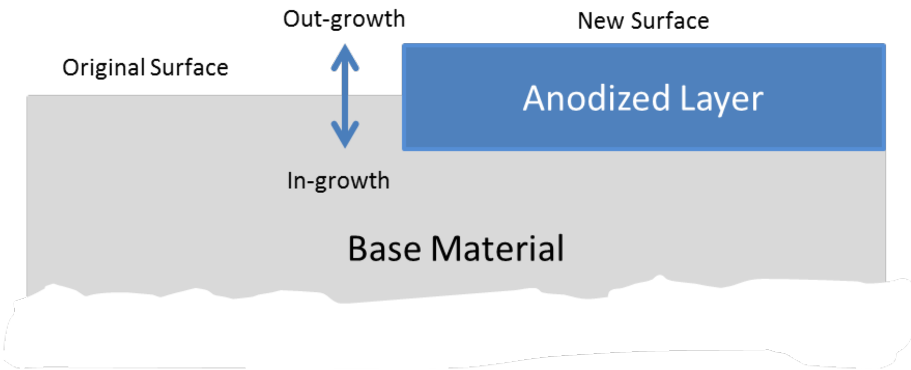

Figure 1

This repair can be used to restore out-of-tolerance dimension of anodized surfaces when fit and function are affected. Hard anodize is used on Class 2 materials only.

4.1.3.2 Chemical Conversion Coating and Brush Anodizing

Mechanically damaged areas on base metal from which the anodize surface has been removed may be touched up using chemical conversion coating or brush anodizing using an applicable method of application (brush or immersion). Normally, the reworked areas should not exceed 5 to 10% of the total anodized area of the component. Chemical conversion coating and brush plating are applied per approved specifications noted on the engineering drawing or OHM/CMM.

This repair can only be used to restore corrosion resistance of damaged surfaces where fit and function are not affected. This repair is used only on Class 2 materials. Chemical conversion coating can be used to repair chromic, sulfuric, and hard anodize surfaces. For hard anodized surfaces, chemical conversion touch up can be used in areas not subjected to abrasion.

4.1.3.3 Magnetron Sputtering of Aluminum Bores

Mechanically damaged areas on base metal requiring a thicker coating than the hard anodize process is capable of providing can be repaired using a magnetron sputtering process. This process has been utilized to build back approximately 0.010 inch (0.0508 mm) thickness.

4.2 Type II (Repair with Bushing)

4.2.1 Diameters

It is generally accepted that bushings can be installed up to an oversized diameter of 0.060 inch (1.5240 mm), since a rework allowance is usually included in the original design. This should be confirmed by OHM/CMM or suitable strength analysis. For new components, the amount a hole can be oversize is limited to a size that still allows full functionality, strength, and life after being opened up further than 0.060 inch (1.5240 mm). Care is often taken to not reduce the flange support area. Also, potential “punch through” of the mating nut or bolt head under axial thrust loads is evaluated.

4.2.2 Flanges

It is generally accepted that bushings could be installed with an oversized flange thickness up to 0.010 inch (0.2540 mm), since a rework allowance is usually included in the original design (see Figure 2). This is typically confirmed by OHM/CMM or suitable strength analysis. This limit can be exceeded if structurally acceptable. Features dimensionally related to the flange thickness or outside flange face are adjusted to account for the increased thickness.

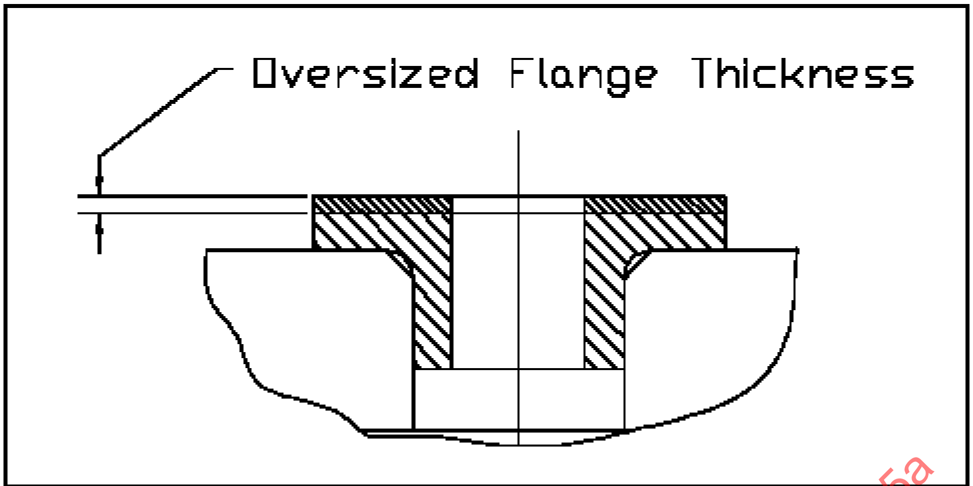

Figure 2

4.2.3 Repair Bushings

Bushings can sometimes be installed where not specified in the original design. This should be confirmed by OHM/CMM or suitable strength analysis. Care should be taken relative to dissimilar metal issues and creation of moisture traps in addition to the strength requirements. To retain the bushing and keep it from rotating, swaging or using an interference fit is recommended (see Figure 3). The effect of interference fit residual stresses on the housing (if the bushing is shrink- or press-fitted in) should be included in the strength evaluation.

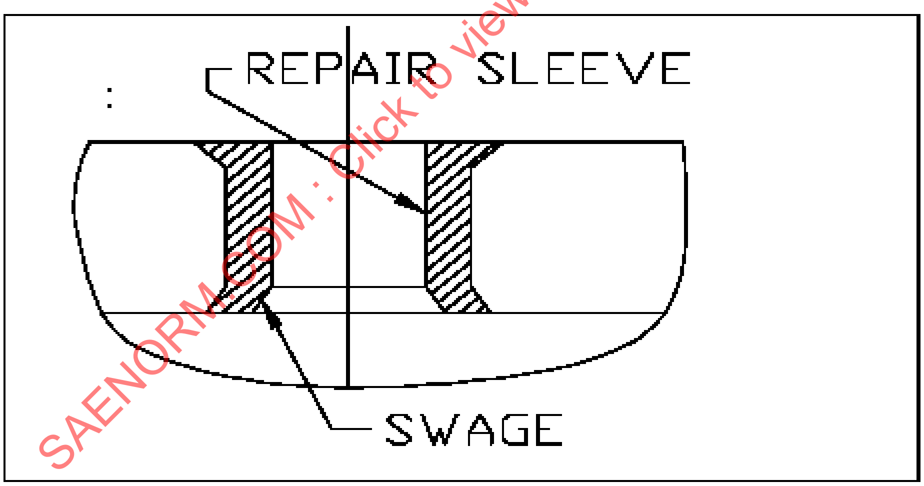

Figure 3

4.3 Type III (Repair of Damage Marks)

4.3.1 This type of damage such as tool marks, scratches, nicks, and excessive surface roughness can occur during machining or during service. Blending of the affected area is required. A commonly accepted ratio is 20:1 or larger; if not possible, this ratio can be reduced only after careful consideration is given to the increase in the stress concentration factor (see Figure 4).

To minimize the risk of heat damage, blending should be accomplished using soft-backed abrasives on a rotary handheld tool. For Class 1 materials, nital/temper etch inspection per the engineering drawing or OHM/CMM to confirm no heat damage was incurred during the course of the repair is typically required on steel above 180 ksi (1241 MPa); this depends on the amount of material removed and the process used.

Cognizant engineer's approval is often required due the difficulty of performing adequate inspection to ensure the blend ratio. Also, if it is suspected that the damage being blended might be a service induced fatigue crack, the suggested repair above does not apply. The cognizant engineer should be contacted for detailed instructions prior to proceeding. Following the repair, a surface integrity validation is typically performed using either magnetic particle inspection or liquid penetrant inspection per the engineering drawing or OHM/CMM, depending on the material.

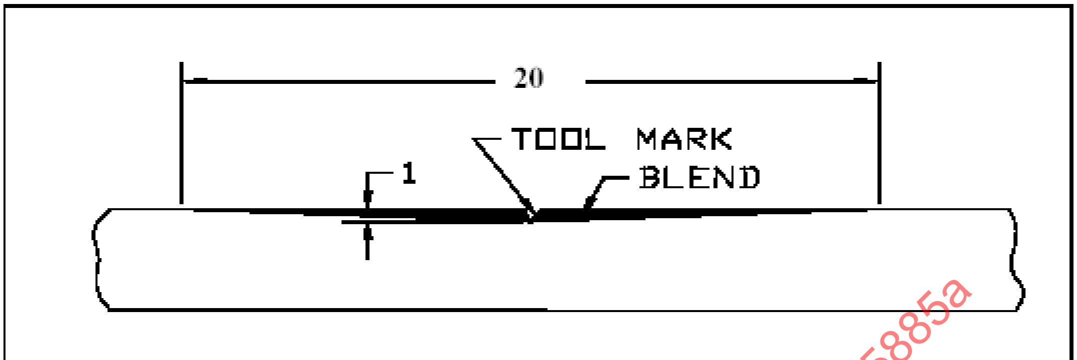

Figure 4

4.3.2 For shot peened areas (or other residual compressive surface stress process), it is important to re-shot peen (or re-apply other residual compressive surface processes) after blending per the OHM/CMM. However, it is generally accepted that re-shot peening/processing is not necessary when material removal is less than 0.0005 inch (0.0127 mm) on Class 1 parts and less than 0.0010 inch (0.0254 mm) on Class 2 parts. Reference to the applicable specification and/or cognizant engineer is advised.

4.3.3 For Class 1 parts, the blend activity should be followed by inspection, reinstatement of compressive surface effect (shot peen or other technique) as necessary, and application of corrosion protection coating (brush Cd or Zn-Ni), primer, and top coat touch-up. For functional surfaces, a nickel fill-in (see 4.1.1.2) followed by a chrome or HVOF cap is relevant.

4.4 Type IV (Repair of Localized Heating Damage)

The surface indication should be removed, and a nital/temper etch inspection should be performed. The complete removal of the overheat indication is essential. In-service issues may result from thermal damaged areas if caution is not taken during machining or grinding processes. Barkhausen Inspection may be utilized to determine if residual stress has built up in the vicinity of the heat damage (refer to ARP4462). In the case of superficial burns due to manufacturing process, a repeated light sand blasting and etching is acceptable. However, it is essential to mask all other close tolerance dimensional characteristics, since they will be affected by the repeated blasting/etching. If blasting does not remove the small superficial burn indication, hand polishing using soft-back abrasives should be used followed by an etching.

Refer to ARP5913 for disposition of landing gear components involved in abnormal heat.

4.5 Type V (Repair of Damaged Plating)

These repairs are for localized areas without need for full coating stripping and re-plating operations. They are also commonly utilized as in-service repairs.

4.5.1 Chrome and Nickel Plating

Pitting in chrome and nickel is not acceptable on all dynamic bearing surfaces, nor on gas sealing areas. Although not generally desirable, some areas (such as non-functional areas) can be left as is, if adequate corrosion protection is provided. To ensure proper corrosion protection, it is essential to determine if the pitting is through to the base metal. Two methods to verify this aspect are commonly used: