ENGINEERING PROCESS SPECIFICATION

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CAGE code 63005

Rolls-Royce®

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Coating, Aluminum-Manganese-Chromium, Electrophoretic, Diffused, for Application to Nickel-Base Components (AEP 32)

Status: **Active**

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1. SCOPE:

1.1 Purpose: This specification covers the procedure for producing an aluminide coating (AEP 32—see paragraph 8.5) by either electrophoretic deposition or selective brush-on slurry application of aluminum-manganese-chromium powder.

1.2 Application: Primarily to provide an oxidation-/hot corrosion-resistant coating on the surfaces of nickel alloy components.

1.3 Powder Application Methods:

1.3.1 Method 1: Electrophoretic deposition of coating powder.

1.3.2 Method 2: Brush-on slurry deposition of coating powder. Application shall be limited to localized areas only.

1.3.3 Method 1 shall be used unless Method 2 has been approved for a specific application by Rolls-Royce Corporation (paragraph 4.4).

1.4 Precautions:

1.4.1 The electrophoretic coating process uses a high direct current (DC) voltage in the application of the coating. The coating facilities must be designed and constructed to provide the operator with maximum protection from electrical shock.

1.4.2 The electrophoretic coating solution is flammable and emits vapors that can reach an explosive concentration. Breathing the fumes may cause toxic effects. The exhaust blower must be on at all times while the coating room is occupied and must be on during all phases of the coating operation. When not in use, the coating solution tanks must be kept covered at all times to minimize evaporation.

1.4.3 Parts coated with EPS 10040 or other aluminum-rich protective coating shall not be exposed to any acid or alkaline cleaning or coating stripping solutions without prior approval by Rolls-Royce Corporation (paragraph 4.4). Such exposure may remove the aluminide coating.

2. APPLICABLE DOCUMENTS: The following publications form a part of this document to the extent specified herein. The applicable issue shall be the current issue, unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence.

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2.1 Rolls-Royce Corporation Engineering Inspection Specifications (EIS's), Engineering Material Specifications (EMS's), and Engineering Process Specifications (EPS's): Available from Rolls-Royce Corporation, P.O. Box 420, Speed Code U30, Indianapolis, IN 46206-0420.

- EIS 1221 *Inspection Requirements and Acceptance Standards, Diffused Aluminide Coatings*
- EMS 27147 *Cement, Plastic, Polystyrene/Toluene/Allyl Isothiocyanate*
- EMS 56714 *Powder, Zein, AEP*
- EMS 56729 *Powder, Aluminum-Chromium-Manganese Alloy, AEP*
- EMS 73632 *Nickel Alloy, Castings, Investment, Corrosion and Heat Resistant, 14Cr – 4.5Mo – O.85Ti – 6Al – 2.3(Cb+Ta) (713C), Vacuum Melted—Vacuum Cast*
- EMS 73646 *Alloy Castings – Investment – Corrosion and Heat Resistant, Nickel Base—9Cr – 10Co – 2.5Mo – 10W – 1.5Ti – 1.5Ta – 5.5Al – 0.015B – 0.05Zr, Vacuum Melt—Vacuum Cast*
- EMS 73657 *Casting, Investment, Corrosion and Heat Resistant, Nickel Base—16Cr – 8.5Co – 1.75Mo – 2.6W – 0.9Cb – 3.4Ti – 1.75Ta – 3.4Al (IN738)*
- EMS 73667 *Alloy Castings, Investment, Corrosion and Heat Treatment, Nickel Base—12.6Cr – 9.0Co – 1.9Mo – 4.0Ti – 4.1Ta – 3.4Al – 0.015B – 0.035Zr – 0.97Hf, Vacuum Melted—Vacuum Cast*
- EMS 73669 *Alloy Castings, Investment, Corrosion and Heat Resistant, Nickel Base—15.5Cr – 9.8Co – 8.3Mo – 3.6Ti – 4.2Al – 0.006B, Vacuum Melted—Vacuum Cast*
- EMS 73680 *Castings, Investment, Corrosion and Heat Resistant, Vacuum Melted—Vacuum Cast, 60Ni – 8.4Cr – 10Co – 0.65Mo – 10W – 1.05Ti – 3.05Ta – 5.5Al – 1.40Hf*
- EMS 73684 *Alloy Castings, Investment, Model 250 First Stage Turbine Wheels, MAR-M247 Low Carbon, Vacuum Melted, Vacuum Cast Hot Isostatic Pressed*
- EMS 73687 *Nickel Alloy, Directionally Solidified (DS Mar-M247 LC)*
- EMS 73688 *Nickel Alloy Castings, Investment, Vacuum Melted and Vacuum Cast, Mar-M247 Low Carbon*
- EMS 73691 *Nickel Alloy Castings, Directionally Solidified (DS CM186LC)*
- EMS 73730 *Nickel Alloy, Cast, Single Crystal (AF56)*
- EMS 73734 *Nickel Alloy, Cast, Single Crystal (Ref: CMSX-4®)*
- EMS 73735 *Nickel Alloy, Cast, Single Crystal (Ref: CMSX-3®)*
- EPS 345 *Cleaning/Degreasing, Aqueous, Vapor, or Steam*
- EPS 12012 *Dry Honing, Aluminum Oxide Abrasive*

3. TECHNICAL REQUIREMENTS:

3.1 Equipment:

3.1.1 Direct Current Power Source (Method 1 Only): Shall be capable of maintaining a constant voltage setting (± 3 V) within the range of 1 to 250 V and a current capability up to 5 amps during a specific coating cycle. Power conductors, controls, and connectors to

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anodes and cathodes shall provide adequate protection to prevent electrical shock to operators.

3.1.2 Tank Construction (Method 1 Only): Tank shall be constructed of corrosion-resistant material, enclosed or insulated to prevent external electrical shock hazard and/or short circuiting. Tank material should be compatible with coating chemicals.

3.1.3 Anodes (Method 1 Only): Primary and auxiliary anodes shall be fabricated from corrosion-resistant metals or alloys that are good electrical conductors.

3.1.4 Masking: Masking material shall have good resistance to repetitive immersions in the dispersing media. Approved materials are listed in paragraphs 8.3.4 through 8.3.7.

3.2 Materials: Electrophoretic solution composition shall be as follows:

3.2.1 Dispersing Media:

	Percent by weight	**Percent by volume**
Isopropanol (99% minimum)	60 ± 5	68.5 ± 4.5
Nitromethane (95% minimum)	40 ± 5	31.5 ± 4.5

A pre-mix solvent of 60 wt % isopropanol and 40 wt % nitromethane (PMI 1222925) is also allowed as a dispersing media.

3.2.2 Solubles:

Zein (see EMS 56714, para 8.2)	0.33 ± 0.07 oz/gal (2.5 ± 0.5 g/L)
Cobalt nitrate hexahydrate (see para 8.3.3)	0.020 ± 0.007 oz/gal (0.15 ± 0.05 g/L)

3.2.3 Insoluble Dispersant: 2.0 to 6.7 oz/gal (15 to 50 g/L Total): Prealloyed AEP 32 (paragraph 8.5) powder (EMS 56729, paragraph 8.1.1).

3.3 Cleaning:

3.3.1 Parts shall be thoroughly cleaned (both exterior and internal passages, where applicable) to remove all dirt, grease, oil, and other foreign materials in accordance with EPS 345, by heating to 1100 to 1300 °F (595 to 705 °C) for 20 to 60 minutes, or by other approved cleaning method.

3.3.2 Solid and Cored Castings: Abrasive clean all exterior surfaces to be coated by dry honing in accordance with EPS 12012 using 120-grit or finer aluminum oxide at 20 to 30 psi (1.4 to 2.1 bar) for pressure-type equipment or 20 to 50 psi (1.4 to 3.4 bar) for suction-type equipment.

3.3.3 Finished Machined Parts: Abrasive clean all exterior surfaces to be coated by dry honing in accordance with EPS 12012 using 220-grit or finer aluminum oxide at 20 to 30 psi (1.4 to 2.1 bar) for pressure-type equipment or 20 to 50 psi (1.4 to 3.4 bar) for suction-type equipment. Attachment surfaces on blades shall be masked.

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3.3.3.1 Extreme care must be taken to ensure removal of residual abrasive media from cored castings and hollow assemblies.

3.3.4 Parts to be coated shall be handled with clean, white, cotton gloves until coating is applied.

3.4 Masking: Parts shall be masked and/or fixtured as required to prevent coating deposition in "no-coat" areas. Masks and fixtures shall be periodically cleaned by wiping with 70% isopropanol/30% water or lightly blasting with aluminum oxide to remove excessive coating buildup.

3.5 Coating Deposition Procedure Method 1:

3.5.1 Immerse masked and/or fixtured parts in the electrophoretic solution and coat using the following parameters. Voltage shall be set initially to achieve the desired current density and maintained at a constant level during the coating cycle. The current will drop during the coating cycle for a properly formulated bath. Initial voltage will vary with total surface area to be coated and with bath composition.

3.5.1.1 Initial current density shall not exceed 13 mA/in.^{2} (2 mA/cm^2). Continuous deposition time shall be sufficient to deposit a green coating weight of 0.005 to 0.023 oz/in.^{2} (0.022 to 0.100 g/cm^2).

Note: Green coating deposition varies with anode and component configuration and is controlled by current density and deposition time.

3.5.1.2 Green Coating Metal Composition:

	Percent by weight
Aluminum	42 ± 4
Chromium	40 ± 4
Manganese	18 ± 4

Note: The weight percentage of chromium shall be less than or equal to the weight percentage of aluminum in the green coat.

3.5.1.3 Each coating lot shall be analyzed for the requirements of paragraph 3.5.1.1 for weight, in accordance with approved procedures. If the requirements are not in accordance with paragraph 3.5.1.1, the lot shall be rejected, the green coating removed, and the parts reprocessed. Periodic chemical analysis of the green coating shall be performed to confirm compliance to paragraph 3.5.1.2.

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3.5.2 Coating Solution Precautions:

3.5.2.1 Water Content: Shall be less than 2.7 oz/gal (20 g/L) during all coating operations. Isopropanol is hygroscopic and may become contaminated with moisture from exposure to air. Water in excess of 2.7 oz/gal (20 g/L) can cause pitting of the green coating. Solvent shall be discarded when the water content is greater than 2.7 oz/gal (20 g/L).

3.5.2.2 Bath: Shall be operated between 60 and 90 °F (16 and 32 °C).

3.5.2.3 Agitation of Solution: Moderate and continuous agitation is absolutely necessary to provide and maintain a homogenous dispersion of the suspended particles (dispersants). Excessive paddle speed can create thin spots in coating. Baffles in the tank are required to eliminate eddies and/or swirling of the bath, which can interfere with the electrophoretic migration of particles, creating a wash or thin spots in the coating. Newly prepared baths or baths having agitation interrupted for more than 15 minutes must be stirred for sufficient time to ensure homogenous dispersion of the particles before coating deposition. Minimum stirring time required must be established for each coating tank and baffle design.

3.5.2.4 Additions: Shall be made as necessary to maintain the required metal powder concentrations as defined in paragraph 3.2.

3.5.2.5 Specific Gravity of Solvent: The specific gravity of the 60% by weight isopropanol/40% by weight nitromethane solvent shall be checked after mixing, once solvent reaches ambient temperature. The specific gravity shall be 0.880 to 0.915.

3.5.3 Remove parts from solution, drain off the coating solution, and allow to dry for not less than 1 minute.

3.5.4 Remove masking and/or fixturing in a manner that will not damage the undiffused coating.

3.5.5 Coated parts shall be visually inspected for evidence of any coating material on surfaces to be left bare. Any stray green coating in contact with surfaces intended to be left uncoated shall be removed with a bristle brush and/or by wiping with 70% by volume isopropanol/30% by volume water solution or other approved method.

3.5.6 Touchup Procedure for Damaged Green Coating: Parts with green (undiffused) coating having areas of damage such as nicks, scratches, or thin or bare areas totaling more than 10% of the surface area to be coated shall be completely reprocessed, starting with paragraph 3.3.2. Parts with total damaged area less than 10% of the surfaces to be coated may be touched up as follows:

3.5.6.1 Touch up parts with a small artist's-type brush using an EMS 56729 slurry, as described below.

3.5.6.2 Powder content of the slurry shall be as described in EMS 56729.

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3.5.6.3 For each 0.35 oz (10 g) of EMS 56729 powder (paragraph 8.1.1), mix with 0.17 to 0.51 oz (5 to 15 mL) of zein solution (about 2.7 to 4.0 oz/gal [20 to 30 g/L] in 60% by weight isopropanol/40% by weight nitromethane solvent) and maintain mechanical agitation during use. Adjust the amount of zein solution to give proper consistency for slurry application. Replace solvent lost by evaporation with 60/40 solvent as necessary to maintain proper consistency.

3.5.6.4 Apply slurry a minimum of two times and additional coats as necessary to ensure adequate green coat thickness. Dry parts after each application.

3.5.7 Diffusion Heat Treatment:

3.5.7.1 Parts shall be positioned on fixtures, racks, or screens to minimize contact with gas path surfaces. Surfaces to be left uncoated must not be in contact with any stray undiffused coating or any previously coated surfaces of the fixtures, racks, or screens.

3.5.7.2 All coated parts shall be heated in dry, high-purity (99.9% minimum) argon or hydrogen, or in vacuum. For atmosphere furnaces, the dew point of the gas at the furnace entrance prior to heating shall be -50 °F (-45 °C) or lower. If vacuum is used, the leak rate shall be not more than 15 microns/hr after pumping down to at least 5×10^{-5} Torr. If partial pressures of argon or hydrogen are used, the required leak rate for the vacuum furnace applies, and the incoming argon or hydrogen must meet the above dew point requirements. A burnout schedule shall be established for each type of furnace to eliminate any deleterious contamination of the parts during the diffusion cycle. The temperature uniformity of all furnaces shall be ± 25 °F (± 14 °C). Overshoot shall be limited to 25 °F (14 °C) above the temperature set point.

3.5.7.2.1 Furnace controls, calibration, uniformity surveys, and pyrometry shall be as agreed between Rolls-Royce Corporation and the user of the specification.

3.5.7.3 Diffusion cycles for representative base materials, unless otherwise specified on the applicable part drawing, shall be as specified in Table 1.

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TABLE 1 – Diffusion Cycles

Specification	Alloy	Temperature Set Point	Diffusion Time	Minimum Cooling Rate to 1400 °F (760 °C)
EMS 73632	IN713C	2050 °F (1120 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73646	MM246	2000 °F (1095 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73657	IN738	2050 °F (1120 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73667	IN792	2050 °F (1120 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73669	C1023	2080 °F (1140 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73680	MM247	2000 °F (1095 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73684	MM247 (HIP'd*)	2000 °F (1095 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73687	MM247DS	2000 °F (1095 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73688	MM247LC	2000 °F (1095 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73691	CM186	1975 °F (1080 °C)	4 hr ± 15 min	50 °F (28 °C)/min
EMS 73730	AF56	1975 °F (1080 °C)	4 hr ± 15 min	50 °F (28 °C)/min
EMS 73734	CMSX-4®	2050-2080 °F (1120-1140 °C)	2 hr ± 15 min	50 °F (28 °C)/min
EMS 73735	CMSX-3®	2000 °F (1095 °C)	2 hr ± 15 min	50 °F (28 °C)/min

*Hot isostatic pressed

3.5.7.4 Heat-up rate must not exceed 30 °F (17 °C) per minute. Rate is defined between 200 °F (93 °C) and 1000 °F (540 °C) but not points in between. At 1000 °F (540 °C), burn-off of the green coat binder is essentially complete. Rapid heat-up rates will cause lifting of the green coat from the substrate and will result in thin or bare spots in the diffused coatings.

3.5.7.5 Diffusion cycles for touchup repair of brazed components shall be as determined by Rolls-Royce Corporation (paragraph 4.4).

3.5.8 Precipitation Age Treatment: Parts requiring precipitation age treatment shall be heat treated in accordance with the applicable part drawing. If permitted by the part drawing, precipitation age treatment may be performed directly following the coating diffusion cycle, provided the parts have been cooled to below 800 °F (425 °C) before starting the precipitation age cycle.

3.5.9 Surface Conditioning for Coating Inspection: Remove diffusion scale by blast cleaning in accordance with EPS 12012 using 220-grit or finer aluminum oxide at 15 to 30 psi (1.0 to 2.1 bar) for pressure-type equipment or 20 to 50 psi (1.4 to 3.4 bar) for suction-type equipment.

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Note: Since suction-type machine pressures vary considerably from one machine to another, it is recommended that each processor establish his own pressures within this range that remove the undiffused scale but avoid removal of diffused coating.

Caution: The blast cleaning operation requires proper technique and careful execution. A 3- to 12-inch (8- to 30-cm) standoff distance from parts shall be maintained to ensure proper cleaning and avoid removal of the coating.

3.5.9.1 By means of an air blast, remove residual blast media. **Special attention must be paid to internal passages of hollow parts; all residual material shall be removed before use.**

3.6 Quality:

3.6.1 Visual and Fluorescent Penetrant Inspection: The coating, when visually or fluorescent penetrant inspected, shall be in accordance with EIS 1221.

3.6.2 Heat Tint: A heat-tint test shall be used to determine whether a group of parts is coated or whether coating is present in a no-coat area, in accordance with EIS 1221. If parts fail to comply with the requirements of EIS 1221, a thermoelectric (paragraph 3.6.2.5) or metallographic (paragraph 3.6.3) evaluation may be performed to determine the acceptability of the heat-tint lot. Coating present in no-coat areas shall be subject to rejection in accordance with paragraphs 3.6.3.1, 3.6.3.3.1, and 3.6.3.3.2.

3.6.2.1 Parts shall be 100% heat-tint inspected. To avoid erroneous heat-tint colorations, part cleanliness must be preserved from the cleaning operation (paragraph 3.5.9) through heat-tint processing by using clean gloves to handle the parts.

3.6.2.2 Cleaned parts shall be heat tinted in a circulating air furnace at temperatures of 1100 to 1300 °F (595 to 705 °C), depending on the base material, for 20 to 60 minutes, and air cooled.

3.6.2.3 If the acceptability of areas of questionable heat tint, such as fillets, cannot be determined from thermoelectric probe evaluation, a representative part from that coating lot shall be sectioned to determine whether the coating thickness is acceptable. Parts having questionable heat-tint coloration that do not have sufficient coating as determined by thermoelectric probe evaluation shall be subject to rejection.

3.6.2.4 Heat-tint coloration after inspection is optional and does not have to be removed. Heat-tint film is very thin, and excessive blasting will remove all or part of the protective coating.

3.6.2.5 Thermoelectric Probe: A thermoelectric probe may be used in addition to heat tint to nondestructively inspect critical areas of coated parts within each diffusion load. A thermoelectric probe can be used qualitatively to detect variations in coating thickness. It can provide a semiquantitative measure of coating thickness if appropriate standards are

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used and if pressure of the probe against the coated surface is controlled. Suitable standards must be made for each base metal/coating combination representing several coating thicknesses.

3.6.3 Metallographic Inspection:

3.6.3.1 Representative parts selected from each diffusion furnace lot (test pieces) shall be metallographically inspected at 500x magnification for coating thickness, coating structure, evidence of stray coating in no-coat areas, and evidence of oxidation or dealloying on machined blade serrations. Parts for sectioning shall be cleaned using the same technique used on the parts they represent. Before sectioning, they shall be heat-tint inspected to aid in selecting areas for evaluation.

3.6.3.2 Sample Preparation:

3.6.3.2.1 Sectioning and polishing of test pieces for metallographic examination of the coated and uncoated surfaces shall use procedures producing minimal heat and physical damage to the coating and base alloy.

3.6.3.2.2 When required to resolve coating microstructure, the following etch procedures are recommended:

- Etchant A: Immerse or swab in 10% hydrochloric acid (reagent grade) in methanol with two to three drops of 30% hydrogen peroxide for the time necessary to resolve the coating microstructure (typically 1 to 3 seconds).

- Etchant B: Immerse or swab in No. 2 stainless etchant consisting of 0.2 oz (5 g) ferric chloride ($FeCl_3$ - $6H_2O$), 1.7 oz (50 mL) hydrochloric acid, and 3.4 oz (100 mL) methanol for the time necessary to resolve the coating microstructure.

- Etchant C: Immerse or swab in MT etch consisting of 33% nitric acid, 33% acetic acid, 1% hydrofluoric acid, and 33% water for the time necessary to resolve the coating microstructure.

3.6.3.3 Coating Thickness:

3.6.3.3.1 Blades: The average coating thickness shall be 0.0015 to 0.0030 inches (0.038 to 0.076 mm) on all surfaces to be coated. Individual values may be 0.0010 to 0.0040 inches (0.025 to 0.102 mm). Unless otherwise specified on the part drawing, the average coating thickness shall be determined on unetched or suitably etched airfoil cross sections at 50% span with a minimum of eight measured values approximately evenly spaced around the airfoil and including both the leading edge and trailing edge. Additional measurements shall be taken and recorded to include minimum and maximum thicknesses, which must be included in determining average coating thickness. Stray coating on surfaces intended to be left bare is acceptable to 0.0007 inches (0.018 mm) maximum, provided it does not interfere with the function of the part.

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3.6.3.3.2 Vanes and Other Nonrotating Parts: The average coating thickness shall be 0.0015 to 0.0035 inches (0.038 to 0.089 mm). Individual values may be 0.0010 to 0.0040 inches (0.025 to 0.102 mm). Thickness on non-airfoil surfaces of vanes may be 0.0008 inches (0.020 mm) minimum. Unless otherwise specified on the part drawing, the average coating thickness shall be determined on unetched or suitably etched airfoil cross sections at 50% span with a minimum of eight measured values approximately evenly spaced around the airfoil and including both the leading edge and trailing edge. Additional measurements shall be taken and recorded to include minimum and maximum thicknesses, which must be included in determining average coating thickness. Stray coating on surfaces intended to be left bare is acceptable to 0.0007 inches (0.018 mm) maximum, provided it does not interfere with the function of the part.

3.6.3.4 Coating Structures: Evaluation of coating structure shall be performed on test pieces etched per paragraph 3.6.3.2.2. Acceptable microstructures are shown in Figure 1.

3.6.3.5 Oxidation and Dealloying:

3.6.3.5.1 Evaluation of oxidation effects shall be performed in the unetched condition. Dealloying must be evaluated on a test piece etched sufficiently to distinguish the matrix gamma prime phase. Etchants recommended in paragraph 3.6.3.2.2 may be used, except etch time is typically 5 seconds or longer.

3.6.3.5.2 The machined blade serration surfaces must conform to the following requirements:

- No continuous surface oxidation is allowed, and neither is intergranular attack (or interdendritic attack for single crystals), which is defined as oxidation (or corrosion) associated with a majority of the surface connected grain boundaries or dendritic features.

- Dealloying shall not exceed 0.001 inches (0.03 mm). Dealloying is observed as a light-etching surface layer due to loss of gamma-prime forming elements.

3.7 Coating Deposition Procedure Method 2: Selective brush-on slurry for parts requiring coating in limited areas only.

3.7.1 Apply EMS 56729 slurry (paragraph 3.5.6.3) with a small artist's-type brush, as described below.

3.7.1.1 Powder content of the slurry shall be as described in EMS 56729.

3.7.1.2 For each 0.4 oz (10 g) of EMS 56729 powder, mix with 0.2 to 0.3 oz (5 to 10 mL) of zein solution (about 2.7 to 4.0 oz/gal [20 to 30 g/L] in 60% by weight isopropanol/40% by weight nitromethane solvent), and maintain mechanical agitation during use. Adjust the amount of zein solution to give proper consistency for slurry application. Replace solvent lost by evaporation with 60/40 solvent as necessary to maintain proper consistency.

3.7.1.3 Apply slurry a minimum of two times and additional coats as necessary to ensure adequate green coat thickness. Dry parts after each application.

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3.7.1.4 Coated parts shall be visually inspected for evidence of any coating material on surfaces to be left bare. Any stray green coating on surfaces intended to be left uncoated shall be removed with a bristle brush and/or by wiping with 70% by volume isopropanol/30% by volume water solution or other approved method.

3.7.1.5 Diffusion heat treat coated parts per paragraphs 3.5.7.1 through 3.5.7.4, except the cycle shall be 1975 °F (1080 °C) for 4 hr ± 15 min, unless otherwise specified.

3.7.1.6 Parts requiring precipitation age treatment shall be heat treated in accordance with the applicable part drawing.

3.7.1.7 Clean parts per paragraphs 3.5.9 and 3.5.9.1.

3.7.1.8 Visually inspect per paragraph 3.6.1.

3.7.1.9 Heat tint per paragraphs 3.6.2.1 through 3.6.2.3, **except metallographic examination is not required for coating thickness determination due to the localized nature of the coating**.

3.7.1.10 A thermoelectric probe may be used in addition to heat tint to nondestructively inspect coating per paragraph 3.6.2.5.

3.8 Reprocessing Procedures:

3.8.1 Touchup Procedure for Damaged Diffused Coatings: Parts with diffused coatings having localized areas of damage such as chips, nicks, and/or small bare areas may be locally repaired only if repeated heat treatments are authorized by Rolls-Royce Corporation for the specific base material involved.

3.8.1.1 Blades: Size of the area requiring touchup is unlimited on the platform and shroud abutment faces. Touchup is limited to a 0.2-inch-diameter (5.1-mm-diameter) or equivalent area on all other surfaces. No more than three such spots may be touched up.

3.8.1.2 Vanes and Other Nonrotating Parts: A total area up to 10% of the total surface area specified to be coated may be touched up.

3.8.1.2.1 If necessary, clean or degrease per EPS 345 or by using another method approved by Rolls-Royce Corporation.

3.8.1.2.2 Air dent the areas to be touched up per EPS 12012, removing any sharp transition to the surrounding sound areas. Use 220-grit aluminum oxide at pressure and standoff distance sufficient to prepare the area without damaging the base metal.

3.8.1.2.3 Touch up parts according to the procedure described in paragraphs 3.5.6.1 through 3.5.6.4.

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3.8.1.2.4 Repeat heat treatment and cleaning steps as described in paragraphs 3.5.7 and 3.5.9, except diffusion cycles for touchup repair of brazed components shall be determined by Rolls-Royce Corporation (paragraph 4.4).

3.8.1.2.5 No part shall be touched up more than twice (original coating cycle plus two reworks).

3.8.1.2.6 Heat Tint: An acceptable heat tint test, as defined in paragraphs 3.6.2.1 through 3.6.2.4, shall be adequate evidence of satisfactory coating coverage for touchup coatings.

3.8.1.2.6.1 Areas that have been touched up will exhibit a coloration slightly different from the original AEP 32 coating after heat tint.

3.8.1.2.6.2 Non-uniform coloration after heat tint due to the touchup process shall not be cause for rejection if the coating thickness in the touched-up area shows satisfactory coating thickness when checked with a thermoelectric probe.

3.8.1.2.6.3 Thermoelectric Probe: A thermoelectric probe (paragraph 3.6.2.5) may be used in addition to heat tint to nondestructively inspect critical areas of touched-up parts.

3.8.2 Strip and Recoat Procedure for Unacceptable Coatings: Parts with coatings not conforming to the requirements of this specification may be stripped according to procedures approved by Rolls-Royce Corporation (paragraph 4.4) and recoated per this specification, provided stripping and repeated heat treatment are authorized by Rolls-Royce Corporation for the specific base material involved. Since stripping of diffused coating also removes some base material, the maximum number of reprocessing cycles allowed shall be two unless otherwise agreed to by the Rolls-Royce technical authority.

3.8.2.1 Uncoated areas may be masked with a suitable masking material to protect the base metal from the stripping solution.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The coating processor shall be responsible for performing all tests. Results of such tests shall be reported to Rolls-Royce Corporation as required by paragraph 4.5. Rolls-Royce Corporation may perform confirmatory testing as required to ensure conformance to all requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to the requirements of paragraph 3.6.3 of this specification are classified as acceptance tests and shall be performed to represent each coating lot in the furnace lot.

4.2.2 Tests to determine conformance to requirements of green coat deposition weight and composition (paragraphs 3.5.1.1 and 3.5.1.2) are classified as in-process acceptance tests and shall be performed as described in paragraph 4.3.

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4.3 Sampling:

4.3.1 Green Coating Weight and Composition: A coating lot is defined as a maximum of 1200 parts of a single part number submitted for coating application at one time. One part from each rack of parts being coated is weighed both before and after coating as an in-process control, and those weights are recorded for future use. If any green coat weight fails to meet the requirements of paragraph 3.5.1.1, that rack of parts shall be rejected. The green coating composition (paragraph 3.5.1.2) shall be determined per a sampling plan agreed on by Rolls-Royce Corporation and the user of this specification. Unless otherwise specified, green coat composition shall be determined once per calendar quarter.

4.3.2 AEP Bath Analysis: Shall be performed daily or, at a minimum, after the total green coating weight deposited from the bath equals 1.2 oz/gal (9 g/L) of solution in the bath. A gravimetric analysis for the insolubles and the zein is acceptable. The zein determination is performed on a centrifuged solution sample. The cobalt nitrate level can be determined only by chemical analysis, but the ratio of zein to cobalt nitrate can be used to estimate quantities of cobalt nitrate for the purpose of making additions to the bath. The bath analysis is used to calculate the required additions to the coating bath. The coating solution shall be chemically (not gravimetrically) analyzed for both cobalt nitrate and insolubles; this shall be done no later than when a total of 4.0 oz/gal (30 g/L) have been deposited from the bath.

4.3.3 Finished Parts (Coated and Diffusion Heat Treated): A furnace lot is defined as all parts loaded into the diffusion furnace and diffused at the same time. A furnace lot may include more than one coating lot.

4.3.3.1 Furnace lots shall be 100% inspected, both visually and by fluorescent penetrant inspection, to determine conformance to paragraph 3.6.1.

4.3.3.2 All parts from each furnace lot shall be visually inspected to determine conformance to heat-tint standards (paragraph 3.6.2.1).

4.3.3.2.1 A thermoelectric probe (paragraph 3.6.2.5) may be used as necessary to ensure satisfactory coating uniformity or to inspect questionable areas observed in heat tint.

4.3.3.3 A minimum of one representative coated and diffusion-treated part from each coating lot included in each furnace lot shall be inspected to determine conformance to metallographic standards (paragraph 3.6.3).

4.3.3.3.1 Parts that are precipitation aged directly following diffusion treatment without interrupting the furnace run shall meet metallographic standards after aging.

Note: When parts are very large or complex, or when part quantities are limited, Rolls-Royce Corporation may authorize the use of control samples of a different configuration, provided that they are of the same base material as the actual parts and that correlation of coating thickness and microstructure between the control configuration and the actual part configuration has been established.

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4.4 Approval:

4.4.1 Raw Material Source Approval: Sources for certain coating raw materials, including zein (paragraph 3.2.2) and insolubles (paragraph 3.2.3), shall be approved by Rolls-Royce Corporation before material is supplied for production use. Approved sources are listed in paragraph 8.1.

4.4.2 Coating Source Approval: Processing to this specification shall be performed only by sources approved by Rolls-Royce Corporation. Approval shall be based on review of a processor's capabilities and process control provisions, and on evaluation of coated sample hardware.

4.4.2.1 Coating Process Approval: Processing for each part number coated shall be approved by Rolls-Royce Corporation before use in production. Approval shall be based on evaluation of coated parts.

4.4.2.2 Changes in materials, type of equipment, processing method or parameters, process controls, or inspection procedures require approval by Rolls-Royce Corporation. For such changes, the supplier shall submit:

a) a description of the change and its potential effect(s) on the product
b) sample parts and/or test material as requested by Rolls-Royce Corporation for evaluation

4.5 Reports: With each shipment of coated parts, the coating supplier shall furnish a report of the results of all tests to determine conformance to the technical requirements of this specification, along with a statement that the coated parts conform to all requirements of this specification and to applicable part drawings. This report shall include the purchase order number, this specification number and its latest revision letter, part number, and quantity in each furnace lot. Records of processing parameters established for each part number shall be maintained by the coating supplier, subject to Rolls-Royce Corporation audit and approval.

4.6 Resampling and Retesting: If any part fails to meet the requirements of this specification, three additional parts may be taken at random from that coating lot (paragraph 4.3.3.3). If any of the three parts fails to meet the requirements of this specification, the furnace lot shall be rejected.

Note: When parts are very large or complex, or when part quantities are limited, Rolls-Royce Corporation may authorize the use of nondestructive thermoelectric probe inspection of additional parts from the coating lot selected at random. If any of the parts fails to meet the requirements of this specification, the coating lot shall be rejected. Precautions for use of the thermoelectric probe (paragraph 3.6.2.5) must be followed.

5. PREPARATION FOR DELIVERY:

5.1 Parts shall be handled and packaged in a manner ensuring the required physical characteristics and properties of the coated parts are preserved.

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5.2 Packages of parts shall be prepared for shipment in accordance with applicable rules and regulations pertaining to the handling and packaging of the parts to ensure safe delivery.

6. ACKNOWLEDGMENT: A supplier shall refer to this specification number and its revision letter in all quotations and when acknowledging purchase orders.

7. REJECTIONS: Coated parts not meeting the requirements of this specification shall be subject to rejection.

8. NOTES:

8.1 Approved Raw Material Sources:

8.1.1 Prealloyed Powder (paragraph 3.2.3): See EMS 56729.

8.1.2 Zein (Corn Gluten—Low Electrolyte Grade; paragraph 3.2.2): See EMS 56714.

8.2 Approved Coating Sources: A list of approved coating sources shall be maintained by Rolls-Royce Corporation.

8.3 Demonstrated Products: The following products have demonstrated capability for use in accordance with this specification. Product brand names and sources are referenced for information only; equivalent products may be procured from other sources.

8.3.1 Isopropanol (99% Minimum): Available from Union Carbide or Shell Chemical Co.

8.3.2 Nitromethane (95% Minimum): Available from Angus Chemical Co., 1500 E. Lake Cook Rd., Buffalo Grove, IL 60089, or W. R. Grace, Lexington, MA 02173.

8.3.3 Cobalt Nitrate Hexahydrate (Reagent Grade): Available from Fisher Scientific Co. or J. T. Baker Chemical Co.

8.3.4 Microsol E-1003: A product of Michigan Chrome and Chemical Co., 8615 Grinnel Ave., Detroit, MI 48213.

8.3.5 GE RTV 108 Silicone Rubber: A product of General Electric, Silicone Products Dept., Waterford, NY 12188.

8.3.6 Ethylene Propylene EPDM or Hypalon (Hydro-Xyproline): Available from Acme Masking Co., 240 Production Dr., Avon, IN 46123.

8.3.7 Maskants:
1. Testor No. 3501 Model Cement: See EMS 27147.
2. 323 Red Stop-Off Lacquer: A product of BASF, 1500 Latham St., Batavia, IL 60510.

8.4 AEP: Rolls-Royce Corporation electrophoretic process.

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8.5 Licensing: AEP 32 is a process developed by Rolls-Royce Corporation. Requests for license to apply AEP 32 must be directed to Rolls-Royce Corporation.

8.6 General: This specification is issued by Rolls-Royce Corporation for use in manufacturing items described by Rolls-Royce Corporation drawings. The user is responsible for compliance to the latest revision of this specification.

8.7 Figure 1 is an integral part of this specification.

8.8 Marginal Indicia: Revision bars indicate changes from the previous issue of this specification.

8.9 CMSX-3® and CMSX-4® are registered trademarks of Cannon-Muskegon Corporation, P.O. Box 506, Muskegon, MI 49443.

8.10 Revision AC is authorized by ESC 500012535977.

Signed Charles J. Teague

Chief, Business and Engineering Improvement

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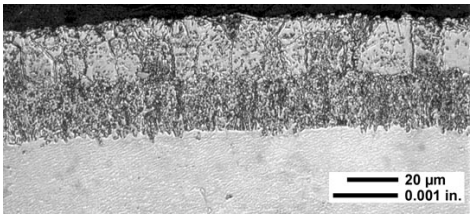
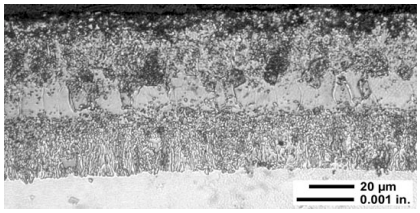
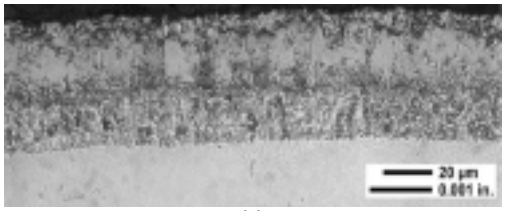


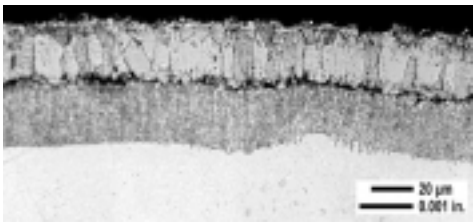
(a)
M247 / AEP 32
1.7 mils



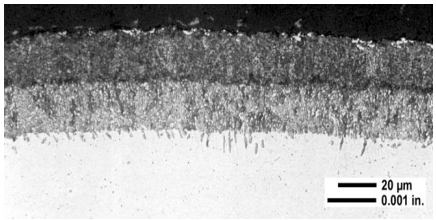
(b)
M247 / AEP 32
2.8 mils



(c)
IN792 / AEP 32
2.0 mils



(d)
CM186LC / AEP 32
1.7 mils



(e)
CMSX-4 / AEP 32
1.6 mils

FIGURE 1 – Typical AEP 32 Microstructures on Representative Nickel-Base Alloys Following Coating Diffusion and Precipitation Aging Heat Treatment (etchant: swabbed in 10% HCl in methanol + H_2O_2 for 3 seconds)

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