NOTE: MIL-STD-1687 has been redesignated as a Manufacturing Process Standard. The cover page has been changed for Administrative reasons. There are no other changes to this Document.

MIL-STD-1687A (SH)
11 FEBRUARY 1987
SUPERSEDING
MIL-STD-1687 (SH)
24 NOVEMBER 1980
(SEE 6.5)

DEPARTMENT OF DEFENSE
MANUFACTURING PROCESS STANDARD

THERMAL SPRAY PROCESSES FOR NAVAL SHIP MACHINERY APPLICATIONS

AMSC N/A AREA MFFP

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

Washington, DC 20362-5101

Thermal Spray Processes for Naval Ship Machinery Applications

1. This Military Standard is approved for use by the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

This standard covers thermal spray processes for repair or overhaul of Naval ship machinery.

CONTENTS

CONTENTS - Continued

of reconfiguration by substitution.

CONTENTS - Continued

d above, necessary [thickness exceeds the allowable maximum, as specified

CONTENTS - Continued

1. SCOPE

1.1 Scope. This standard covers thermal spray processes for machinery repair and corrosion protection of Naval ship machinery, except the spraying of aluminum for corrosion protection which is covered in DOD-STD-2138. This standard does not apply to primary and secondary systems of nuclear ships. Included are requirements for the qualification of thermal spray procedures and operators, requirements and guidance for use of thermal spray material and equipment, quality assurance requirements, and descriptions of applicable qualification tests.

1.1.1 The thermal spray processes covered by this standard are: (a) wire spraying of consumable coating material using oxygen-fuel gas, or using two consumable electrodes in an electric arc system, and (b) powder spraying, using oxygen-fuel gas or plasma arc.

1.2 Application. Thermal spray coatings shall be used only for machinery applications specifically permitted herein (see 5.5.2) or for which prior approval has been obtained from the Naval Sea Systems Command (NAVSEA).

1.2.1 Requirements of this standard pertain only to the thermal spray coatings applied to ferrous and non-ferrous metal substrates.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standard. Unless otherwise specified, the following specifications and standard of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this standard to the extent specified herein.

SPECIFICATIONS

FEDERAL

O-T-620	- 1,1,1-Trichloroethane, Technical, Inhibited (Methyl Chloroform).
BB-A-106	- Acetylene, Technical, Dissolved.
BB-A-1034	- Air, Compressed, for Breathing Purposes.
BB-H-886	- Hydrogen.
BB-H-1168	- Helium, Technical.
BB-O-925	- Oxygen, Technical, Gas and Liquid.
TT-T-548	- Toluene, Technical.

MILITARY

MIL-M-3800	- Metallizing Outfits (Wire-Gas), Guns and Accessories.
MIL-W-6712	- Wire; Metallizing.
MIL-A-18455	- Argon, Technical.

MILITARY (Continued)

MIL-P-80109 - Plasma Spray Systems, Powder, Guns, and Accessories.
MIL-M-80141 - Metallizing Outfits, Powder-Gas, Guns and Accessories.
MIL-M-80226 - Metallizing System, Wire, Electric Arc, Guns and Accessories.
MIL-P-83348 - Powders, Plasma Spray.

STANDARD

MILITARY

DOD-STD-2138 - Metal Sprayed Coating Systems for Corrosion Protection Aboard Naval Ships. (Metric)

(Copies of specifications and standards required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.1.2 Other Government publication. The following other Government publication forms a part of this specification to the extent specified herein. Unless otherwise specified, the issues shall be those in effect on the date of the solicitation.

PUBLICATIONS

DEPARTMENT OF TRANSPORTATION (DOT)

Code of Federal Regulations (CFR) 29, 1910.107 - Spray booths.

(The Code of Federal Regulations (CFR) and the Federal Register (FR) are for sale on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DoDISS specified in the solicitation. The issues of documents which have not been adopted shall be those in effect on the date of the cited DoDISS.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

C 633 - Standard Test Method for Adhesion or Cohesive Strength of Flame-Sprayed Coatings. (DoD adopted)
D 4285 - Standard Test Method for Indicating Oil or Water in Compressed Air.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

400 grit paper | | 104 | Sand lightly with number

AMERICAN WELDING SOCIETY (AWS)
OPP - Thermal Spraying - Practice, Theory and Application.
A3.0 - Standard Welding Terms and Definitions Including Terms for Brazing, Soldering, Thermal Spraying and Thermal Cutting

(Application for copies should be addressed to the American Welding Society, Inc., 550 NW LeJeune Road, P.O. Box 351040, Miami, FL 33135.)

STEEL STRUCTURES PAINTING COUNCIL (SSPC)
SP 5 - White Metal Blast Cleaning.

(Application for copies should be addressed to the Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, PA 15213.)

(Nongovernment standards are generally available for reference from libraries. They are also distributed among nongovernment standards bodies and using Federal agencies.)

2.3 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence.

3. DEFINITIONS

3.1 Definitions used in the preparation of drawings, spraying procedures, specifications, and correspondence related to the thermal spraying shall conform to AWS A3.0 and OPP.

3.2 The following definitions are applicable to this standard:

(a) Blasting. A method of cleaning or surface roughening by a forcibly projected stream of sharp angular abrasive.
(b) Bond coat. A preliminary (or prime) coat of material which improves adherence of the subsequent thermal spray deposit.
(c) Coating system. One or more thermal spray coatings that are qualified for use singly or in combination. An example of a one-coating system is a stainless steel coating applied for restoration of dimensions. An example of a two-coating system is a nickel-base bond coat and ceramic finish coat for a steam seal.
(d) Composite powder. Powder particles that are formed by physically combining two or more materials in intimate contact, so that the end particles function as a unit.
(e) Electric arc spraying. A thermal spraying process wherein the heat source is an electric arc struck between two consumable electrodes of a coating material, and compressed gas (usually air) is used to atomize and propel the material to the work piece.
(f) Flame spraying. A thermal spraying process wherein an oxy-fuel gas flame is utilized as the source of heat for melting the coating materials in powder, wire, rod, or cored form. Compressed gas may or may not be used for atomizing and propelling the material to the work piece.

(g) Fused spray deposit. A self-fluxing spray deposit which is subsequently heated to coalescence within itself and with the substrate.
(h) Gradated coating. A thermal sprayed deposit composed of mixed materials in successive layers which progressively change in composition from the constituent material of the substrate to the surface of the sprayed deposit.
(i) Hard facing. A process of depositing a coating onto a surface for the purpose of resisting abrasion, erosion, wear, galling or impact. Various coatings may be used either in the as-sprayed condition or machined or ground to dimensions.
(j) Interface. The contact surface between the spray deposit and the substrate or two different types of sprayed materials.
(k) Masking. The method of protecting areas adjacent to the surface to be thermally sprayed or blasted to prevent adherence of a coating or surface roughening.
(l) Plasma spraying. A thermal spraying process wherein a non-transferred constricted electric arc-gas mixture (called a plasma) is utilized as the source of heat for melting and propelling the coating material to the work piece.
(m) Powder flame spraying. A method of flame spraying wherein the material to be sprayed is in powder form.
(n) Seal coat. Material applied in liquid form, to infiltrate the pores of a thermal spray deposit.
(o) Spalling. The flaking or separation of a sprayed coating.
(p) Substrate. Any material upon which a thermal sprayed coating is deposited.
(q) Thermal spraying. A group of processes wherein finely divided metallic or nonmetallic materials are deposited in a molten or semi-molten condition to form a coating. The coating may initially be in the form of powder, ceramic rod, or wire.
(r) Wire flame spraying. A method of flame spraying wherein the metallic material to be sprayed is in wire form.

4. GENERAL REQUIREMENTS

4.1 Quality assurance system. A written quality assurance system shall be implemented and maintained which assures that the requirements of this standard and the functions of the thermal sprayed coatings are met (see 6.3).

4.1.1 Management. Effective management for quality of thermal spray of machinery components shall be clearly prescribed by written procedures. Written procedures shall be prepared which assign responsibility and provide accountability for performing work and inspection. Personnel performing quality functions shall have sufficient, well-defined responsibility, authority and the organizational freedom to identify and evaluate problems and to initiate, recommend, or provide solutions. Management shall review the status and adequacy of the quality program through semi-annual documented audits.

4.1.2 Inspection system. The performing activity shall maintain an inspection system adequate to assure NAVSEA or authorized agent that all of the requirements of this standard have been met. Written procedures shall be prepared to assign responsibility and provide accountability for performing work and inspection. Personnel performing acceptance inspections shall be trained and qualified for the work they are to perform. Records of such training shall be maintained.

4.1.3 Records. Unless otherwise specified herein, written records shall be prepared and maintained for each sprayed component (see 4.1.4). The records shall include at least the following information:

(a) Identification of spraying activity.
(b) Specific identification of component and system (such as, no. 1 fire pump main).
(c) Component drawing or part number.
(d) Component material (Military, ASTM, or other specification).
(e) Ship identification.
(f) Job order or work number.
(g) Cleaning method and method of base metal preparation (abrasive blasting, threading).
(h) Sketch showing area to be sprayed, undercut depth and length, shoulders, masking locations.
(i) Reason for spraying.
(j) Spray procedure identification (and revision).
(k) Bond and finish coat material - generic type and manufacturer's identification.
(l) As-sprayed coating thickness (bond and finish).
(m) Final coating thickness.
(n) Method of surface finishing (grinding, machining).
(o) If ground, state grinding wheel and surface finish.
(p) Sealant material and sequence of application.
(q) Date sprayed.
(r) Sprayer's identification.
(s) Inspection procedure and results.
(t) Inspection personnel identification.
(u) Cognizant NAVSEA equipment manager.
(v) NAVSEA Materials and Assurance Engineering Office approval date.
(w) Date installed.
(x) Installation and alignment personnel.
(y) Installed ship compartment location.

4.1.4 Record form. A record form shall be prepared prior to commencement of the operation which it covers. Operations shall be recorded prior to the commencement of the next operation. Each item on the record form shall be signed and dated by the operator, except for those checkpoints designated for verification by the inspectors. When a specific item on the record form is not applicable, the letters "N.A." (Not applicable) shall be entered. Prior to acceptance, all items on the record forms shall be marked as specified (see 4.1.3).

4.1.5 Maintenance of records. Unless otherwise specified, the sprayed component record form shall be maintained by the performing activity and shall be available to NAVSEA upon request. Disposition of records shall be as agreed upon by the NAVSEA agent or the contractor. The performing activity shall maintain records to be made available to NAVSEA or its authorized agent.

4.1.6 Noncompliance. In the event of noncompliance with the requirements of this standard, the applicable work covered by this standard shall be suspended until the performing activity has demonstrated that work deficiencies have been corrected.

4.2 Qualification and certification requirements.

4.2.1 Facility certification requirements. Performing activities shall have thermal spray facilities that meet the requirements for working areas (see 5.2.1 through 5.2.5).

4.2.1.1 Naval shipyards. Prior to production implementation, Naval shipyards shall submit a request to NAVSEA Materials and Assurance Engineering Office for certification of their thermal spray facility. The request shall contain written evidence that the facility meets the requirements of this standard.

4.2.1.2 Other Government and commerical activities. Prior to contract award, activities shall submit a request to the Supervisor of Shipbuilding for certification of their thermal spray facility. The request shall contain written evidence that the facility meets requirements of this standard.

4.2.2 Quality control program approval. Performing activities shall have a quality control program that addresses requirements for management (see 4.1.1, 4.1.2, 4.1.4, 4.1.5, 4.3, 4.4, 5.3, and 6.3). In addition, each activity shall have a written audit plan and audit the thermal spray operation on a periodic basis.

4.2.2.1 Naval shipyards. Prior to production work, Naval shipyards shall submit a request to NAVSEA Materials and Assurance Engineering Office for certification of their quality control program for thermal spray.

4.2.2.2 Other Government and commercial activities. Prior to contract award, activities shall submit a request to the Supervisor of Shipbuilding for certification of their quality control program for thermal spray (see 6.3).

4.2.3 Thermal spray procedure approval. Thermal spray procedures shall meet the requirements specified in 4.3.

4.2.3.1 Naval shipyards. Thermal spray procedures shall be approved by NAVSEA.

4.2.3.2 Ships Intermediate Maintenance Activities (SIMA) and Afloat IMAs. Thermal spray procedures shall be approved by NAVSEA.

4.2.3.3 Other Government and commercial activities. Thermal spray procedures shall be approved by NAVSEA.

4.3 Spraying procedure qualification. Spraying procedure qualification shall include preparation of spraying procedure and procedure qualification test data (see 4.3.1.1).

4.3.1 Spraying procedures. Performing activities shall prepare written spraying procedures and perform tests (see 4.3.3) as required to qualify these procedures. The procedures shall include at least the items listed on figures 1 through 4, and a listing of the sequence in which the various processes (such as blasting, inspections, and degreasing) are performed. An approved spray procedure may be used by a facility other than the developing facility. Each spray operator who will be using a previously qualified procedure shall be qualified on that procedure in accordance with 4.4.3.

4.3.1.1 Submittal for approval. Prior to the utilization of the spraying procedure, the performing activity shall submit and obtain approval of the test qualification data from NAVSEA (see 6.3). Procedures shall be submitted with the supporting test qualification data. Data submitted shall not relieve the performing activity of responsibility for conformance with other requirements of this standard. Contractors shall be responsible for similar qualification of all sub-contractors.

4.3.2 Procedure qualification testing. Procedure qualification testing shall consist of a visual examination, microscopic examination, bend test and bond tests of sprayed specimens prepared by an operator using the proposed procedure. For the visual and bend examination, two specimens shall be sprayed in accordance with 4.6.1.2 and examined and tested in accordance with 4.6.2 and 4.6.4. Results of the tests shall conform to the requirements of 4.3.3.1 and 4.3.3.3. For the microscopic examination, two specimens shall be prepared in accordance with 4.6.1.1, and examined in accordance with 4.6.3. Results of the examination shall conform to the requirements of 4.3.3.2. For the bond test, five specimens shall be prepared and tested in accordance with 4.6.1.3 and 4.6.5, and shall meet the requirements of 4.3.3.4.

4.3.3 Qualification test requirements.

4.3.3.1 Visual examination requirement. The as sprayed coating shall have a uniform appearance and shall be free of the following:

(a) Blisters.
(b) Cracks.
(c) Chips or loosely adhering particles.
(d) Evidence of oil or other contaminants.
(e) Pits exposing the undercoat or substrate.
(f) Coating separation.
(g) Spatter, or unmelted particles.

4.3.3.2 Microscopic examination. The constituents of the coating shall be uniformly distributed and there shall be no separations between the coating and substrate. The porosity and oxide content shall not exceed the limits specified in table I (see 4.3.3.5). Bondline contamination (such as, abrasive blasting grit, disbonds, and oxidation at the substrate and coating interface) shall be less than 10 percent. Unreacted globular particles shall be less than 10 percent of the coating cross-sectional area with the average diameter of the particles not exceeding 0.002 inch.

TABLE I. Thermal spray coating properties.

Spray category	Spray material	Process[1/]	Substrate[2/]	Minimum average bond strength (lb/in^2)[3/]	Minimum single specimen bond strength (lb/in^2)[4/]	Maximum coating thickness (mils)[5/]	Maximum porosity (percent)[6/]	Maximum oxide (percent)[6/]
1.0	Carbon steel							
1.1	- wire	AW	C	4500	3500	50	8	20
2.0	Austenitic stainless (with bond coat)							
2.1	- wire	FW	C	4000	3000	50	6	20
3.0	420 stainless							
3.1	- powder	PP	C	4500	3500	75	6	20
3.2	- wire	AW	C	4000	3000	50	8	20
3.3	- wire	FW	C	3500	2500	50	6	20
4.0	Nickel-aluminum							
4.1	- powder	FP, PP	C, N	4500	3500	50	6	20
5.0	Aluminum-bronze							
5.1	- powder	FP, PP	B	4000	3000	125	6	20
5.2	- wire	FW	B	4500	3500	125	6	20
6.0	Nickel-copper							
6.1	- powder	FP, PP	N	4500	3500	40	6	20
6.2	- wire	AW	N	4000	3000	40	8	20

See footnotes at end of table.

TABLE I. Thermal spray coating properties. - Continued

Spray category	Spray material	Process 1/	Substrate 2/	Minimum average bond strength (lb/in^2) 3/	Minimum single specimen bond strength (lb/in^2) 4/	Maximum coating thickness (mils) 5/	Maximum porosity (percent) 6/	Maximum oxide (percent) 6/
7.0	Copper-nickel							
7.1	- powder	FP, PP	Cu	3000	2000	40	6	20
7.2	- wire	AW	Cu	3000	2000	40	8	20
8.0	Alumina-titania							
8.1	- ceramic powder	FP, PP	C,N,B,Cu	7/ 3500	7/ 2500	15	4	--
9.0	Babbitt							
9.1	- wire (with bond coat)	AW	C	8/ 2250	8/ 1700	no limit	8	20

1/ Spray processes are arc-wire (AW), flame-wire (FW), plasma-powder (PP), and flame-powder (FP) applied as single or dual coating systems. Dual coating systems are identified by the bond coat system and finish coat system.
2/ Substrates are: C = carbon, low alloy and stainless steel, cast iron, B = bronze, N = nickel base, Cu = copper base (other than bronze).
3/ Average of five specimens (see 4.3.3.4 and 4.4.5.4).
4/ See 4.3.3.4 and 4.4.5.4.
5/ The maximum coating thickness that can be applied successfully depends on the specific component dimensions, the specific chemistry of the spray material and other factors.
6/ Requirements apply to both the top and finish coats. Oxide requirements do not apply to ceramic powders.
7/ When applied over a bond coat.
8/ Tensile bond strength when tested in accordance with 4.6.1.3 and 4.6.5.

4.3.3.3 Bend test. No flaking, delamination or gross cracking of the coating shall occur due to bending (see 4.6.4). Small hairline cracks or alligatoring of the coating in the vicinity of the bend are permissible. Ceramic coatings may exhibit flaking associated only with the edges of the bend specimen.

4.3.3.4 Bond test. The average and minimum single specimen bond strengths of the five tested specimens shall meet or exceed the applicable bond strengths specified in table I (see 4.3.3.5).

4.3.3.5 Non-established requirements. When limits for comparison are not specified in table I, the test data shall be submitted to NAVSEA for approval (see 6.3).

4.3.4 Extent of use of qualified spraying procedure.

4.3.4.1 Substrate material. A qualified procedure for a coating or coating system may be used on any substrate which is in the same general composition group (see 4.3.4.1.1) as the substrate used in the qualification tests. Changes in the abrasive blasting parameters may be needed to achieve the required surface roughness profile for substrates with a hardness value greater than 10 Rockwell C points higher than that of the substrate used in the qualification tests. For each sprayed component there shall be verification that the anchor tooth profile meets the requirements of 5.4.4 (see 4.5.1).

4.3.4.1.1 Materials shall be grouped as follows: carbon, low alloy, stainless steels, and cast iron; nickel base alloys; copper base alloys; aluminum base alloys; tin base alloys; and titanium alloys.

4.3.4.2 Spray procedure. The using activity shall verify by demonstration that the procedure meets the requirements of this standard. Test parameters and results shall be documented.

4.3.4.3 Essential elements. A change in any of the essential elements listed below requires requalification of the procedure. However, minor changes in parameters are allowed, provided the test results of the original procedure or table I are met or exceeded.

(a) Material type.
(b) Grit type and size.
(c) Gun type and model (for plasma and oxy-fuel powder).
(d) Nozzle type and size.
(e) Primary gas type, pressure, and flow rate (for plasma).
(f) Secondary gas type and pressure (for plasma).
(g) Powder port (for plasma).
(h) Operating voltage (for plasma).
(i) Linear surface speed (feet per minute same as revolutions per minute (r/min) times circumference times traverse speed).
(j) Deposition rate (pounds per hour).
(k) Coating thickness per pass.
(l) Change of fuel gas type (for oxy-fuel powder and oxy-fuel wire).

4.4 Personnel training, qualification, and certification.

4.4.1 General. This section provides the requirements for training, qualification, and certification of spray operators. A spray operator shall be qualified by demonstrating, as specified herein, the ability to apply the specified coating system, using the applicable approved thermal spray process.

4.4.2 Training for operators and inspectors.

4.4.2.1 General. The following minimum training and written tests are required for qualification and certification. Activities shall maintain records of their training program and written tests.

4.4.2.2 Operators. Spray operators shall receive classroom and hands-on training on:

(a) Basic safety, equipment and tool handling.
(b) The general theory and applicability of thermal sprayed coating systems; surface preparation; the flame, electric arc and plasma spray coating processes and maintenance and repair of equipment; sealants; finishing; quality control; diagnosis of good and degraded coatings.
(c) Specific training on the thermal spray equipment and coating processes for which operators are being qualified. The minimum training time for the various processes shall be:

Coating process	Training time (hours)		
	Basic	Classroom	On-the-job
Flame	20	---	40
Electric arc	20	---	20
Plasma	20	20	80

4.4.2.3 Operator written test. The operator shall satisfactorily complete a written test covering the critical aspects of the theory, applications criteria, this standard, and aspects of the coating processes and equipment operation for which he is being qualified. The written test shall be approved by NAVSEA.

4.4.2.4 Vision test requirements. Each spray operator and inspector shall pass an annual vision test. Vision tests shall be conducted using standard test methods for determining visual acuity. The standard of acceptance for vision tests shall be natural or corrected near distance acuity such that the individual is capable of reading JI letters on the standard Jaegar type chart for near vision. Other equivalent visual tests may be substituted for the Jaegar chart.

4.4.2.5 Inspector training. Inspectors shall be given at least 6 hours of classroom instruction on the general theory, application and coating processes, quality assurance, and requirements of this standard with emphasis on the inspection information and action. The training shall include hands-on training with the inspection tools (such as, 10X magnifier, coating thickness gauge, profile tape) on good and bad coatings on representative parts.

4.4.2.6 Inspector written test. The inspector shall satisfactorily complete a written test covering the training material. The written test shall include, at a minimum, questions on the essential elements specified in 4.4.2.2, and shall be approved by NAVSEA.

4.4.3 Operator qualification testing. The operator shall prepare test specimens in accordance with 4.6.1 for visual, microscopic, bend and bond tests. Two specimens shall be prepared for the visual, microscopic and bend examinations (the same panels may be used for these examinations), and five specimens for the bond test. The specimens shall be examined and tested in accordance with 4.6.2 through 4.6.5, and meet the requirements of 4.4.5.1 through 4.4.5.4. The operator shall use a qualified procedure developed for the particular coating and thermal spray process. The operator shall set up the spraying equipment according to the parameters required by the spraying procedure. The substrate test specimens shall be the substrate used in the qualification of the procedure in accordance with 4.3.4.1.

4.4.4 Alternative qualification methods. The operator may also be qualified on a new procedure by demonstrating satisfactory performance in accordance with 4.3.2.

4.4.5 Qualification test examinations.

4.4.5.1 Visual examination. The results of the visual examination shall meet the requirements of 4.3.3.1.

4.4.5.2 Microscopic examination. The results of the microscopic examination shall meet the requirements of table II.

4.4.5.3 Bend test examination. Results of bend tests shall meet the requirements of 4.3.3.3.

4.4.5.4 Bond test examination. The average and minimum single specimen bond strengths of the five tested specimens shall meet or exceed the applicable bond strengths specified in table I, or the minimum average and single specimen bond strengths approved for procedure qualification.

4.4.5.5 Limits of certification. Operators meeting the requirements for the performance tests shall be certified to perform spraying with the coating system and spray process used in qualification testing.

4.4.5.6 Maintenance of certification. Certification shall be maintained in accordance with 4.4.5.6.1 through 4.4.5.6.3.

4.4.5.6.1 Certification of the operator shall be retained unless a period of 6 months has elapsed since the last production use of the thermal spray process by that operator.

4.4.5.6.2 Operators whose certification has lapsed may be requalified by satisfactorily completing the qualification tests of 4.4.3.

4.4.5.6.3 Qualification testing may also be required at any time an operator's performance is questionable as evidenced by documented rejected data or as requested by NAVSEA or its delegated representative.

4.4.6 Records for operator qualification. Records of qualification and requalification test data results and annual eye examination results shall be maintained by the thermal spray shop or activity, and shall be subject to review and audit by NAVSEA or authorized agent.

4.5 Quality control.

4.5.1 In-process inspection. In-process inspection of each sprayed component shall assure, as a minimum, verification of the anchor-tooth prepared surface with a profile tape test; no moisture, oil, grit, contaminants, blisters, cracks, chips, pits, or coating separation are present before or during spraying; coating thickness per pass conforms to the procedure, if this is an essential element; and the coating manufacturer's recommended temperature range is maintained.

4.5.2 End item requirement. Inspection and testing of end item shall be as specified in the contract.

4.5.2.1 Inspection. As a minimum, the end item inspection of sprayed coatings shall include a visual examination. The finished coating, when examined with a 10X magnification, shall be free of defects such as cracks, blisters, chips or loosely-adhering particles, oil or other contaminants which bleed out through the coating, pits exposing the undercoat or substrate, and coating separation. The item shall be checked for correct dimensions.

4.5.3 Test specimens for quality control. Prior to commencement of each day's production, a bend test specimen shall be prepared in accordance with 4.6.1.2 and tested in accordance with 4.6.4; the specimen shall meet the requirements of 4.3.3.1. In the event of failure, the cause shall be identified and the problem corrected, and another specimen shall be sprayed and tested as above. The spray procedure should be changed as needed to prevent future failure. When specified by the contract, quality control of items used in critical applications shall include testing of specimens which are prepared during the production run and are representative of the production part whenever possible. The quality control testing, the sampling plan (for spraying of multiple items) and the requirements for the specimens shall be as specified in the contract.

4.6 Test procedures.

4.6.1 Preparation of test specimens.

4.6.1.1 Specimens for microscopic examination. Panels approximately 3 by 2 inches by 0.050 inch (minimum) shall be sprayed on one of the large faces using the appropriate spraying procedure and metal substrate. The coating thickness shall be 0.008 inch (minimum).

4.6.1.2 Specimens for visual and bend tests. Panels approximately 3 by 2 inches by 0.050 inch (minimum) to 0.063 inch (maximum) shall be sprayed on one of the large faces using the appropriate spraying procedure and metal substrate. The coating thickness shall be 0.008 ± 0.002 inch, or the maximum thickness recommended by the coating manufacturer, whichever is smaller. Two-coat samples shall have 0.002 to 0.003 inch bond coat and at least 0.005 inch top coat.

4.6.1.3 Specimens for bond test. Specimens shall be machined and tested in accordance with ASTM C 633.

4.6.2 Visual examination. Each of the as-sprayed specimens shall be examined at 20 to 50X magnification.

4.6.3 Microscopic examination. For microscopic examination, a section 0.75 to 1.00 inch long by 0.25 to 0.50 inch wide shall be cut from each of the prepared panels. The section shall be mounted on the longer side of the cross-section and then prepared metallographically. Cross-sections shall be examined at 100 to 200X magnification for the final examination. The oxide and porosity contents shall be determined by the use of line-intercept, grid-area, or optical comparison techniques, or by using comparison photographs, as shown on figure 5.

4.6.4 Bend test. The sprayed panels shall be bent approximately 180 degrees on a 1/2-inch diameter rod. The coating shall be on the tensile side of the bend. The bend specimen shall be examined visually without the aid of magnification.

4.6.5 Bond test.

4.6.5.1 Spraying. Spraying shall be performed using the appropriate procedure and substrate. Areas not to be sprayed shall be masked on the outer diameter to prevent overspraying. The as-sprayed thickness shall be greater than 0.015 inch.

4.6.5.2 Application. The coating shall be applied as evenly and uniformly as possible to maintain the squareness of the machined test specimen. If the squareness of the machined specimen cannot be maintained during the coating, grinding is permissible to restore the squareness, provided the coating thickness is not reduced below the minimum thickness stipulated by the manufacturer. After grinding, the specimen may be cleaned by vapor degreasing or solvent washing.

5. DETAILED REQUIREMENTS

5.1 Equipment.

5.1.1 Spraying systems.

5.1.1.1 Wire oxygen-fuel gas spray. Equipment for the wire spray system shall meet the requirements in accordance with MIL-M-3800. The atomizing air shall meet the requirements of 5.1.2.1.

5.1.1.2 Powder oxygen-fuel gas spray. The powder spray system shall include the powder spray gun, necessary hoses, flowmeter, fuel gas and oxygen regulators, and mechanical or aspirator feed for powder. Equipment shall meet the requirements specified in MIL-M-80141.

5.1.1.3 Arc spray. The electric arc system shall consist of an electric arc gun, flowmeter, compressed air, power supply unit and wire control unit. Equipment shall meet the requirements specified in MIL-M-80226. Conversion units to adapt existing suitable power sources for electric arc spraying are also acceptable as long as performance is in accordance with MIL-M-80226. The atomizing air shall meet the requirements of 5.1.2.1.

5.1.1.4 Plasma spray. The plasma arc spray system shall include a plasma spray gun, power unit, control console and feed hopper. Equipment shall meet the requirements specified in MIL-P-80109.

5.1.1.5 Thermal spray systems. Equipment not covered by the Military Specifications specified in 5.1.1.1 through 5.1.1.4 shall be qualified by the performing activity.

5.1.2 Abrasive blasting equipment. Abrasive blasting equipment is necessary to roughen areas which are to be thermal sprayed. Abrasive blast equipment shall meet the requirements of 5.2.2 and shall be free of oil and other contaminants.

5.1.2.1 Air equipment. The air equipment used for the abrasive blast, wire-oxygen-fuel gas spray and arc spray processes shall utilize air having a maximum of 5 milligrams condensed hydrocarbons per cubic meter and a dew point of plus 14°F or lower at standard temperature and pressure (68°F, 14.5 lb/in^2 absolute) prior to the final filtering and moisture separation unit. Standards which apply are ASTM D 4285 and BB-A-1034. For abrasive blasting, minimum air pressure at the blast generator of 50 lb/in^2 and 75 lb/in^2 is required for pressure type and suction type blasting units, respectively.

5.1.3 Fixturing for mechanical positioning. Fixtures for mechanical positioning shall be used whenever possible to support the work piece and thermal spray gun in order to maintain a constant, controllable and repeatable gun-to-work distance and angle. Relative movement between work piece and gun shall be accurately controlled and the proper surface feet per minute maintained, as specified in the approved procedure.

5.2 Facilities.

5.2.1 Working areas. The following minimum requirements shall be met for thermal spray working areas.

5.2.1.1 Abrasive blasting areas. If abrasive blasting is carried out in an enclosed area other than a designated blasting booth, the air in the enclosed areas shall change at least once per minute. Additional safe breathing apparatus (operator's hood) shall be used.

5.2.1.2 Thermal spraying areas.

5.2.1.2.1 Enclosed areas. Enclosed areas shall be equipped with positive exhaust and wet dust collector systems which provide adequate air flow in accordance with AWS OPP and CFR 29, part 1910.107. An air respirator mask and eye and ear protection shall be provided for the operator.

5.2.1.2.2 Open areas. Thermal spraying in open areas shall be carried out only when the components to be sprayed are adequately protected and the dust and noise do not interfere with adjacent operations.

5.2.2 Abrasive blasting equipment. The following list of equipment identifies the minimum required for performing abrasive blasting operations. Equipment shall be in satisfactory working order. Gauges shall be properly calibrated.

(a) Blaster utilizing air free of oil and moisture according to 5.1.2.1.
(b) Steel blasting table or cabinet.
(c) Oil and moisture separator.
(d) Air pressure regulators with pressure gauges.
(e) Profile tape.
(f) Blast nozzle equipped with a dead-man switch.
(g) Abrasive (see 5.3.3).
(h) Sample metal coupons.
(i) Caliper or dial micrometer.

5.2.3 Thermal spray equipment. The list of equipment for thermal spray operations shall meet the requirements of 5.1.1 for the applicable spraying system. Equipment shall be in satisfactory working order. Gauges and flow meters shall be properly calibrated, and all gas and air connections shall be soap tested for leaks every 3 months. In-line water and oil filters shall be located between the compressor and the metal spray equipment. These filters shall be periodically inspected and serviced to assure delivery of uncontaminated dry air. When greater control is required, automatic dew point measuring instruments with feedback to control the quality of air shall be installed. Optional equipment may be required as specified in the contract for special application in accordance with MIL-M-3800.

5.2.4 Protective equipment. The following protective equipment shall be worn by thermal spray operators.

(a) Air respirator.
(b) Noise protection (ear muffs and plugs).
(c) Eye protection.
(d) Protective clothing.

5.2.5 Fixturing for mechanical positioning. Fixturing for mechanical positioning shall be as specified in 5.1.3.

5.3 Materials.

5.3.1 Coating materials.

5.3.1.1 Coating type. The coating material shall be as specified in the contract or by engineering personnel of the performing activity.

5.3.1.2 Thermal spray wire and powder. Wire and powder used for thermal spraying shall be in accordance with MIL-W-6712 or MIL-P-83348, respectively. Materials not included in MIL-W-6712 or MIL-P-83348 may be used, providing a qualified spray procedure has been established for the material (see 4.3). Wire and powder shall be the same as specified in the procedure to be used.

5.3.1.3 Storage, identification, and separation of wire and powder. Stored wire and powder shall be protected from environments that can harm the quality of sprayed coatings. Powder suspected of being contaminated by foreign matter shall not be used. Storage recommendations of the coating manufacturer shall be followed. Powders shall be shaken prior to use to break up any segregation or agglomeration that may have occurred during storage. The contents of powder containers and wire reels shall be identified.

5.3.2 Thermal spray gases.

5.3.2.1 For flame spraying. The gases listed below are recommended for flame spraying. Other gases may be used for a spray procedure if that spray procedure has been qualified for that gas.

Gas	Specification	Type
Oxygen	BB-O-925	Commercial
Acetylene	BB-A-106	Commercial

5.3.2.2 For plasma spraying. Gases for the plasma spray process shall be as follows:

Gas	Specification
Hydrogen	BB-H-886 Pre-purified 99.95 percent Maximum oxygen content 0.05 percent
Nitrogen	Pre-purified Maximum oxygen content 0.002 percent
Argon	MIL-A-18455 High purity Maximum dewpoint minus 76°F
Helium	BB-H-1168, grade A

5.3.3 Abrasive blasting particles. Abrasive blasting particles used for surface preparation shall be aluminum oxide grit to provide the anchor tooth pattern for thermal spray application. Chilled angular iron grit may be used only on carbon and low alloy steels and aluminum substrates. The aluminum oxide particles shall have a 16 to 30 mesh size. The chilled iron grit shall have a 25 to 40 mesh size.

5.3.3.1 Requirements. Abrasive particles shall be clean, dry, sharp, and free of excessive fines. Excessive fines are defined as greater than 25 percent fines.

5.3.3.2 Restrictions. Abrasive particles shall not contain any feldspar or other mineral constituents that tend to break down and remain on the surface. Abrasive particles that may have been used for cleaning heavily contaminated surfaces shall not be used for final surface preparation, even though the abrasive has been rescreened. Grit that is noticeably worn or dull when compared with new grit under a magnification of 10X shall not be used.

5.3.4 Masking materials.

5.3.4.1 For abrasive blasting. Any masking material which provides adequate protection of the substrate and does not cause corrosion or contamination of the spray coating or substrate may be used. Following abrasive blasting, any masking material which is unsuitable as a masking material for the thermal spray process shall be removed.

5.3.4.2 For thermal spraying. Tapes, liquid masking compounds, silicone rubber or metal shielding may be used as thermal spraying masking materials. Tapes used for spray masking shall be designed for high temperature use. Materials shall not cause corrosion or contamination of the sprayed coatings.

5.3.4.3 Irregular shapes. For instances when holes, slots, keyways or other types of recesses cannot be protected by tapes or shields, inserts of carbon or metal may be used. These inserts are left in place during abrasive blasting and spraying, and may be removed upon completion of surface finishing.

5.3.5 Sealants. The sealant, if required, shall be specified for each specific application.

5.4 Process.

5.4.1 Surface condition. Areas to be thermal sprayed, and adjacent areas, shall be free from grease, oil, paint, corrosion products, moisture, or any other substance which may contaminate the coating.

5.4.1.1 Solvent cleaning. Prior to any blasting or spraying, all surfaces which have come in contact with any oil or grease shall be solvent cleaned. Vapor degreasing is preferred; however, solvent washing may be used. Solvents shall not cause any detrimental attacks of the substrate material or leave any residue film on the substrate. Trichloroethane in accordance with O-T-620, or toluene in accordance with TT-T-548 are acceptable cleaners. Due to the flammable and toxic nature of most solvents, proper precautions, such as adequate ventilation shall be followed during solvent cleaning (see 5.4.8 for safety precautions). Precautions shall also be exercised to protect any parts which may be attacked by the solvents. Any anchor tooth surface that has come in contact with oil or grease shall be solvent cleaned or vapor degreased and then reblasted for new anchor tooth.

5.4.1.2 Heat cleaning. Porous materials which have been contaminated with grease or oil shall be solvent cleaned and then heated for 4 hours to char and drive out the foreign materials from the pores. Steel castings shall be heated at 650°F maximum. For heat-treatable nonferrous alloys, engineering personnel of the performing activity shall be contacted for baking temperature range.

5.4.2 Machining for surface preparation.

5.4.2.1 Undercutting. The substrate shall be undercut when necessary, as listed below. The undercut shall be limited to a depth that will not reduce the component strength (see 5.5.1.1).

(a) Allow for a uniform finish coating thickness.
(b) Remove existing sprayed or plated coatings.
(c) Remove damaged or contaminated base metal.

5.4.2.2 Threading or grooving of cylindrical surfaces. For heavy buildup, the substrate may be threaded or grooved to counteract shrinkage stresses in the coating. The substrate should be undercut before threading. A small radius shall be machined at the root of each thread, or U-shaped grooves shall be used. The substrate shall be abrasive blasted after threading.

5.4.2.3 Shoulders. At each of the undercut sections on a cylindrical part, the shoulders shall be cut at an angle of 15 to 45 degrees. Dovetails shall not be used. A radius of 0.015 to 0.020 inch should be cut at the corner of the undercut.

5.4.2.3.1 The undercut should not extend to the end of the shaft. A weld bead may be deposited at the end of the shaft to provide a shoulder, if no mechanical or metallurgical damage to the substrate is caused.

5.4.3 Masking. Masking shall be performed on all adjacent areas which may be exposed or affected by the blasting or thermal spraying process.

5.4.4 Abrasive blasting for surface preparation. Prior to thermal spraying, the surfaces to be coated shall be prepared by abrasive blasting to a clean metal surface and a 2 to 3 mils anchor-tooth surface profile. When distortion may be encountered due to the part configuration, the anchor-tooth pattern may be reduced to a 1 mil profile, minimum, provided the other tests (such as bend and bond tests) meet requirements.

5.4.4.1 Prior to reuse, the aluminum oxide shall be screened using a 30-mesh screen, visually inspected for debris and oil contamination, and shall pass the following oil-contamination test:

(a) Fill a clean 150-milliliter (mL) (5-ounce) vial or bottle half full of screened abrasive particles.
(b) Fill the remainder of the vial or bottle with clean water.
(c) Cap and shake vial or bottle.
(d) Inspect water for oil sheen.
(e) If any oil is observed, the abrasive particles shall not be used in the final anchor-tooth blasting process.
(f) Clean blasting equipment, replace blasting material, and retest.

5.4.4.2 The blasted surface shall have a white metal blast appearance with an anchor-tooth (not peened) surface profile as specified in 5.4.4 and validated (measured) with profile tape and a dial micrometer. Blasting shall be done in accordance with SSPC 5. A white metal blast cleaned surface finish is defined as a steel surface with a gray-white, uniform metallic color, slightly roughened to form a suitable anchor pattern for coatings. The surface shall be free of oil, grease, dirt, mill scale, rust, corrosion products, oxides, paint, or any other foreign matter. The color of the clean surface may be affected by the particular abrasive medium used. Photographic or other visual standards of surface preparation shall be used to further define the surface if specified in the contract or order. Abrasive blasted surfaces shall not be allowed to come in contact with contaminated surfaces prior to completion of metal spray and sealing processes. Prepared surfaces shall be handled only with clean gloves, rags, or slings. Contact with any oil or grease (such as touching with a bare hand) may result in failure of the coating. The slightest presence of oil, oxidation or other foreign material on the surface to be sprayed may result in separation of the thermal spray coating. The blasted surface is rejectable if the white metal blast condition is lost.

5.4.5 Spraying.

5.4.5.1 The spraying operation shall be started within 2 hours after preparation of the surface has been completed. If more than 15 minutes, but not over 2 hours, is expected to elapse between the preparation of the surface and the spraying operation, or where the part shall be removed to another location, the prepared surface shall be protected from oxidation and contamination and from handling and fingermarks. Wrapping with clean paper (free of newsprint) will usually provide adequate protection. If more than 2 hours elapse between surface preparation and spraying, or if oxidation or contamination from any other source occurs, then the surface shall be cleaned and re-anchor-tooth blasted.

5.4.5.2 Components shall not be sprayed if the substrate temperature is below 60°F, or if the substrate temperature is less than 10°F above the dew point of the ambient air. Wherever possible (or practical) the work shall be preheated to 200 to 225°F to eliminate surface moisture. Higher preheats (350°F) may be required on a case basis for specific substrates or coatings which may develop defects due to thickness of coating, thermal gradients, or differences in coefficients of expansion. Temperature readings shall be taken using a contact pyrometer; temperature sticks or similar devices shall not be used as detrimental material contamination will result. If preheating is done with a gas flame, the flames shall not be directly applied onto the area to be sprayed to avoid possible surface oxidation and contamination by carbon deposits. Gas flame preheating is acceptable if test specimens that are preheated with a gas flame pass their respective test criteria.

5.4.5.3 The spraying operation shall be interrupted only to measure thickness or temperature, to change spraying material from bond or undercoat to finish coat, or to permit cooling to prevent overheating. During spraying, the temperature of the work shall not exceed 350°F or the tempering or aging temperature of the substrate, whichever is lower. Cooling may be accomplished by use of blast of clean, dry air, carbon dioxide or other suitable gas introduced near, but not directly upon, the area being sprayed.

5.4.5.4 The direction of the thermal spray shall be as close as possible to an angle of 90 degrees with the surface being coated and not less than 45 degrees.

5.4.5.5 The work shall be allowed to cool normally to room temperature after spraying is completed. If it is necessary to cool the work more quickly, a blast of air, carbon dioxide or other suitable gas may be directed onto the work. The blast shall be maneuvered to obtain a uniform cooling rate over the entire section. There shall not be any quenching with liquid.

5.4.6 Application of sealant. Thermal sprayed coatings shall be sealed after spraying and again after finishing to minimize corrosion of the substrate. The particular sealant selected will depend on the maximum use temperature of the component and the purpose of sealing the coatings. Some applications may not require that a sealant be used, but elimination of the sealant requires NAVSEA approval.

5.4.7 Surface finishing. Surface finishing shall be used to obtain the specified dimensions and to provide a finer surface finish than the as-sprayed condition. Coatings may be used in the as-sprayed condition whenever permitted. The selection or finishing method depends on the type, hardness, and thickness of the coating. The preferred method is grinding; wet grinding is recommended. Soft materials, such as bronze and babbitt, may be single-point machined.

5.4.7.1 Care shall be taken in any machining or grinding operation in order to avoid damage to the coating. Improper techniques during the finishing operation could result in pull-out of particles, thus producing a severely pitted surface or heat checking. The sprayed particles shall be cleanly sheared and not pulled from the surface as a result of the finishing operation.

5.4.8 Safety precautions. Safety practices shall be as follows.

5.4.8.1 Thermal spraying, like any other industrial process has its inherent hazards. Potential hazards include vapors, dusts and fumes, gases, the wire spray gun, noise and arc ultraviolet radiation. These hazards can be eliminated or minimized when proper safety precautions are taken. The requirements of AWS OPP shall be complied with.

5.4.8.2 Approved solvents (such as, toluene, trichloroethane and alcohol) have vapors that are harmful and can be fatal; and, therefore, shall be used only with adequate ventilation. Prolonged breathing of vapors and repeated contact of solvent with the skin shall be avoided. Toluene and alcohol are also flammable liquids and proper precautionary measures shall be taken.

5.4.8.3 Before opening any gas valve, assure there is adequate ventilation in the work area. Examine all gas equipment regularly for leaks and loose connections, tightening or replacing as necessary. Gas cylinders shall be secured to keep them from falling. Cylinders in use shall be kept away from the thermal spray operation so that molten spray or flame will not reach them. If this is not possible, fire resistant shields shall be provided. When not in use, shut off gas and place valve caps on cylinders.

5.4.8.4 When abrasive blasting in semi-confined spaces, use face shields with dust hoods or helmets with forced fed purified air, to protect the eyes, face, chin and neck from flying particles. Personnel near blasting operations shall wear protective safety eyewear.

5.4.8.5 Maintain thermal spray guns in accordance with manufacturer's recommendations. Do not light the wire gun without wire in the nozzle as flames may shoot back into the gun causing equipment damage and operator injury. When lighting the gun, use a friction lighter; do not use matches.

5.4.8.6 Both abrasive blasting and thermal spraying generate dusts and fumes, posing a respiratory hazard. Adequate ventilation combined with use of proper personal protection equipment normally provide satisfactory protection. In closed areas, a water wash booth with a positive exhaust system shall be used to minimize the hazardous concentrations of dusts and fumes. Appropriate personal respiratory protection shall be worn during spraying and sealing operations. If operator discomfort such as dizziness or nausea develops, stop spraying. Determine the cause for the discomfort and correct the cause before resuming the spraying process.

5.4.8.7 Noise levels generated by the thermal spray process are sufficient to cause temporary deafness or permanent loss of hearing, and fatigue. Ear muffs and properly fitted soft rubber ear plugs shall be worn by thermal spray operators and personnel in the immediate spray vicinity to reduce the high intensity noise levels to acceptable conditions. Use of cotton wads is specifically prohibited.

5.4.8.8 Infrared, visible and ultraviolet radiation from the thermal spray process can cause eye discomfort and damage. When spraying, a suitable filter plate shall be used with the helmet, face shield or goggles as follows:

(a)	Wire flame spraying:	Shades 2 - 4
(b)	Powder flame spraying:	Shades 3 - 6
(c)	Plasma spraying:	Shades 9 - 12
(d)	Wire arc spraying:	Shades 9 - 12

WARNING: Covers shall be placed over windows of the thermal spray facility when spraying to protect the eyes of personnel working outside or passing by.

5.4.8.9 Flame-resistant clothing and leather or rubber gauntlets shall be worn during thermal spraying to keep harmful flying particles from thermal sprayed materials from skin contact. Aluminized clothing may be used, taking care radiation and ultraviolet light are not reflected onto unprotected skin areas. Care shall also be taken as aluminized clothing may present a danger from electric shock.

5.4.8.10 Operators shall wear protective equipment as specified in 5.2.4.

5.4.8.11 Two persons shall be present at all times during the spraying operation; one inside the spray booth and one outside.

5.5 Thermal spray applications.

5.5.1 General.

5.5.1.1 Thermal spray coatings can be applied to buildup worn or mismachined parts and to improve abrasion resistance. Thermal spray coatings are not intended to fill gouges or similar localized damage without building up the entire area. Thermal spray deposits do not restore properties such as tensile strength or resistance to fatigue stresses.

5.5.1.2 Information contained in this section is presented for the purpose of assisting in the selection of a coating which would be appropriate for the intended application and also suitable to the capabilities of the performing facility. Selection shall be made from the presented listings in tables I and II whenever possible. Thermal spray applications and coatings not specified in tables I and II and 5.5.2 shall receive NAVSEA approval on a case-by-case basis before spraying.

TABLE II. Recommended spray procedures.1/

Substrate	Application	Spray process2/	Spray material code3/	Spray category4/
Carbon, low alloy, and stainless steel; Cast iron	Fit	PP	P1	4.1
		FP	P1	4.1
		FW/FW	W1/W2	2.1
	Wear, seal, erosion	PP/PP	P1/P2	5/ 4.1/8.1
		FP/FP	P1/P2	4.1/8.1
Nickel base alloys	Fit	PP	P3	6.1
		FP	P3	6.1
		FW	W3	6.2
	Wear, seal, erosion	PP/PP	P3/P2	5/ 6.1/8.1
		FP/FP	P3/P2	6.1/8.1
Bronze	Fit	PP	P4	5.1
		FP	P4	5.1
		FW/FW	W1/W4	5.2
	Wear, seal, erosion	PP/PP	P4/P2	5/ 5.1/8.1
		FP/FP	P4/P2	5.1/8.1

1/ These procedures are recommended for the listed applications and substrates (operators must be qualified in accordance with 4.4.3). Other procedures may be used if the procedures and operators are qualified in accordance with 4.3 and 4.4.3, respectively.
3/ See table III for powder and wire chemistries.
4/ Spray categories and associated bond strength, porosity, oxide and thickness requirements are given in table I.
5/ The bond strength requirements for the ceramic top coat apply (spray category 8.1 from table I).

TABLE III. Spray material compositions.

Spray material code 1/	Description	Nominal chemical composition (percent)								Specification
		Al	Mo	Ni	Cr	Fe	Cu	C	Other	
P1	Composite powder	7.0	5.5	Bal	9.0	5.0	--	--	--	---
P2	Ceramic powder	--	--	--	--	--	--	--	87 Al_2O_3, 13 TiO_2	---
P3	Monel powder	--	--	70	--	--	30	--	--	---
P4	Al-bonze powder	10	--	--	--	--	Bal	--	--	---
W1	Ni-aluminum wire	20	--	80	--	--	--	--	--	Nickel-aluminum 2/
W2	Austenitic wire	--	--	5.0	18.0	Bal	--	0.15 max	Mn 8.75	Stainless 18-5 2/
W3	Ni-copper wire	0.5 max	--	66.5	--	2.5 max	Bal	.3 max	Mn 2.0 max	Nickel-copper 2/
W4	Al-bronze wire	9.5	--	--	--	1.0	88 min	--	--	Aluminum-bronze 2/

1/ From table II.
2/ As designated in MIL-W-6712.

5.5.2 Approved applications.

5.5.2.1 Machinery. Thermal spray is approved for machinery applications on surface ships with the following exceptions:

(a) Primary and secondary nuclear systems.
(b) Main propulsion turbines.
(c) Ship's service turbine generators.
(d) Reduction gears.
(e) Lineshafts and lineshaft bearings.

5.5.2.1.1 Equipment. Permitted applications on surface ships include main feed pumps, forced draft blowers, and equipment of equal or lesser criticality. Permitted repairs on these equipments are:

(a) Repair of static fit areas to restore original dimensions, finish, and alignment.
(b) Repair of seal (including packing) areas to restore original dimensions and finish.
(c) Repair of fit areas on shafts to restore original dimensions and finish (except for motor generator sets).
(d) Buildup of pump shaft sleeves and wear rings to restore original dimensions.
(e) Repair of bearing shaft journals to restore original dimensions.
(f) Babbitt bearings for auxiliary equipment.

Thermal spray is not approved for repair of submarine components. Requests for deviations to this exclusion should be addressed to NAVSEA.

5.5.2.2 Proposed applications. Applications that are not specified in 5.5.2.1 require specific NAVSEA approval. This approval will be based on the results of a laboratory or service test to determine the adequacy of the coating in the proposed application.

6. NOTES

6.1 Intended use. This standard defines the qualification, procedure approval, and documentation requirements, and approved applications for thermal spray processes used for machinery repair and corrosion protection (except thermal spraying of aluminum for corrosion protection) of Naval machinery.

6.2 General requirements. All spraying activities should:

(a) Prepare a written quality assurance system document (see 4.1).
(b) Obtain NAVSEA certification of the quality assurance system and thermal spray facilities (see 4.2.1 and 4.2.2).
(c) Train and qualify all spray operators and inspectors (see 4.4).
(d) Obtain NAVSEA approval of spray procedures or demonstrate ability to use previously approved procedures (see 4.2.3, 4.3.1, and 4.3.4).
(e) Prepare and submit sprayed component record forms (see 4.1.3, 4.1.4, and 4.1.5).

6.3 Data requirements. When this standard is used in an acquisition which incorporates a DD Form 1423, Contract Data Requirements List (CDRL), the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved CDRL incorporated into the contract. When the provisions of DoD FAR Supplement, Part 27, Sub-Part 27.410-6 (DD Form 1423) are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this standard are cited in the following paragraphs.

Paragraph no.	Data requirement title	Applicable DID no.	Option
4.1 and 4.2.2	Plan, quality assurance program	UDI-R-21374	----
4.2.2.2, 4.3.1.1, and 4.3.3.5	Certification data/report	UDI-A-23264	----

(Data item descriptions related to this standard, and identified in section 6 will be approved and listed as such in DoD 5010.12-L, AMSDL. Copies of data item descriptions required by the contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.)

6.4 Subject term (key word) listing.

Electric arc
Plasma
Powder flame
Spray
Thermal
Wire flame

6.5 Changes from previous issue. Asterisks or vertical lines are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Preparing activity:
Navy - SH
(Project MFFP-N346)

A. Materials (Military specification and trade names)

Coating: bond coat _____ finish coat _____

Substrate _____

Lot no. _____

B. Preparation

Method of cleaning _____

Masking information _____

Fixturing type _____

Blast grit type and size _____

Nozzle to work distance _____

Nozzle size _____

C. Spray equipment supplements

Gun type _____

Gears type _____

Air cap type _____

Wire nozzle type no. _____

Nozzle orifice size _____

Type of gas used (1) _____

Type of gas used (2) _____

Lighting pressures (1) _____

Lighting pressures (2) _____

Flow (1) _____

Flow (2) _____

Air _____

D. Coating parameters

Pounds/hour _____

Gun to work distance in. _____

Surface feet per minute _____

Preheat temperature _____

Spray time (per pass) _____

Total no. of passes _____

Thickness per pass _____

Method of cooling:

Air _____ Gas _____

Forced _____ Static _____

Coating thickness:

As-sprayed _____

After finishing _____

E. Sealer type

F. Finishing method

FIGURE 1. Wire oxy-fuel spray process and parameter record.

A. Materials (Military specification and trade names)

Coating: bond coat _____ Finish coat _____

Substrate _____

Lot no. _____

B. Preparation

Method of cleaning _____

Masking information _____

Fixturing type _____

Blast grit type and size _____

Nozzle to work distance _____

C. Spray equipment supplements

Gun type _____

Wire size _____

Atomizing gas _____

Type _____

Pressure _____

Atomizing air lb/in^2 _____

Volts _____

Amps _____

Spray distance _____

D. Coating parameters

Pounds/hour _____

Gun to work distance (in) _____

Surface feet per minute _____

Preheat temp. _____

Spray time per pass _____

Total no. of passes _____

Thickness per pass _____

Method of cooling:

Air _____ Gas _____

Forced _____ Static _____

Coating thickness:

As-sprayed _____

After finishing _____

E. Sealer type

F. Finishing method

FIGURE 2. Wire arc spray process and parameter record.

A. Materials (Military specification and trade names)

Coating: bond coat _____ Finish coat _____

Substrate _____

Lot no. _____

B. Preparation

Method of cleaning _____

Masking information _____

Fixturing type _____

Blast grit type and size _____

Nozzle to work distance _____

Nozzle size _____

C. Spray equipment supplements

Gun type _____

Nozzle type no. _____

Air cap _____

Type of gas used (1) _____

Type of gas used (2) _____

Auxiliary equipment _____

D. Arc gas settings

Regulator (1) lb/in^2 _____

Regulator (2) lb/in^2 _____

Console flow C.F.H. _____

Gas (1) _____

Gas (2) _____

E. Powder feeder

Type _____

Carrier gas _____ Pressure _____

Flow C.F.H. _____

Wheel RPM _____

Vibrator type _____ Pressure _____

Metering valve _____

Flow control clicks _____

Meter wheel _____

Spray rate _____

Transport valve setting _____

Powder valve setting _____

F. Coating parameters

Gun to work distance in. _____

Surface feet per minute _____

Preheat temperature _____

Spray time (per pass) _____

Pounds per hour _____

FIGURE 3. Powder oxygen - fuel spray process and parameter record.

Total no. of passes _____

Coating thickness per pass _____

Method of cooling:

Air _____ Gas _____

Forced _____ Static _____

Air jets: Pressure _____

Cross _____

Coating thickness:

As sprayed _____

After finishing _____

G. Sealer type

H. Finishing method

FIGURE 3. Powder oxygen - fuel spray process and parameter record. - Continued

A. Materials (Military specification and trade names)

Coating: bond coat _____ Finish coat _____

Substrate _____

Lot no. _____

B. Preparation

Method of cleaning _____

Masking information _____

Fixturing type _____

Blast grit type and size _____

Nozzle to work distance _____

Nozzle size _____

C. Spray equipment supplements

Thermal spray gun type _____

Nozzle type no. _____

Type of gas used (1) _____

Type of gas used (2) _____

D. Arc gas settings

Regulator (1) lb/in^2 _____

Regulator (2) lb/in^2 _____

Console flow C.F.H. _____

E. Power

Voltage dc operating _____

Amperes dc operating _____

E. Powder feeder

Type _____

Carrier gas _____

Flow C.F.H. _____

Wheel r/min _____

Powder port _____

Powder gas orifice _____

Air vibrator _____ Pressure ___

Meter wheel _____

Spray rate _____

G. Coating parameters

Gun to work distance in. _____

Surface feet per minute _____

Preheat temperature _____

Pounds per hour _____

Spray time (per pass) _____

Total no. of passes _____

Coating thickness/pass _____

Method of cooling:

Air _____ Gas _____

Forced _____ Static _____

*Adjust gas flow as necessary to obtain the voltage range required.

FIGURE 4. Plasma spray process and parameter record.

Coating thickness:

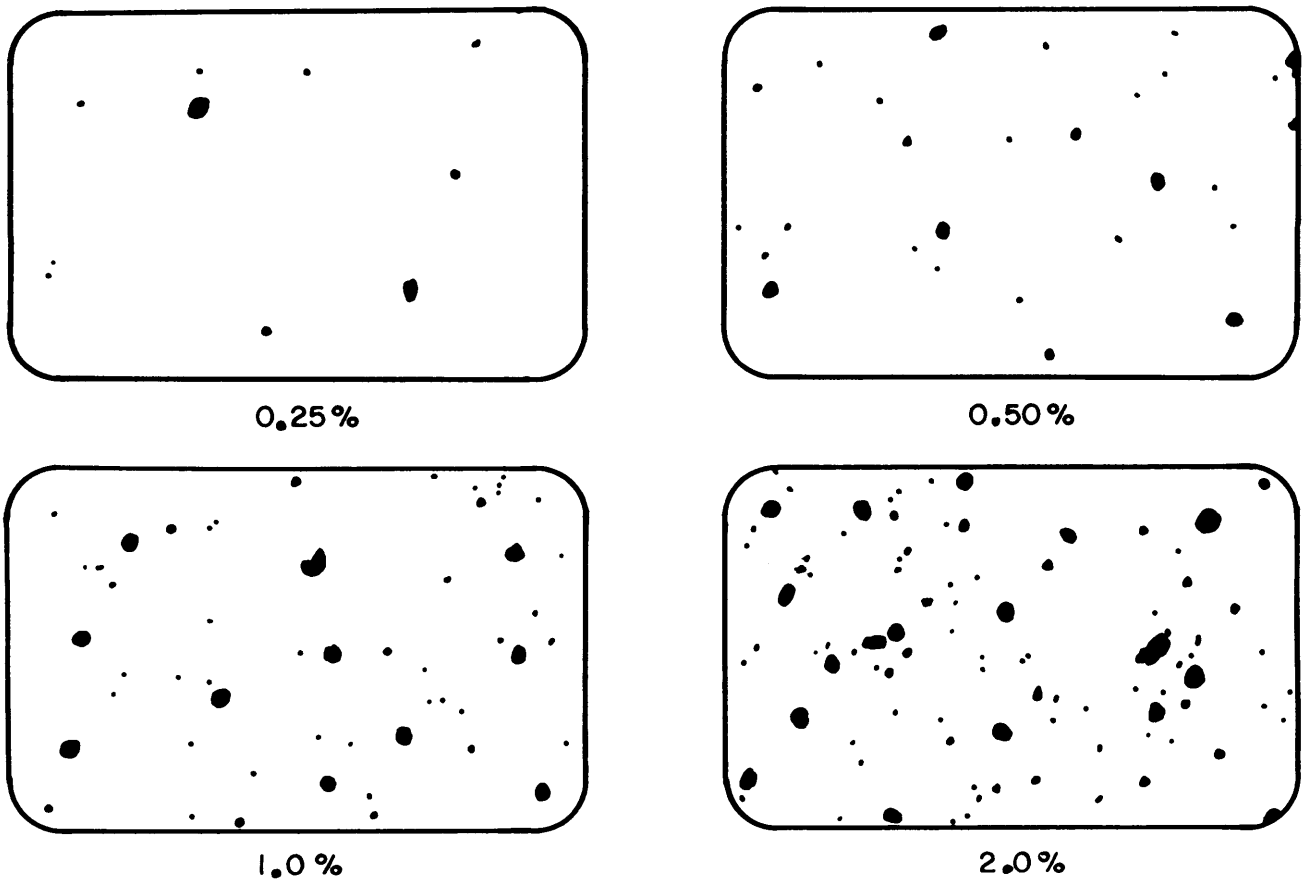
As sprayed _____

As finished _____

H. Sealer type

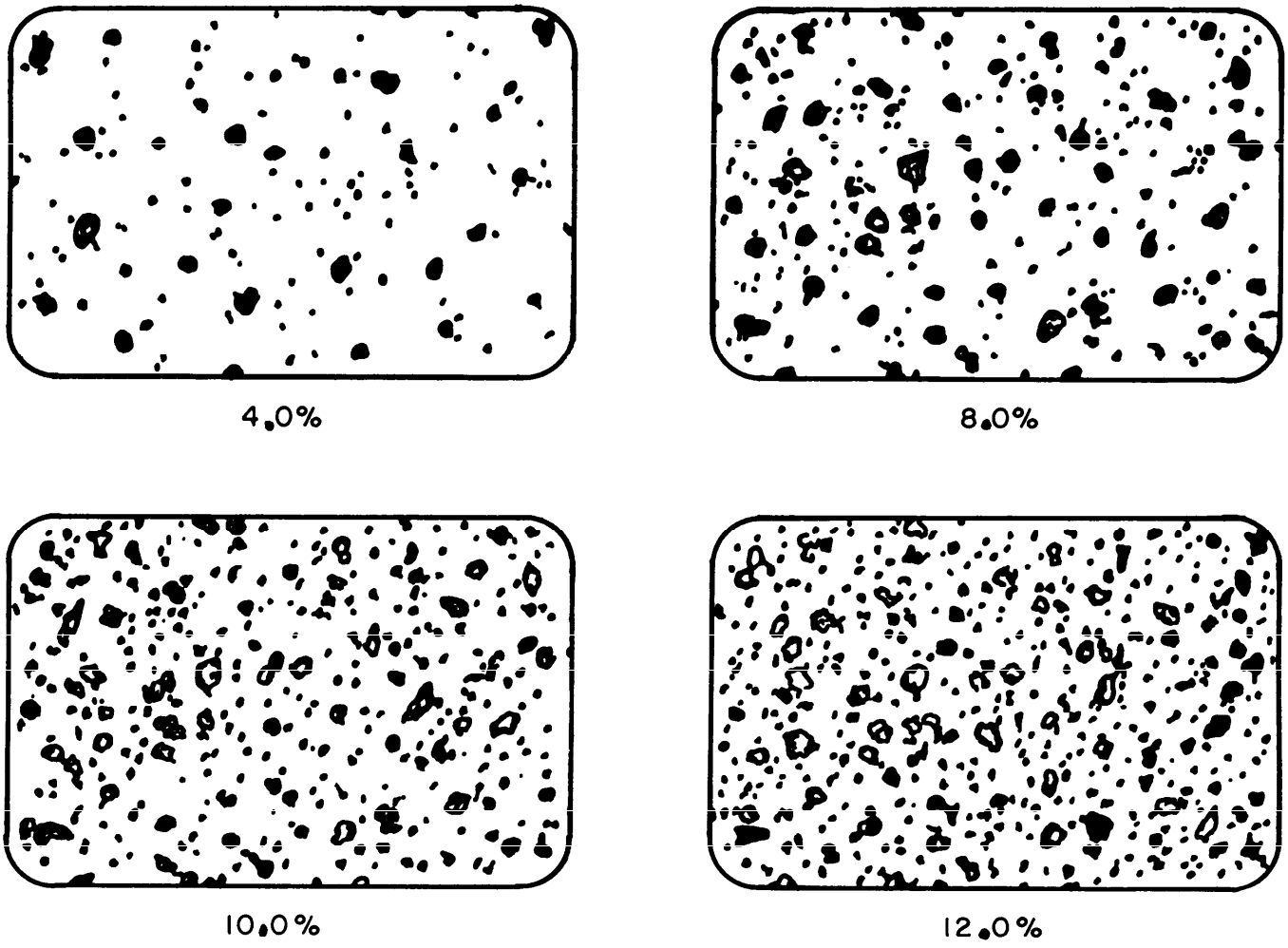
I. Finishing method

FIGURE 4. Plasma spray process and parameter record. - Continued



SH 13203134

FIGURE 5. Oxide, porosity comparison chart (200X).



SH 13203134

FIGURE 5. Oxide, porosity comparison chart (200X). - Continued

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-STD-1687A	Thermal Spray Processes For Naval Ship Machinery Applications

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
	☐ VENDOR ☐ USER ☐ MANUFACTURER ☐ OTHER *(Specify)*:
b. ADDRESS *(Street, City, State, ZIP Code)*	

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

DD FORM 82 MAR 1426 PREVIOUS EDITION IS OBSOLETE.

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)