

AWS C2.19/C2.19M:2023  
An American National Standard

---

---

# Specification for the Application of Thermal Spray Coatings to Machine Elements for OEM and Repair



**AWS C2.19/C2.19M:2023**  
**An American National Standard**

**Approved by the**  
**American National Standards Institute**  
**September 26, 2023**

# **Specification for the Application of Thermal Spray Coatings to Machine Elements for OEM and Repair**

**2nd Edition**

**Revises AWS C2.19/C2.19M:2013**

Prepared by the  
American Welding Society (AWS) C2 Committee on Thermal Spray

Under the Direction of the  
AWS Technical Activities Committee

Approved by the  
AWS Board of Directors

## **Abstract**

This standard defines requirements for thermal spray coating systems for OEM and repair applications. Included are HVOF (High Velocity Oxyfuel) coatings that can be used as an alternative to hard chrome plating. The essential equipment, procedures for surface preparation, and the application of specific thermal spray coatings and sealers are detailed with in-process quality control checkpoints. This standard also presents management requirements and procedures for qualification, procedure approval, and documentation. Also covered are approved applications for thermal spray processes used for OEM and repair of machinery components along with minimum training requirements for thermal spray operators and inspectors. This specification has several annexes including annexes on safety, bend testing, and bond testing.



ISBN Print: 978-1-64322-285-1  
ISBN PDF: 978-1-64322-286-8  
© 2023 by American Welding Society  
All rights reserved  
Printed in the United States of America

**Photocopy Rights.** No portion of this standard may be reproduced, stored in a retrieval system, or transmitted in any form, including mechanical, photocopying, recording, or otherwise, without the prior written permission of the copyright owner.

Authorization to photocopy items for internal, personal, or educational classroom use only or the internal, personal, or educational classroom use only of specific clients is granted by the American Welding Society provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, tel: (978) 750-8400; Internet: <[www.copyright.com](http://www.copyright.com)>.

## Statement on the Use of American Welding Society Standards

All standards (codes, specifications, recommended practices, methods, classifications, and guides) of the American Welding Society (AWS) are voluntary consensus standards that have been developed in accordance with the rules of the American National Standards Institute (ANSI). When AWS American National Standards are either incorporated in, or made part of, documents that are included in federal or state laws and regulations, or the regulations of other governmental bodies, their provisions carry the full legal authority of the statute. In such cases, any changes in those AWS standards must be approved by the governmental body having statutory jurisdiction before they can become a part of those laws and regulations. In all cases, these standards carry the full legal authority of the contract or other document that invokes the AWS standards. Where this contractual relationship exists, changes in or deviations from requirements of an AWS standard must be by agreement between the contracting parties.

AWS American National Standards are developed through a consensus standards development process that brings together volunteers representing varied viewpoints and interests to achieve consensus. While AWS administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its standards.

AWS disclaims liability for any injury to persons or to property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this standard. AWS also makes no guarantee or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this standard available, AWS is neither undertaking to render professional or other services for or on behalf of any person or entity, nor is AWS undertaking to perform any duty owed by any person or entity to someone else. Anyone using these documents should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. It is assumed that the use of this standard and its provisions is entrusted to appropriately qualified and competent personnel.

This standard may be superseded by new editions. This standard may also be corrected through publication of amendments or errata, or supplemented by publication of addenda. Information on the latest editions of AWS standards including amendments, errata, and addenda is posted on the AWS web page ([www.aws.org](http://www.aws.org)). Users should ensure that they have the latest edition, amendments, errata, and addenda.

Publication of this standard does not authorize infringement of any patent or trade name. Users of this standard accept any and all liabilities for infringement of any patent or trade name items. AWS disclaims liability for the infringement of any patent or product trade name resulting from the use of this standard.

AWS does not monitor, police, or enforce compliance with this standard, nor does it have the power to do so.

Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the appropriate technical committee. Such requests should be addressed to the American Welding Society, Attention: Managing Director, Standards Development, 8669 NW 36 St, # 130, Miami, FL 33166 (see Annex F). With regard to technical inquiries made concerning AWS standards, oral opinions on AWS standards may be rendered. These opinions are offered solely as a convenience to users of this standard, and they do not constitute professional advice. Such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

This standard is subject to revision at any time by the AWS C2 Committee on Thermal Spray. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS C2 Committee on Thermal Spray and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS C2 Committee on Thermal Spray to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.tee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

## Personnel

### AWS C2 Committee on Thermal Spray

|                                       |                                               |
|---------------------------------------|-----------------------------------------------|
| D. C. Hayden, Chair                   | <i>Hayden Corporation</i>                     |
| J. Ryan, 1 <sup>st</sup> Vice Chair   | <i>Techmet Alloys, LLC</i>                    |
| D. A. Lee, 2 <sup>nd</sup> Vice Chair | <i>David Lee Consulting</i>                   |
| J. M. Rosario, Secretary              | <i>American Welding Society</i>               |
| W. J. Arata Jr.                       | <i>Steward Advanced Materials</i>             |
| D. M. Beneteau                        | <i>Centerline Ltd.</i>                        |
| C. C. Berndt                          | <i>Swinburne University of Technology</i>     |
| M. M. Blasingame                      | <i>Superior Shot Peening, Incorporated</i>    |
| G. Blohm                              | <i>Metalizing Pro, Incorporated</i>           |
| A. B. Duminie                         | <i>North American Hoganas</i>                 |
| D. T. Haegele                         | <i>Select-Arc, Incorporated</i>               |
| I. R. Lasa                            | <i>Lasa and Associates Corrosion Services</i> |
| N. J. Latona                          | <i>Polymet Corporation</i>                    |
| C. Ma                                 | <i>Curtiss-Wright Corporation</i>             |
| W. Mosier                             | <i>Polymet Corporation</i>                    |
| J. W. Rice                            | <i>Veritas Steel</i>                          |
| K. Sampath                            | <i>Consultant</i>                             |
| C. Sauer                              | <i>NAVAIR</i>                                 |
| K. L. Sender                          | <i>Oerlikon Metco (US), Incorporated</i>      |
| K. N. Tran                            | <i>Naval Sea Systems Command</i>              |
| M. Weinstein                          | <i>Wall Colmonoy Corporation</i>              |
| A. P. Yanski                          | <i>Praxair</i>                                |

### Advisors to the AWS C2 Committee on Thermal Spray

|                   |                                              |
|-------------------|----------------------------------------------|
| R. Ahmed          | <i>Petronas Carigali Sdn Bhd</i>             |
| L. F. Grimenstein | <i>Nation Coating Systems, Incorporated</i>  |
| D. L. Hale        | <i>Ineel</i>                                 |
| J. O. Hayden      | <i>Hayden Corporation</i>                    |
| J. Medrano        | <i>Oerlikon Metco (US), Incorporated</i>     |
| C. Tudor          | <i>International MetalFusion Corporation</i> |
| T. H. Via         | <i>Via Technologies</i>                      |

### AWS C2A Subcommittee on Machine Element Repair and Restoration

|                     |                                            |
|---------------------|--------------------------------------------|
| D. C. Hayden, Chair | <i>Hayden Corporation</i>                  |
| M. M. Blasingame    | <i>Superior Shot Peening, Incorporated</i> |
| D. A. Lee           | <i>David Lee Consulting</i>                |
| C. Sauer            | <i>NAVAIR</i>                              |
| K. L. Sender        | <i>Oerlikon Metco (US), Incorporated</i>   |
| K. N. Tran          | <i>Naval Sea Systems Command</i>           |

### Advisors to the AWS C2A Subcommittee on Machine Element Repair and Restoration

|                   |                                      |
|-------------------|--------------------------------------|
| J. T. Butler      | <i>Joseph T Butler, Incorporated</i> |
| J. J. DeLoach Jr. | <i>Naval Surface Warfare Center</i>  |
| J. O. Hayden      | <i>Hayden Corporation</i>            |

|                |                                                     |
|----------------|-----------------------------------------------------|
| B. J. Rampolla | <i>Alion Science &amp; Technology, Incorporated</i> |
| A. Roy         | <i>Quality Calibration and Consulting</i>           |
| S. Szapra      | <i>Naval Surface Warfare Center</i>                 |
| R. J. Wong     | <i>Naval Surface Warfare Center</i>                 |
| A. P. Yanski   | <i>Praxair</i>                                      |

## Foreword

This foreword is not part of this standard but is included for informational purposes only.

The first edition of AWS C2.19/C2.19M:2013, *Specification for the Application of Thermal Spray Coatings to Machine Elements for OEM and Repair*, was developed pursuant to a request from the U.S. Naval Sea Systems Command to migrate MIL-STD-1687A(SH), *Thermal Spray Processes for Naval Ship Machinery Applications*, to an ANSI approved AWS Standard.

This is the second edition of the standard. A vertical line in the margin or underlined text in clauses, tables, or figures indicates an editorial or technical change from the 2013 edition.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS C2 Committee on Thermal Spray, American Welding Society, 8669 NW 36 St, #130 Miami, FL 33166.

# Table of Contents

|                                                                      | Page No.  |
|----------------------------------------------------------------------|-----------|
| <i>Personnel</i> .....                                               | v         |
| <i>Foreword</i> .....                                                | vii       |
| <i>List of Figures</i> .....                                         | xi        |
| <i>List of Tables</i> .....                                          | xi        |
| <b>1. General Requirements</b> .....                                 | <b>1</b>  |
| 1.1 Scope .....                                                      | 1         |
| 1.2 Units of Measure .....                                           | 1         |
| 1.3 Safety .....                                                     | 1         |
| <b>2. Normative References</b> .....                                 | <b>2</b>  |
| <b>3. Terms and Definitions</b> .....                                | <b>3</b>  |
| <b>4. General Applications</b> .....                                 | <b>5</b>  |
| 4.1 <u>Application Considerations</u> .....                          | 5         |
| <b>5. Management, Engineering, and Production Requirements</b> ..... | <b>12</b> |
| 5.1 Purchaser and Thermal Spray Contractor Requirements .....        | 12        |
| 5.2 Qualification and Certification Requirements .....               | 13        |
| 5.3 Spray Procedure Qualification .....                              | 13        |
| 5.4 Personnel Training and Qualification .....                       | 15        |
| 5.5 Quality Control .....                                            | 17        |
| 5.6 Test Procedure .....                                             | 18        |
| <b>6. Facility Requirements</b> .....                                | <b>19</b> |
| 6.1 Working Areas .....                                              | 19        |
| 6.2 <u>Equipment</u> .....                                           | 19        |
| <b>7. Materials</b> .....                                            | <b>20</b> |
| 7.1 Coating Materials (Feedstock) .....                              | 20        |
| 7.2 Thermal Spray Gases <u>and Liquid Fuels</u> .....                | 20        |
| 7.3 Abrasive Blasting Particles .....                                | 23        |
| 7.4 Masking Materials .....                                          | 23        |
| 7.5 Sealants .....                                                   | 23        |
| <b>8. Thermal Spray Application Process</b> .....                    | <b>23</b> |
| 8.1 Surface Condition .....                                          | 23        |
| 8.2 Machining for Surface Preparation .....                          | 23        |
| 8.3 Masking .....                                                    | 24        |
| 8.4 Abrasive Blasting for Surface Preparation .....                  | 24        |
| 8.5 Thermal Spraying .....                                           | 24        |
| 8.6 Application of Sealant .....                                     | 25        |
| 8.7 Surface Finishing .....                                          | 25        |
| <b>9. Records</b> .....                                              | <b>25</b> |
| Annex A (Informative)—Safety Information for Thermal Spray .....     | 35        |
| Annex B (Informative)—Bend Test .....                                | 45        |
| Annex C (Informative)—Bond Testing—Supplementary Information .....   | 47        |



Annex D (Informative)—List of Informative References . . . . . 49

Annex E (Informative)—Conversion Factors. . . . . 51

Annex F (Informative)—Requesting an Official Interpretation on an AWS Standard. . . . . 53

List of AWS Documents on Thermal Spray . . . . . 55

## List of Figures

| Figure |                                                                                  | Page No. |
|--------|----------------------------------------------------------------------------------|----------|
| 1      | Thermal Spray Engineering Job Order (EJO) . . . . .                              | 26       |
| 2      | Thermal Spray Job Control Record (JCR) . . . . .                                 | 27       |
| 3      | Oxide and Porosity Content Comparison Chart (200x) . . . . .                     | 28       |
| 4      | Flame Wire (FW) Spray Process and Parameter Record . . . . .                     | 29       |
| 5      | Arc Wire (AW) Spray Process and Parameter Record . . . . .                       | 30       |
| 6      | Flame Powder (FP) Spray Process <u>and</u> Parameter Record . . . . .            | 31       |
| 7      | Plasma Powder (PP) Spray Process and Parameter Record . . . . .                  | 32       |
| 8      | High Velocity Oxy <u>fuel</u> Powder (HP) Process and Parameter Record . . . . . | 33       |

## List of Tables

| Table |                                                                                                                                | Page No. |
|-------|--------------------------------------------------------------------------------------------------------------------------------|----------|
| 1     | Recommended Thermal Spray Applications . . . . .                                                                               | 6        |
| 2     | Nominal Chemical Composition of Thermal Spray Feedstock . . . . .                                                              | 7        |
| 3     | Thermal Spray Coating Properties and Minimum Strength Requirements . . . . .                                                   | 9        |
| 4     | Thermal Spray Operator Qualification Tests ( <u>TSOQT</u> ) Required for Spray Categories and Material Qualification . . . . . | 17       |
| 5     | Minimum Training Time . . . . .                                                                                                | 18       |
| 6     | Recommended Gases for Flame Spraying . . . . .                                                                                 | 21       |
| 7     | Specified Gases for Plasma Spraying . . . . .                                                                                  | 21       |
| 8     | <u>Specified Gases for HVOF and HVAF Spraying</u> . . . . .                                                                    | 22       |
| 9     | <u>Specified Liquid Fuels for HVOF and HVAF Spraying</u> . . . . .                                                             | 22       |

# Specification for the Application of Thermal Spray Coatings to Machine Elements for OEM and Repair

## 1. General Requirements

**1.1 Scope.** This specification covers thermal spray processes for original equipment manufacturers (OEMs) and the repair of machinery components. The scope includes (1) recommended applications, (2) management and engineering requirements, (3) equipment and facility requirements, (4) feedstock materials, and (5) application processes for thermal spray coatings.

The thermal spray processes covered by this standard are combustion, high velocity oxyfuel or airfuel, electric arc, and plasma processes. These processes use either powder and/or wire as feedstock.

Development of this standard was initiated at the request of the U.S. Navy to replace MIL-STD-1687A (SH), *Thermal Spray Processes for Naval Ship Machinery Applications*.

Others may use this standard and annexes to establish contract document requirements between equipment owners (purchaser) and thermal spray coating contractors where they may choose to invoke all or only a portion of this specification's requirements as fits the needs of their work.

**1.2 Units of Measurement.** This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

**1.3 Safety.** Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein.

Safety and health information is available from the following sources:

American Welding Society:

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

U.S. Department of Labor Regulations:

- (1) CFR-29, Part 1910.107 *Spray Finishing using Flammable and Combustible Liquids*

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.