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400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 2447B

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Superseding AMS 2447A

Submitted for recognition as an American National Standard

Coating, Thermal Spray
High Velocity Oxygen/Fuel Process

1. SCOPE:

1.1 Purpose:

This specification covers engineering requirements for applying thermal spray coatings utilizing high velocity oxygen fuel (HVOF) combustion driven processes and the properties for such coatings.

1.2 Application:

This process has been used typically to provide coatings of lower porosity and higher adhesive, and/or cohesive, strength than generally attainable with typical plasma spray processes for applications requiring wear, heat, and corrosion resistance and for dimensional restoration, but usage is not limited to such applications.

1.3 Safety - Hazardous Materials:

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification 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.

QUESTIONS REGARDING THIS DOCUMENT: (724) 772-7161 FAX: (724) 776-0243
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SAE WEB ADDRESS: http://www.sae.org

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 4027	Aluminum Alloy, Sheet, and Plate, 1.0Mg - 0.060Si - 0.28Cu - 0.2Cr (6061: -T6 Sheet, -T651 Plate), Solution and Precipitation Heat Treated
AMS 4117	Aluminum Alloy Bars, Rolled or Cold Finished Rods, Wire, and Flash Welded Rings, 1.0Mg - 0.60Si - 0.28Cu - 0.20Cr (6061: -T6, -T651), Solution and Precipitation Heat Treated
MAM 4911	Titanium Alloy Sheet, Strip, and Plate, 6A1 - 4V, Annealed
AMS 4911	Titanium Alloy Sheet, Strip, and Plate, 6A1 - 4V, Annealed
AMS 4928	Titanium Alloy Bars, Wire, Forgings, and Rings, 6A1 - 4V, Annealed
AMS 5510	Steel Corrosion and Heat Resistance Sheet, Strip, and Plate, 18Cr - 10.5 Ni - 0.40Ti (30321), Solution Heat Treated
AMS 5596	Nickel, Alloy Corrosion and Heat Resistant, Sheet Strip, Foil and Plate, 52.5Ni - 19Cr - 3.0Mo - 5.1Cb - 0.90Ti - 0.5A1 - 18Fe, Consumable Electrode or Vacuum Induction Melted, 1755 °F (958 °C) Solution Heat Treated
AMS 5645	Steel, Corrosion and Heat Resistant Bars, Wire, Forgings, Tubing and Rings, 18Cr - 10Ni - 0.40Ti (30321), Solution Heat Treated
AMS 5662	Nickel Alloy, Corrosion Resistant Bars, Forgings, and Rings, 52.5Ni - 19Cr - 3.0Mo - 5.1Cb - 0.90Ti - 0.50Al - 18Fe, Consumable Electrode or Vacuum Induction Melted, 1775 °F (968 °C) Solution Heat Treated, Precipitation Hardenable
AMS 7879	Tungsten Carbide-Cobalt Powder, Cast and Crushed

2.3 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM C 633	Adhesion or Cohesive Strength of Flame-Sprayed Coatings
ASTM E 384	Microhardness of Materials

3. TECHNICAL REQUIREMENTS:

3.1 Equipment:

3.1.1 Torch: A specially constructed gun that utilizes combustion products to generate a high velocity gas stream for heating of the coating material to a molten or plasticized state, and transfer of the coating material to the work piece.

3.1.2 System: The system shall be fitted with controls for adjusting and monitoring the gas(es) and fuel(s) used to operate the torch.

3.1.2.1 Indicating devices used as a system controls, as applicable to the process gases and fuels, shall have a minimum accuracy as follows:

pressure gauges: ±1.5% of full scale
flow meters: ±2% of full scale

3.1.3 Powder Feeder: The powder feed system shall supply a metered flow of material.

3.2 Materials:

3.2.1 Gases and Fuels: Specifications utilized by the processor for procurement of these materials shall be acceptable to purchaser.

3.2.2 Coating Material: Shall conform to the specification referenced by the drawing or otherwise specified by purchaser. All powders shall be dry, free flowing and uniformly blended.

3.2.2.1 Coating Designation: Coating specification number and appropriate suffix number designate the material composition to be applied in accordance with Table 1; e.g., AMS 2447-7 indicates that the part is to be coated with 78W - 16Co - 5.1C powder.

3.3 Preparation:

3.3.1 The processes and procedures given herein apply only to the properties of the as-deposited coating. The purchaser is responsible for the effects of any post deposition processing.

3.3.2 Cleaning: Surfaces to be coated shall be thoroughly cleaned to remove moisture, oil, grease, dirt, scale, paint and other foreign material. Final cleaning shall take place no more than four hours prior to coating. Cleaning procedures shall not cause hydrogen embrittlement in ferrous materials or other detrimental surface contamination in materials, which are to be coated.

3.3.3 Masking: Parts shall be masked to protect surfaces which are not to be coated.

3.3.4 Surface Conditioning: Surfaces to be coated may be grit blasted to produce a uniform matte finish.

3.4 Application:

3.4.1 Preheating: Surfaces to be coated shall be preheated to temperature, not less than that necessary to remove moisture. Preheating may be accomplished by use of the torch or by other suitable means. Maximum substrate temperature during preheating shall not exceed limits shown in 3.4.3.

TABLE 1 - Powder Specification

Coating Designation	Typical Composition	Recommended Method of Manufacture	Recommended Particle Size, Microns
AMS 2447-1	57Co - 25 Cr - 10 Ni - 7W (STELLITE® Alloy No. 31 or equivalent)	Gas Atomized	-45/+5
AMS 2447-2	60Co - 29 Mo - 8 Cr - 3Si (TRIBALOY® Alloy T-400 or equivalent)	Gas Atomized	-45/+10
AMS 2447-3	69Cr - 20Ni - 11C ($75Cr_3C_2$ - 25 Ni Cr)	Sintered	-53/+10
AMS 2447-4	95Ni - 5Al (Alloyed Ni-Al)	Gas Atomized	-45/+15
AMS 2447-5	76Ni - 18Cr - 6Al (Alloyed Ni-Cr-Al)	Gas Atomized	-45/+15
AMS 2447-6	60Ni - 19Cr - 18Fe - 3Mo (Inconel® 718 or equivalent)	Gas Atomized	-53/+15
AMS 2447-7	78W - 16Co - 5.1C (83WC - 17Co)	Agglomerated Sintered	-53/+10
AMS 2447-8	82W - 11Co - 4.1C (88WC - 12Co, AMS 7879)	Cast	-45/+5
AMS 2447-9	82W - 10Co - 4Cr - 3.5C (86WC - 10Co - 4Cr)	Sintered	-53/+10
AMS 2447-10	86W/10Ni/3.5C (90WC - 10Ni)	Cast	-53/+10

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3.4.2 Coating: Coating material shall be deposited on the designated surface to a sufficient thickness to permit finishing to specified dimensions. Coating thickness requirements do not apply to areas designated as optional coating areas.

3.4.2.1 Areas on which coating is optional shall, if coated, be prepared and handled in the same manner as the area on which coating is required.

3.4.2.2 Whenever possible, a constant gun-to-work distance, and a spray angle of 90 degrees ± 15 should be maintained.

3.4.2.3 Spray deposition shall be continuous, except for interruptions to measure coating thickness and/or for cooling cycles to maintain part below maximum allowable temperature.

3.4.3 Substrate Temperature: Unless otherwise specified, maximum temperature of the substrate during preheating and coating application shall not exceed the temperatures shown in Table 2.

TABLE 2 - Maximum Substrate Temperature

Part Basis Material	Temperature
Aluminum Alloys	250 °F (121 °C)
Magnesium Alloys	350 °F (176 °C)
Steel, Including Corrosion Resistant Alloys	350 °F (177 °C)
Nickel and Cobalt Alloys	400 °F (204 °C)
Titanium Alloys	350 °F (177 °C)

3.4.4 Test Specimens: Specimens shall be coated, as far as practicable, using the process procedures identified on the Coating Process Control Sheet (See Figure 1) for the parts they represent.

3.4.4.1 Specimen Material: Unless otherwise specified by purchaser, test specimens shall be made from the materials as listed in Table 3.

TABLE 3 - Test Specimen Material

Part Basis Material	Bond Strength Specimen	Metallographic and Bend Specimen
Aluminum and Magnesium Alloys	AMS 4117	AMS 4027
Nickel and Cobalt Alloys	AMS 5662	AMS 5596
All Steels	AMS 5645	AMS 5510
Titanium and Titanium Alloys	AMS 4928	AMS 4911, MAM 4911

3.5 Surface Finishing: Procedures for finishing shall be as agreed upon by purchaser and processor.

3.6 Properties:

3.6.1 Adhesion:

PROCESSOR:_____ COATING SPECIFICATION:_____
PURCHASER:_____

APPLICATION:
PART NAME:_____
PART NUMBER: _____ BASIS MATERIAL:_____

PREPARATION:
PRE-BLAST CLEANING:_____
BLASTING GRIT TYPE:_____GRIT SIZE:_____PRESSURE:_____
BLASTING TIME, INTENSITY, COVERAGE: _____

SPRAY EQUIPMENT & ACCESSORY EQUIPMENT:
MANUFACTURER: _____ TORCH: _____
POWDER PORT: _____ HEAD: _____ NOZZLE: _____
INJECTOR: OXYGEN: _____ FUEL: _____ POWDER: _____
ADAPTORS:_____

CONSOLE PARAMETERS:
OXYGEN: SUPPLY PRESSURE: _____
TORCH PRESSURE: _____FLOW RATE: _____
FUEL: TYPE: _____ SUPPLY PRESSURE: _____
TORCH PRESSURE: _____ FLOW RATE: _____

POWDER FEEDER:
FEEDER TYPE: _____
CARRIER GAS: _____SUPPLY PRESSURE:_____
FEEDER PRESSURE:_____FLOW RATE: _____DIAL: _____
VIBRATOR USED: [ ]YES [ ]NO AMPLITUDE: _____
FEEDER HOSE: DIAMETER:_____LENGTH:_____

COATING PROCESS DATA:
PREHEAT TEMPERATURE: _____ MAXIMUM PART TEMPERATURE: _____
COOLING, METHOD: _____ POSITION: _____
COOLING, CYCLE TIME: _____ SPRAY, CYCLE TIME:_____
SPRAY, NO. OF CYCLES:_____ SPRAY, COATING THICKNESS:_____

WORK HANDLING:
PART MOTION: _____ SPEED: _____
GUN MOTION: _____SPEED: _____
GUN-TO-WORK: DISTANCE: _____ ANGLE: _____
SPRAY MASKING/FIXTURES: _____

METALLOGRAPHY:
MICROSTRUCTURE: _____ HARDNESS: _____
BOND STRENGTH: _____ BEND TEST: _____
COATING MATERIAL: _____ LOT/BATCH NO:_____

OPERATOR: _____ CERTIFICATION NO: _____
APPROVAL: _____ DATE: _____

FIGURE 1 - Coating Process Control Sheet

3.6.1.1 Bend Test: Specimens prepared and tested in accordance with 3.7.1 shall not show separation of the coating from the substrate, when examined visually without magnification. Cracking of the coating and minimal separation at the edges of the specimen shall be considered acceptable.

3.6.1.2 Bond Strength: Specimens, prepared and tested in accordance with 3.7.2, shall comply with the requirements shown in Table 4.

TABLE 4 - Coating Properties

Coating Designation	Minimum Hardness	Oxides Max%	Voids Max%	Quantity of Unmelts Max	Bond Strength Min, psi (MPa)
AMS 2447-1	400 (HV100)	5	1	5	8,000 (5.6)
AMS 2447-2	500 (HV300)	2	1	2	9,000 (6.4)
AMS 2447-3	800 (HV300)	2	1	-	10,000 (7.0)
AMS 2447-4	275 (HV100)	2	1	3	8,000 (7.0)
AMS 2447-5	350 (HV100)	2	1	3	8,000 (5.6)
AMS 2447-6	375 (HV300)	5	1	3	9,000 (6.4)
AMS 2447-7	1050 (HV300)	1	1	-	10,000 (7.0)
AMS 2447-8	1000 (HV300)	1	1	-	10,000 (7.0)
AMS 2447-9	1050 (HV300)	1	1	-	10,000 (7.0)
AMS 2447-10	1000 (HV300)	1	1	-	10,000 (7.0)

3.6.2 Coating Hardness: Specimens prepared and tested in accordance with 3.7.3 shall comply with the requirements shown in Table 4.

3.6.3 Microstructure: Examination of a suitably prepared cross-sectioned specimen shall show the coatings to be free from cracks and the coating/interface line to have no separation. Microstructural properties shall be evaluated in accordance with the following:

3.6.3.1 Voids and Oxides: Not greater than as specified in Table 4 in any field of view (approximately 0.02 inch (0.51 mm) in length) when examined at 400X magnification on the cross sectioned specimen.

3.6.3.2 Unmelted Particles: Not greater than as specified in Table 4 in any field of view (approximately 0.04 inch (1.0 mm) in length) when viewed at 200X magnification on the cross sectioned specimen.

3.6.3.3 Interface: Contamination of the coating/substrate interface with surface preparation media shall not exceed 10% in any field of view (approximately 0.04 inch (1.0 mm) in length) when viewed at 200X magnification on the cross sectioned specimen.

3.7 Test Methods:

3.7.1 Bend Test: Test panels (See Table 3) approximately 0.05 x 1.0 x 3.0 inches (1.3 x 25 x 76 mm) shall be coated on one side to a thickness of 0.001 to 0.003 inch (0.025 to 0.076 mm). Panels shall be tested by being bent around a 0.5 inch (12.7 mm) diameter bar, with the coated surface on the outside of the bend, at a rate of approximately ten degrees per second. Panels shall be bent to obtain a 90 degree permanent set.

3.7.2 Bond Strength: Test specimens (See Table 3) approximately 1.0 inch (25 mm) in diameter by 2.0 inches (51 mm) long, shall be coated to a thickness of 0.008 to 0.012 inch (0.2 to 0.3 mm). Specimens shall be prepared and tested in accordance with ASTM C 633.

3.7.3 Microhardness: Test specimens, approximately 0.05 x 1.0 x 3.0 inches (1.3 x 25 x 76 mm) shall be coated on one side to a minimum thickness of 0.008 inch (0.20 mm). The hardness shall be the average of a minimum of ten evenly spaced indentations determined in accordance with ASTM E 384.

3.8 Quality:

Coating, as received by purchaser, shall be adherent to the basis material and shall have a uniform, continuous surface free from spalling, chipping, flaking, and other imperfections detrimental to usage of the coating.

3.9 Tolerances:

Unless otherwise specified by the purchaser, a tolerance of -0 to +0.125 inch (3.2 mm) is allowed on the boundaries of the area designated to be coated.

3.10 Definition:

3.10.1 Lot: A lot shall be all parts of a similar configuration, coated sequentially on the same machine setup using the same batch of coating material and process parameters, within a shift or eight hours of torch time, and presented for processor's inspection at one time.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

Processor shall supply all test specimens for processor's tests and shall be responsible for performance of all required tests. When parts are to be tested, such parts shall be supplied by the purchaser. Purchaser reserves the right to sample and to perform any conformity testing deemed necessary to ensure that the coating conforms to the requirements of this specification.