

**NACE Standard NACE NO.12/AWS C2.23M/SSPC CS-23 STANDARD PRACTICE**  
**Item No. 21100**

# Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel

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**ISBN 0-87171-713-15**  
**NACE No. 12/AWS C2.23M/SSPC CS-23**

## ABSTRACT

*Revised in 2016! This revised NACE/AWS/SSPC joint standard contains requirements for the application of zinc and aluminum alloys to steel substrates using thermal spray, often referred to as "metallizing." The metal coatings are referred to as metalized or "thermal spray coatings" (TSCs). The standard includes requirements for surface preparation, coating application, repairing coating defects, measurement of coating thickness, adhesion testing of the applied coating, and application of sealers and topcoats over the thermally sprayed metal coating. This standard is intended for use by facility owners and specifiers who develop project specifications for the application of thermally sprayed coatings for the preservation and maintenance of steel structures and components. The standard also may be used by thermal spray coating inspectors to assess the quality of surface preparation and coating application, and by thermal spray contractors to develop project work plans.*

## KEYWORDS

*bend test, coatings, corrosion resistant coatings, cut test, erosion resistant coatings, job control record, JCR, job reference standard, JRS, metallizing, protective coating, steels, TG 146, thermal spray, thermal spray equipment, TSC feedstock material, TSC inspectors, TSCs*

## Foreword

*In NACE/AWS/SSPC standards, the terms shall, must, should, and may are used in accordance with Paragraph 2.2.1.8 of the Agreement between NACE International and SSPC: The Society for Protective Coatings. The terms shall and must are used to state mandatory requirements. The term should is used to state something considered good and is recommended but is not mandatory. The term may is used to state something considered optional.*

This NACE/AWS/SSPC joint standard contains requirements for the application of zinc and aluminum alloys to steel substrates by melting feedstock with heat from combustion or electric arc and propelling the molten metal particles onto the substrates using compressed air or another gas. This process is called thermal spray, often referred to as “metalizing,” and the metal coatings are referred to as metalized or “thermal spray coatings” (TSCs).

This standard is intended for use by facility owners and specifiers who develop project specifications for the application of thermally sprayed coatings for the preservation and maintenance of steel structures and components. It also may be used by thermal spray coating inspectors to assess the quality of surface preparation and coating application, and by thermal spray contractors to develop project work plans.

This joint standard was originally published in 2003 by SSPC<sup>(1)</sup> committee C.1.14 (formerly C.1.2.B), AWS<sup>(2)</sup> C2 Committee and NACE<sup>(3)</sup> Task Group (TG) 146. It was revised in 2016 by SSPC C.1.14, “Committee on Thermal Spray Coatings”; AWS C2 Committee on Thermal Spraying; and NACE TG 146, “Coatings, Thermal Spray,” and administered by NACE Specific Technology Group (STG) 02, “Protective Coatings and Linings—Atmospheric”; and sponsored by NACE STG 39, “Process Industry—Materials Applications.” It is published by NACE International under the auspices of STG 02.

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## Section 1: General

- 1.1 General:** This joint standard is a procedure for the application of metallic thermal spray coating (TSCs) of aluminum, zinc, and their alloys and composites for the corrosion protection of steel. Required equipment, application procedures, and in-process quality control (QC) checkpoints are specified. Other thermal spray corrosion and erosion resistant coatings such as carbides, cobalt, nickel, and other alloys are not included in this standard. The powder thermal spray and cold spray processes are not included in this standard.
- 1.2 Scope:** Included are requirements for surface preparation, coating application, repair of coating defects, measurement of coating thickness, adhesion testing of the applied coating, and application of sealers and topcoats over the thermally sprayed metal coating. Not included in this standard are requirements for design and fabrication, thermal spray equipment qualification, coating selection, and operator and inspector certification. For successful thermal spray application, the steel structure and components should be designed and fabricated in accordance with NACE SP0178.<sup>1</sup> Additional consideration should be given to weldments and components, or structures with thermal cut edges, whose hardness may preclude adequate profile depth.
- 1.3 Safety:** The basic precautions for thermal spraying are essentially the same as for welding and cutting. Information on safety can be found in ANSI<sup>(4)</sup> Z49.1, Safety in Welding, Cutting, and Allied Processes;<sup>2</sup> and NFPA<sup>(5)</sup> 58, Standard for the Storage and Handling of Liquefied Petroleum Gases.<sup>3</sup> Read and follow safety precautions in the manufacturer's equipment technical instructions and manuals and the feedstock safety data sheet (SDS). See U.S. Code of Federal Regulations (CFR)<sup>(6)</sup> Title 29 CFR 1910.94(c)(6)(i), "Ventilation,"<sup>4</sup> for Occupational Safety & Health Administration (OSHA)<sup>(7)</sup> ventilation requirements for spray booths.
- 1.3.1** This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety issues associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations before use.
- 1.3.2** Potential thermal spraying hazards include exposure to vapors, dust, fumes, gases, noise (from the spray gun), and arc ultraviolet (UV) radiation. Additionally, improperly used thermal spray equipment can create potential fire and explosion hazards from oxygen, fuel, and compressed gases and a potential electrical shock hazard from the electrical and electronic equipment and charged wire spools. To minimize hazards, proper safety precautions shall be followed. Operators shall comply with the procedures in the safety references, the manufacturer's technical manuals, and the safety data sheets (SDS).
- 1.3.3** All TSC equipment operators shall be qualified to a prequalified procedure before production application of the coating. Procedure and TSC equipment operator qualifications shall be retained by the contractor and made available to the end user upon request.

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<sup>(4)</sup> American National Standards Institute (ANSI), 1819 L Street NW, Suite 600, Washington, DC, 20036.

<sup>(5)</sup> National Fire Protection Association (NFPA), 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

<sup>(6)</sup> U.S. Code of Federal Regulations (CFR), U.S. Government Printing Office (GPO), 732 N. Capitol Street NW, Washington, DC 20401.

<sup>(7)</sup> Occupational Safety & Health Administration (OSHA), U.S. Dept. of Labor, 200 Constitution Ave NW, Washington, DC 20210.

**1.4 Units of Measure:** This standard makes use of both the ASTM<sup>(8)</sup> SI 10, "American National Standard for Metric Practice" International System Units (SI)<sup>5</sup> of units and U.S. Customary units. The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way. This standard uses SI units with the U.S. Customary conversions shown in parentheses

## Section 2: Definitions

Definitions preceded by an asterisk (\*) are taken from the 2011 "SSPC Protective Coatings Glossary."<sup>6</sup>

**Bend test:** The bend test is a qualitative test of the ductility and tensile adhesion of the TSC. It serves as a macro-system test of surface preparation, equipment setup, spray parameters, and application procedures (see Nonmandatory Appendix A).

**Adhesion Test, Tensile (Pull-Off):** The method for testing the greatest perpendicular force that an area of coating can withstand before: (1) detaching from the surface (adhesion) or (2) fracturing within a layer of coating or substrate (cohesion). The method can also be used to determine whether a coating will remain intact at a particular applied tensile force. This standard test method is defined in ASTM D4541.<sup>7</sup>

**Companion coupon:** A small rectangular metal sample approximately 100 mm x 150 mm x 6 mm (4 in x 6 in x 0.25 in) surface-prepared and coated concurrently with the job reference standard (JRS) or production piece, used for inspection.

**Cut test:** The cut test is a subjective, nonquantitative test that consists of a single cut through the TSC to the substrate without severely cutting into the substrate (see Appendix B).

**Immersion Service:** Use of a coating under water or other liquid; in this service, the coating may be called a lining.

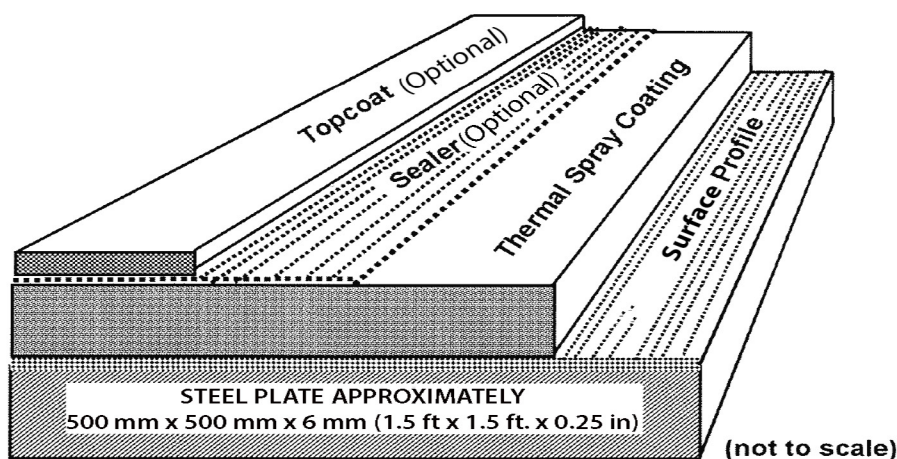


**Figure 1: Job Reference Standard Illustration.**  
(NOTE: The topcoat and sealer are included when specified.)

**Job Control Record (JCR):** The JCR is a record form that enumerates the essential job information and the in-process QC checkpoints required by this standard. The JCR includes information on safety precautions, and the equipment, parameters, and procedures for surface preparation, thermal spraying, and sealing or sealing and top coating.

**Job Reference Standard (JRS):** The JRS is a job site pass/fail reference standard representative of the whole job or major sections of the job (see Paragraph 3.2, Section 7, and Figure 1).

**Light flash rusted surface:** A thermal spray coating surface that, when viewed without magnification, exhibits small quantities of a rusty layer through which the carbon steel substrate may be observed. The rust or discoloration may be evenly distributed or present in patches, but it is tightly adherent and not easily removed by lightly wiping with a cloth.<sup>8-11</sup> (In this standard, the words “thermal spray coating” should be substituted for the words “carbon steel” in the definition.)

**Nonvisible contamination:** Nonvisible contamination is the presence of organic matter, such as thin films of oil and grease, and inorganic and/or soluble ionic materials such as chlorides, ferrous salts, nitrates, and sulfates that may be present on the substrate.<sup>8-11</sup>

**Overspray:** The portion of the thermal spray material that is not thermally fused or bonded to the intended surface or substrate.

**Sealer:** An optional part of the process in which a material is used to fill porosity and voids in the metalized surface.

**Weldment:** An assembly joined by welding.

## Section 3: Summary of Practice

The procedure for application of TSCs for the corrosion protection of steel includes: (1) surface preparation of the substrate, (2) application of the TSC, and (3) when specified, application of a sealer or of a sealer and topcoat. The procedure includes the use of suitable equipment for abrasive blasting, thermal spraying, sealing/topcoating and in-process QC checkpoints.

- 3.1 TSC System Requirements:** Table 1 summarizes minimum TSC System requirements.
- 3.2 JRS:** A JRS (see Section 7) shall be prepared, inspected, and found to meet the specifications before the production work begins. It shall be used as a comparative standard during the thermal spray process.
- 3.3** If the steel surface to be coated is not ferromagnetic, a companion coupon of ferromagnetic steel shall be prepared for verification of TSC thickness.

**Table 1**  
**Minimum TSC System Requirements and Acceptance Tests**

| TSC System Requirements      |                                                      |                                                                              |                                                                                         |
|------------------------------|------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Operation                    | Hold Point                                           | Requirement                                                                  | Acceptance Tests                                                                        |
| Pre-Preparation Requirements | Proper Feedstock (Paragraph 4)                       | Per contract requirement                                                     | AWS C.2.25/C.2.25M <sup>12</sup> or ASTM B833 <sup>13</sup>                             |
|                              | Ambient Conditions (Paragraph 5.1.1)                 | Temperature of the substrate is a minimum of 3 °C (5 °F) above the dew point | ASTM E337 <sup>14</sup>                                                                 |
|                              | Cleanliness of Abrasive                              | complies with SSPC- AB 1, 2, 3 as applicable                                 | SSPC-AB 1 <sup>15</sup> , 2 <sup>16</sup> , or 3 <sup>17</sup> as applicable            |
|                              | Cleanliness of Compressed Air (Paragraph 5.1.2)      | Free of Contaminant                                                          | ASTM D4285 <sup>18</sup>                                                                |
| Surface Preparation          | Surface Cleanliness (Paragraph 5.2.1)                | NACE No. 2/ SSPC-SP 10 minimum NACE No. 1/SSPC-SP 5 for immersion service    | NACE No. 2/ SSPC-SP 10 <sup>19</sup> Paragraph 2 NACE No. 1/SSPC SP-5 <sup>20</sup> (A) |
|                              | Water soluble contaminants (Paragraph 5.2.1) (B)     | Per the contract requirements                                                | SSPC-Guide 15 <sup>21</sup>                                                             |
|                              | Surface profile (Paragraph 5.4.1)                    | Range 65 µm (2.5 mil) to 125 µm (5.0 mil)                                    | ASTM D4417 <sup>22</sup> (Method B or C) in accordance with SSPC-PA 17 <sup>23</sup>    |
| TSC Coating                  | Minimum and Maximum Coating Thickness <sup>(C)</sup> | Per contract requirement                                                     | SSPC-PA 224 <sup>(C)</sup> Inspection Level 4                                           |
|                              | Applied Coating Appearance                           | Smooth and uniform. No blisters, cracks, loose particles or exposed steel.   | Compare with accepted job reference standard                                            |
|                              | Tensile adhesion                                     | See Table 2                                                                  | ASTM D4541 <sup>7</sup> , Method C, D, E, or F <sup>(D)</sup>                           |

<sup>(A)</sup> NACE No. 1/SSPC-SP 5 is generally used for exposures in very corrosive atmospheres and immersion service.  
<sup>(B)</sup> SSPC-Guide 15 describes methods for detection and analysis of soluble salts.  
<sup>(C)</sup> Verify accuracy of the gauge and measure the TSC thickness in accordance with SSPC-PA 2.  
<sup>(D)</sup> Specify the ASTM D4541 Method to be used and its minimum acceptable value for the Job Reference Standard and the job work surfaces.

## Section 4: TSC Feedstock Requirements

The TSC feedstock material shall be zinc, aluminum, or 85/15 Zn/Al alloy in accordance with AWS C2.25/C2.25M or ASTM B833 in accordance with the procurement documents (project specification). The records and material test reports shall be retained and made available to the end user upon request (see Section 11).

## Section 5: Surface Preparation Requirements

### 5.1 Pre-preparation Requirements

**5.1.1 Ambient Conditions:** The steel surface temperature shall be at least 3 °C (5 °F) above the dew point temperature of the ambient air.

**5.1.2 Cleanliness of Compressed Air:** Verify the cleanliness of compressed air in accordance with ASTM D4285.

### 5.2 Surface Cleanliness

**5.2.1** Immediately before the TSC application, the steel substrate shall be prepared in accordance with:

- (1) White metal finish, NACE No. 1/SSPC-SP 5, for immersion service; or
- (2) The minimum of near-white metal finish, NACE No. 2/SSPC-SP 10, for other service applications; and
- (3) The level of nonvisible contamination specified in the procurement documents (project specifications).

Although the surface preparation and the TSC application are normally performed during the same shift, dehumidification or other methods may be utilized to preserve the surface cleanliness for a longer period if approved by the owner. The surface shall be inspected just before the application of the TSC and shall comply with the requirements of the applicable standard.

Appendix C (nonmandatory) contains descriptions of SSPC Environmental Zones, including immersion service.

**5.2.2** Mineral and slag abrasives including aluminum oxide shall be selected and evaluated in accordance with SSPC-AB 1, recycled ferrous metallic abrasives in accordance with SSPC-AB 2, and steel grit in accordance with SSPC-AB 3 (see Appendix C3). SSPC-VIS 125 provides visual reference photographs illustrating typical examples of NACE No. 2/SSPC-SP 10 and NACE No. 1/SSPC-SP 5 cleanliness. The reference photographs are often used to supplement, but not to replace, the requirements of the written standards.

**5.2.3** Blast surface preservation products shall not be used.

**5.3** Surface Profile: Unless otherwise specified, the steel substrate shall have, at a minimum, a sharp angular profile with a minimum depth of 65 µm (2.5 mil) and a maximum depth of 125 µm (5.0 mil) as measured in accordance with SSPC-PA 17, using ASTM D4417 Method B (depth micrometer) or Method C (replica tape). If Method C is used, measurements close to the upper limit of tape measurement capability should be confirmed using Method B to ensure that the maximum depth has not been exceeded.

## Section 6: Thermal Spray Equipment Setup

Thermal spray equipment shall be set up, adjusted, and the correct spray pattern verified, in accordance with the equipment manufacturer's instructions and technical manuals or the TSC applicator's qualified procedure.